Infant industry protection of manufacturing firms in the context of international fragmentation: Evidence from South Africa

by

Tabani Maposa

19397225

Submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

at the Gordon Institute of Business Science

University of Pretoria

27 November 2023

SUPERVISOR

Prof. Marianne Matthee

Declaration Regarding Plagiarism

1. I understand what plagiarism entails and am aware of the University's policy in this regard.
2. I declare that this work is my own, original work. Where someone else's work was used (whether from a printed source, the Internet, or any other source) due acknowledgement was given and reference was made according to departmental requirements.

Tabani Maposa………………………………… 27 November 2023
Signature Date

Ethics Statement

The author, whose name appears on the title of this thesis, has obtained, for the research described in this work, the applicable research ethics approval. The author declares that he/she has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for researchers and the Policy guidelines for responsible research.

Acknowledgement

I would like to express my sincere gratitude to the departmental staff and the university at large for assisting me throughout my studies. I am grateful to my supervisor Prof. Marianne Matthee for her feedback and guidance throughout this journey. Thank you to my family and friends for the support.

Abstract

The survival of vulnerable manufacturing firms within infant industries in African countries is threatened by competing final goods imports from foreign more established competitors. The low survival rate of such firms negatively impacts the countries' economic growth and development. The infant industry protection framework has over the decades been widely purported as key to the growth and nurturing of vulnerable firms, however, its implementation in African countries has been lacking. Nonetheless, its conventional and principal mechanism of application through high import tariffs, quotas and complete bans on competing imports, resulting in the isolation of vulnerable industries from global trade has been deemed too costly and less practicable in poor economies.

At the same time, the global economic climate has been rapidly evolving over the past few decades. The advent of the pivotal international fragmentation phenomenon has induced an insurgence of global trade in intermediate inputs that are fundamental to manufacturing processes, particularly in high-technology manufacturing. African countries generally impose high import tariffs on such inputs; a scenario that worsens the survival prospects of their vulnerable nascent firms that utilise the inputs.

There is a dearth of literature on studies that integrate infant industry protection into the contemporary international fragmentation system using imported intermediate inputs as the nexus of the configuration. Applying the infant industry protection theory to tap into the benefits from both these paradigms, this study aligns infant industry protection with international fragmentation while retaining a core infant industry protection aspect of improving the survival prospects of vulnerable nascent manufacturing firms. In contributing to theory, this thesis characterises instantaneous integration into international fragmentation as a primary feature of the protection framework while advancing a mere survival motive (rather than a costly dominance motive) based on a low cost of protection in resource-constrained African developing countries. Practically, this study contributes by formulating a novel set of policy prescriptions suitable for application to vulnerable firms in medium to high-technology manufacturing industries.

A positivist, deductive, variable-oriented policy evaluation study based on a policy-scenario simulation quantitative analytical technique using a computable general equilibrium model was designed. Because of the complex global trade systems associated with international fragmentation, an apt advanced Multi Region Input Output (MRIO) database that uniquely and accurately allocates imports by agent and region was incorporated in evaluating the impact of imported intermediate inputs tariff reduction on the value of exports from South Africa's electrical and electronic manufacturing industry. Results indicated an overall 21.36% gain in export value suggesting that a tailormade infant industry protection framework that is integrated into and aligned to international fragmentation could more realistically, and cost-effectively enhance firm survival in a resource-constrained African economy.

Keywords: infant industry protection, international fragmentation, intermediate inputs, firm survival, African country, computable general equilibrium, technology transfer

Table of Contents

Chapter

Appendices

List of tables

List of figures

List of acronyms

ADB	African Development Bank
AREI	Association of Representatives for the Electronics Industry
BRICS	Brazil, Russia, India, China, South Africa
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium
CIA	Central Intelligence Agency
DTI	Department of Trade and Industry
ECA	Economic Commission for Africa
EU	European Union
EU GSP	European Union Generalised System of Preferences
EV	Equivalent Variation
GDP	Gross Domestic Product
GEIS	General Export Incentive Scheme
GEMPACK	General Equilibrium Modelling Package
GTAP	Global Trade Analysis Project
ICT	Information and Communication Technology
IDC	Industrial Development Corporation
IDEA	International Distribution of Electronics Association
IMF	International Monetary Fund
ITA	International Trade and Administration
ITAC	International Trade Administration Commission

JEITA	Japan Electronics and Information Technology Industries Association
MAcMap	Market Access Map
MRIO	Multi Region Input Output
NDP	National Development Plan
OECD	Organisation for Economic Co-operation and Development
SAM	Social Accounting Matrix
SARS	South African Revenue Service
SEDA	Small Enterprise Development Agency
SETA	Sector Education and Training Authority
StatsSA	Statistics South Africa
UN	United Nations
UN-COMTRADE	United Nations Commodity Trade
UNCTAD	United Nations Conference on Trade and Development
UNIDO	United Nations Industrial Development Organisation
WB	World Bank
WDI	World Development Indicators
WITS	World Integrated Trade Solution
WTO	World Trade Organisation

Chapter 1: Introduction

African countries' economic growth trajectories have in the past decades disappointingly fallen below economic theoretical postulations (Asongu & Minkoua, 2018; Benita, 2019; Chang, 2013; Wu, 2017). During the early 1990s, many researchers predicted that African countries would experience accelerated economic growth based on the rising wave of open borders and free trade, however, statistics show that the economic growth rates of these countries have been declining steeply (Hassan et al., 2006). This phenomenon has generated interest from scholars and policymakers alike, with Parada (2018) attributing such poor economic growth to a lack of effective economic policies that stimulate the growth and development of industries under the continuing more open and freer trade conditions.

Poor economic growth in developing countries has coincided with a lack of growth in technologically enhanced, value-added manufactured goods output (Gault & Zhang, 2011; Lall, 2005; Mijiyawa, 2017). When compared to firms within similar manufacturing sectors in Asian and developed countries, Gault and Zhang (2011), Lall (2005) and Mijiyawa (2017) maintain that firms in African countries have shown much worse performance. Some firms have failed to grow or expand while others have ceased to exist altogether, due to uncurbed competition from foreign, more established firms mainly from industrialised advanced economies (Brenton et al., 2010; Melitz & Trefler, 2012; Shikur, 2020). According to Chang and Andreoni (2020), and Grossman and Horn (1988), the survival rate of new firms in developing countries' manufacturing industries (particularly in the technology intensive sectors) is very low since such firms struggle to enter the markets that are dominated by seasoned foreign producers.

South Africa's value-added goods exports, for instance, have not been impressive, particularly for the period 2005 to 2014, resulting in a 15% drop in South Africa's share of world exports (Pieterse et al, 2016). Stern and Ramkolowan (2021) also identify a downward trend up to the year 2019. Im et al. (2014) attribute this decline to the stagnation in the dynamism and competitiveness of South Africa's large firms in some sectors. Even though this could mean smaller, newer firms taking over and becoming more dynamic and competitive in driving exports and aggregate growth, such small firms struggle to survive, let alone thrive as sustainable sources of exports (Draper et al., 2018; Im et al., 2014). South Africa's export volume rose by only three percent between 2008 and 2019 compared to a 17% rise in imports, while the average annual gain in export volume from the year 1960 to the year 2019 was 0.45% (Edwards, 2021). According to the author, South

Africa's exports compare poorly to other emerging economies such as Chile, Malaysia and Brazil that show an annual average export volume growth rate of three percent.

Nonetheless, appropriate policy frameworks for expansive industry growth in developing countries remain hugely debated (Chang & Andreoni, 2020). Wu (2019) alludes to the fact that scholars have up to now found that the propensity for the formulation of such policy frameworks is influenced by specific economic factors of the concerned countries. With reference to African countries, Mijiyawa (2017) argues that it is no longer a question of whether they should engage in expansive industry growth-biased policy formulation, but rather a matter of whether they are doing it right and how they can improve. Dosi et al. (2020) concur by suggesting that such policies are central to developing economies closing the development gap to advanced economies. The Economic Commission for Africa (ECA, 2016) adds that it is clearly difficult for catch-up economies such as African countries to maintain the survival of vulnerable emerging firms and industries, hence the need for thoughtful revision of their economic growth and development policies.

The infant industry protection framework that is based on the infant industry theory is predicted to be a viable solution to the general economic growth challenges and specifically to the low survival rate of firms that are vulnerable to foreign competition in developing less industrialised economies (Cohen & Delong, 2016; Juhasz, 2018; Miravete, 2003). Infant industry protection refers to governments' tendencies to protect infant industries from foreign competition (Mustafa, 2020) and it is the main concept of focus in this thesis. The infant industry protection framework is a subset of industrial policy and is regarded as an industrialisation strategy (Andreoni & Chang, 2019; Schott, 2016). Because of the broad nature of the subject of industrial policy and industrialisation, this study did not pursue these concepts beyond the infant industry protection framework.

Final goods exports from vulnerable firms and competing final goods imports undeniably play a role in infant industry protection and the survival of vulnerable firms. On the one hand, goods exports are a desirable and important indicator of firm growth with evidence showing that exporters are more productive than non-exporters of the same size in the same industry (Kowalski et al., 2015; Le & Valadkhani, 2014). On the other hand, final goods imports that compete against domestic output from emerging vulnerable firms are generally discouraged because they suppress demand for such domestic output hence negatively impacting the survival prospects of the vulnerable firms (Kalygina, 2022; Rekiso, 2020). It is also worth mentioning that the traditional methods of infant industry protection application, that is, high import tariffs and quotas on competing imports result in a burden on consumer spending and a deterioration of consumer welfare. Besedes and Prusa (2006) and Brenton et al. (2010) therefore conclude that for developing countries to achieve higher aggregate export flows, they need to maintain reasonable and consistent levels of export flows from manufacturing firms that have the potential for future growth. The sustenance of higher export flows requires the survival of the firms in the first place, but empirical evidence has shown that the survival rate of vulnerable firms, is very low in most developing countries (Esteve-Pérez & Sahiti, 2019).

At the same time, the global economic climate has been rapidly evolving over the past few decades. The advent of the pivotal international fragmentation phenomenon has induced an insurgence of global trade in intermediate inputs that are fundamental to manufacturing processes, particularly in high technology manufacturing (Zhang, 2020). International fragmentation is the spread of production processes across countries whereby the production stages rely on imported intermediate inputs (Bond 2001; Chatterjee & Gupta, 2014; Jones & Marjit, 2001; Mitra & Gupta, 2017). According to Hausmann (2014) and Zhang (2020), trade in intermediate inputs that are linked to international fragmentation accounts for a large portion of international trade. Data for some European countries as well as Asian and Latin American developing countries show a high level of engagement in international fragmentation-induced intermediate inputs use. For example, with respect to the electronic manufacturing industry, as much as 85% of intermediate inputs imported into Hungary end up in the country's exports, while the figure stands at 75% for China, South Korea and Mexico (Gaulier et al., 2020; Organisation for Economic Co-operation and Development [OECD], 2013). The phenomenon of international fragmentation is further discussed in Section 2.4 of this thesis.

Imports in the form of intermediate inputs are considered to play a significant role in general firm productivity and firm export flows (Hausmann, 2014; Zhang, 2020). For instance, it can be argued that a strategic reduction in imported intermediate input tariffs, hence reduced production costs, could improve the survival of vulnerable firms that use such intermediate inputs. However, African economies have not been able to embrace this opportunity, and as Kowalski et al. (2015) note, Eastern and Southern African countries still impose some of the highest tariffs on imported intermediate inputs.

While infant industry protection remains a relevant strategy for firm protection, the emergence of international fragmentation and the prevalence of international fragmentation-induced intermediate inputs over the past decades have elicited the core purpose of this thesis, that is, to evaluate the effectiveness of an infant industry protection framework in such a modernised global system. This thesis, therefore, seamlessly integrated an infant industry protection framework into the international fragmentation system using imported international fragmentation-induced intermediate inputs as the nexus of the configuration, in an endeavour to enhance the survival prospects of vulnerable manufacturing firms. In a slight variation to the conventional mechanism of application and theoretical dimension of the infant industry framework, that centres on trade restrictive high tariffs, this study attempted to enhance the survival prospects of vulnerable firms from a nuanced theoretical approach that promotes the integration of infant industries into the international fragmentation system. A Computable General Equilibrium (CGE) model was adopted for this policy evaluation study. The CGE model is further addressed in Chapter Four of this thesis.

The rest of this chapter briefly outlines the focus and direction of this thesis. The research problem, the study objective, the research questions and the study contribution are presented successively in the following sections.

1.1 Research problem

Some nascent manufacturing firms in developing economies that compete in global markets face momentous challenges in their attempt to either grow and expand or merely survive (Cimoli et al., 2020). This occurrence is widely attributed to a lack of economic protection from more competitive and well-established foreign firms (Aiginger & Rodrik, 2020; Chang, 2010; Jongwanich, 2020; Pack & Saggi, 2006). Melitz and Trefler (2012) as well as Opoku and Yan (2019) argue that these vulnerable firms' lack of competitiveness has contributed to developing countries' poor overall economic outlook (such as very low economic growth, high unemployment, widening inequality gaps, increasing poverty and rising national debt). Consequently, the global economic inequalities between the developed industrialised countries of the global north and the developing countries of the global south have become a constant feature (Strange, 2020).

Several manufacturing industries, particularly the medium to high technology manufacturing industries, in African countries rely on imported intermediate inputs for their production processes yet most of these countries impose some of the highest tariffs on imported intermediate inputs (Kowalski et al., 2015). Of specific interest in this thesis were the electrical and electronic manufacturing firms in South Africa. Data from the World Integrated Trade Solution (WITS, 2020) shows that these firms import intermediate inputs albeit at a high cost, due to a relatively higher import tariff rate (compared to advanced countries), which arguably exacerbates the firms' weak competitiveness and low survival prospects. According to WITS (2020), South Africa's tariff data for the year 2018 shows that imported electrical and electronic intermediate inputs tariffs are in some cases as high as 34 % ad valorem (a tax that is charged as a percentage of the value of goods). Even though the general average import tariff rate has fallen since South Africa's commitment to the World Trade Organisation (WTO) in the 1990s, some importers still complain about the current inconsistent tariff structure (International Trade and Administration [ITA], 2019). For instance, Van de Groenendaal (2016) notes that high import tariffs are levied on electronic intermediate inputs such as switches and transistors, whereas the import tariffs on electrical and electronic finished goods are sometimes maintained at relatively lower rates. South Africa's electrical and electronic manufacturing industry is further discussed in Sections 2.3.2, 3.4 and 3.5 of this thesis.

Developing countries' general policy structure is an open trade phenomenon that is defined by their allegiance to the WTO. This phenomenon amplifies trade deficits by stimulating more final product imports than exports (Rekiso, 2020); an unpleasant scenario for emerging, vulnerable domestic manufacturing firms that compete against such imports (Santos-Paulino & Thirlwall, 2004). Furthermore, Wu (2019) argues that such a phenomenon is inclined to create winners and losers where the losers are the vulnerable less competitive firms in developing countries. It can be argued that vulnerable firms in developing countries, therefore, require some form of state assistance before they can fairly compete against their well-established competitors from more advanced economies. However, Dosi et al. (2020) point out that one prime obstacle faced by policymakers, business managers, economists and political scientists in developing countries is to identify the appropriate policies that are central to such a catching up process.

Accordingly, to solve the fundamental economic problems in developing countries, it remains imperative to protect, nurture, grow and maintain the survival of vulnerable manufacturing firms, particularly those firms within infant industries that have the potential to contribute significantly to national economic growth. For example, the electrical and electronic manufacturing industry in South Africa not only faces competition from imported competing final goods; it also faces tariffs on the intermediate inputs that it uses in its production processes. Kowalski et al. (2015) indicate that some form of government policy intervention could be the lifeline for such vulnerable industries while Andreoni and Tregenna (2020) argue that middle income countries such as South Africa have continuously faced challenges in aligning domestic production systems to global value chains.

1.2 Purpose and objective of thesis

Weiss (2018) asserts that one setback for vulnerable manufacturing firms, particularly medium to high technology firms, in Africa's economies is that they are in many instances not integrated into international production and trade systems; a scenario that further deteriorates such firms' survival prospects. This thesis therefore formulated a set of economic policy prescriptions that could assist in maintaining a high survival and growth rate of vulnerable nascent firms within infant industries in African countries. To achieve this, this thesis integrated an infant industry protection framework into the international fragmentation system, using imported international fragmentation-induced intermediate inputs as the main focal point of the integration process. Intermediate inputs are a major feature of international fragmentation (Zhang, 2020) while the survival and high performance of infant industries are believed to have a positive impact on a country's economic growth trajectory (Esteve-Pérez & Sahiti, 2019).

The effectiveness of the configuration between the infant industry protection framework and the international fragmentation system was evaluated by determining the impact of imported international fragmentation-induced intermediate inputs tariff reduction on the value of exports from South Africa's electrical and electronic manufacturing industry. Furthermore, the effect of technology transfer via international fragmentation-induced intermediate inputs on the value of exports was examined.

1.3 Research question and hypotheses

To explore the relevance of international fragmentation-induced intermediate inputs in facilitating the survival of vulnerable firms, within an infant industry protection framework, in African countries this thesis, therefore, asks the following questions:

Main Question: What is the impact of an infant industry protection policy framework in the backdrop of international fragmentation-induced intermediate inputs, on the performance of the electrical and electronic manufacturing industry in South Africa?

Sub question 1: What is the effect of imported high technology intermediate inputs tariff reduction on the value of electrical and electronic manufacturing firms' export flows, within an infant industry protection framework?

Sub question 2: What is the effect of technology transfer on the relationship between imported high technology intermediate inputs tariff reduction and the value of electrical and electronic manufacturing firms' export flows, within an infant industry protection framework?

Following on the above questions, the following were hypothesised.

H1: Elimination of import tariffs on international fragmentation-induced intermediate inputs positively impacts the value of South Africa's electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

H2: Technology transfer through intermediate inputs enhances the positive impact of imported international fragmentation-induced intermediate inputs tariff reduction, on the value of South Africa's electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

1.4 Theoretical contribution

This thesis makes two main contributions to the theory. The first contribution is made by propounding an infant industry protection framework that facilitates instantaneous global integration of vulnerable firms, as a slight variation to the traditional infant industry theory that postulates an initial period of isolation from the global trade platform through highly restrictive trade barriers. A second contribution to theory is through the emphasis of a mere firm survival dimension (rather than a dominance aspect) by adopting a less costly and less restrictive set of policy prescriptions. The two contributions to the theory are elaborated in the two following sub subsections.

1.4.1 A framework premised on international fragmentation-induced inputs

The infant industry theory states that governments should protect nascent undeveloped firms against foreign, more established competitors until a time when they can compete (Andreoni & Chang, 2019; Levy, 2009). The theory's mechanism of application has traditionally and principally focused on imposing high tariffs and quantitative restrictions (quotas and complete bans) on imported competing final goods and on support to vulnerable industries through various heavy government subsidies (Lane, 2020). Likewise, a plethora of studies including Lin and Chang (2009), and Wu (2019) portray the infant industry theory as highly antagonistic to global integration.

Aiginger and Rodrik (2020) indicate that the infant industry theory has become very pertinent to African economies because the risk of a low survival rate of nascent vulnerable manufacturing firms is high. The authors continue to highlight that this is due to a higher prevalence of crippling imported final goods competition from more established foreign firms. The crippling effect of competing final goods imports makes it difficult for emerging vulnerable firms to break into the global trade platform. However, the advent of international fragmentation coupled with international fragmentation-induced intermediate inputs (Gasiorek et al., 2020) has offered an unexplored avenue for the integration of the vulnerable firms into the bigger global trade platform, at the same time potentially ameliorating the survival rate of such firms. It is clear from previous research that the primary motive of infant industry protection should be to enhance the growth and development of vulnerable industries. International fragmentation processes are predominant in high technology industries such as the electrical and electronic manufacturing industry because of the technical divisibility of the stages of production (Lall et al., 2010). This aspect is further discussed in Section 2.4 of this thesis.

This thesis, therefore, contributes by approaching the infant industry theory from a dimension that allows for global integration of protected nascent vulnerable firms through a major focus on imported international fragmentation-induced intermediate inputs. This dimension differs from the rather highly protectionist and isolationist policy approach that is synonymous with the conventional infant industry argument's high tariffs and quantitative restrictions on imported competing final goods.

1.4.2 Mere survival

The infant industry argument has in the recent past been resurrected particularly with reference to industries in developing economies (Abboushi, 2010; ECA, 2016; Slaughter, 2004) that strive for mere survival. Notwithstanding, its origination by Hamilton (1791) was more inclined towards achieving dominance (hence adopting a high cost and strictly protectionist approach) by arguably well to do societies, in this case, the USA at the time. For instance, in his seminal text on the infant industry argument, Hamilton (1791) motivates for the protection and development of weapons of war because he laments the embarrassment that the United States had endured in its previous unsuccessful war. It also appears that Hamilton (1791) and later List (1841) advocated for the rather more costly simultaneous protection of different industries such as the protection of the agricultural and manufacturing industries at the same time. According to Bobulescu (2003), List's rationale was to advance domestic industries' development to the same level as that of foreign competing nations' industries before any open trade agreements between nations could be reached.

While modern day economic policy studies ordinarily associate infant industry protection with poorer catch up economies (with very limited resources and state support) such as developing economies (Foster & Azmeh, 2020; Sercovich & Teubal, 2013), paradoxically, the entrenchment of the argument in a pure dominance motive still persists whereby a very high bar is ordinarily set in terms of cost requirement projection for effective protection and in estimating or predicting the sustainability (success or failure) of such protection. The initial propositions of infant industry protection by Hamilton (1791), included a few policy alternatives that were relevant to the growth and development of vulnerable industries, however, it is undeniable that the highly dynamic evolution in global trade, international fragmentation processes and bespoke global trade treaties, warrant a revisit of the theoretical basis that has in the past been adopted by a great deal of countries.

The infant industry theory's principal high-cost dimension arguably driven by a dominance motive, appears to neither accommodate nor befit vulnerable resource strained firms in African economies that in turn lack adequate resources to effectively implement its highly costly policy strategies (high tariffs, quotas or bans on imports, huge government subsidies and costly research and development facilities). The high cost of protection that is associated with the traditional infant industry protection framework arguably gave birth to the additions to the theory by Bastable (1921), which require cost and time limitations. It can be argued that such limitations are an indication that highly costly policies are likely unsustainable in the long run. The Mill-Bastable test states that the cumulative benefits from protection should exceed the cost of protection and the protection must be temporary (Melitz, 2005). For vulnerable firms in resource-strained African economies to be afforded sufficient protection to merely survive, the cost of such protection must be reduced. This research, therefore, formulated a less costly application of the theory whereby firms directly enjoy some of the benefits of global integration while engaging in low-cost production because of tariff reductions on imported international fragmentation-induced intermediate inputs. To this effect, this thesis contributes by approaching the infant industry theory through this less costly mere survival motive.

1.5 Practical contribution

This thesis contributes by formulating and evaluating a novel set of policy prescriptions that can potentially be adopted in enhancing the survival of nascent vulnerable manufacturing firms in African economies. A few studies such as that of the ECA (2016) support infant industry protection within the African context, but merely stop at mentioning or proposing that the infant industry protection framework would be rewarding if applied to African countries. To close this gap between theory and practice, this research empirically evaluates the effectiveness of an infant industry protection framework that is integrated into the contemporary international fragmentation system within an African economy context. The outcome of this research will assist business practitioners and government legislative branches in making informed decisions concerning the application of this, or similar policy structures. A high survival rate of vulnerable manufacturing firms leading to the growth and maturity of infant industries is arguably a potential stimulus for increased employment and improved overall economic performance.

Belloc and Di Maio (2011) argue that before infant industry protection can be applied, the government must correctly identify the appropriate industry that needs to be protected, which has the potential to be successfully developed. A study by Draper et al. (2018) reveals that South Africa’s medium to high technology exports declined in approximately 16 years from the early 2000s to 2016. Data from the Japan Electronics and Information Technology Industries Association (JEITA, 2020) shows that the average annual global output from the electrical and electronics manufacturing industry increased substantially in the period from 2015 to 2018, however, South Africa’s electrical and electronic manufacturing industry shows suboptimal performance with a decline in output over the same period. The Department of Trade and Industry (DTI, 2018) reports that the value of exports from South Africa’s electrical and electronic manufacturing industry is only 35% of the total value of electrical and electronic goods imports. This shows the imbalance between imports and exports of high technology goods and a great opportunity for the electrical and electronic manufacturing industry to expand further into both the domestic and foreign markets.

The above studies show that there is an opportunity and potential for South Africa’s electrical and electronic manufacturing industry to grow, in the sense that the domestic industry indicates a decline in output whereas the average global output from the same industry is increasing. The above studies also reveal that South Africa’s domestic demand for electrical and electronic goods outweighs exports from domestic electrical and electronic goods manufacturers. An industry showing such an undesirable performance trend arguably requires some form of intervention to address any constraints that limit its survival, growth and development.

The electrical and electronic manufacturing industry in South Africa relies on imported intermediate inputs such as electronic chips, but policy regulations for this industry, with respect to the accessibility of such inputs, are unfavourable (Van de Groenendaal, 2016). The Industrial Development Corporation (IDC, 2017) states that the industry also relies on exports for its growth, and it shows potential in this dimension, nonetheless, its overall performance is still way below global standard performances. Therefore, a further contribution in this thesis is to contend that the domestic electrical and electronic manufacturing industry in South Africa is an infant industry that has potential to grow and develop if appropriately protected. The two aspects of intermediate inputs and manufactured exports, with respect to the electrical and electronic industry in South Africa, are further discussed in Sections 2.5 and 2.8.1.

1.6 Methodological contribution

Kehoe et al. (2017) point out that while Computable General Equilibrium (CGE) models are a prevalent, pivotal and standard analysis tool in policy work, their use in academic research lags. Kehoe et al. (2017) argue that this is true particularly when the current frequency of CGE models use is compared to the golden era (from the 80s to the 2000s) of CGE models development, advancement and application in academic research, a period during which the models made a significant breakthrough into international trade literature. Hertel (2012) also identifies the 1990s to the early 2000s as a period of ground-breaking developments and advancements in GTAP modelling within academic research, during which the first GTAP database was released.

According to Kehoe et al. (2017), the consensus is that CGE models may have been successfully developed and are fit for purpose hence the decline in academic research that pertains to model development and advancement, however, the application of the models across diverse industries, such as in identifying industries in which positive gains from policy reforms can possibly occur, is subdued in academic research. This thesis, therefore, contributes by adopting a GTAP model, specifically the GTAP MRIO version, to integrate an infant industry protection framework for South Africa's electrical and electronic manufacturing industry into the international fragmentation system. While this research adds to the growing number of studies that adopt the GTAP model in international trade analysis, it is rather unique in that it incorporates the GTAP MRIO database and an infant industry protection framework within the context of an African economy.

1.7 Conclusion

This chapter has presented the purpose and objective of this thesis, that is, the integration of an infant industry protection framework into international fragmentation using imported intermediate inputs as the main focal point. This is achieved through the formulation of a set of policy prescriptions that are aimed at enhancing the survival of a vulnerable industry in an African economy. The setting is the electrical and electronic manufacturing industry in South Africa. The chapter highlighted the research problem and research questions. The theoretical contributions, practical contributions as well as methodological contributions were also presented.

1.7.1 Outline of thesis

This thesis is composed of eight chapters. This introductory chapter presented the background, purpose, research questions and contribution of the thesis. Chapter Two presents a review of the literature on the concept of infant industry protection, the international fragmentation phenomenon, imported intermediate inputs, the application of tariffs on imports and the significance of exports in manufacturing firms. Chapter Three focuses on the study context. The chapter highlights the importance of manufacturing industries to African economies, a description of the electrical and electronic manufacturing industry in South Africa, industrial and general economic performance in South Africa as well as growth opportunities that exist for the electrical and electronic manufacturing industry. Also discussed in Chapter Three is the government's policy towards the electrical and electronic manufacturing industry.

The study methodology is discussed in Chapter Four. The chapter details the GTAP 10 database which provided the main data for the research. It also discusses the CGE modelling approach that is adopted for data analysis. The GTAP model that is implemented in data analysis and all the modifications that are applied to both the model and the database are elaborated in this chapter. Chapter Four also justifies the adoption of CGE modelling for this study. Chapter Five outlines the execution of the research method. The chapter discusses model specifications and simulation scenarios. In Chapter Six, the results of the simulations from the GTAP model are presented. Tests such as sensitivity analysis that verify the reliability of the model results are also examined. The chapter further provides a comparative analysis of the results obtained through various simulations. The experimental results of the study are discussed in Chapter Seven. Chapter Eight concludes this thesis. The chapter focuses on the contributions made based on the experimental results. Chapter Eight also highlights study limitations and policy recommendations.

Chapter 2: Literature review

2.1 Overview

The survival rate of nascent firms within infant industries in African countries has been relatively lower in comparison to advanced countries and a major cause has been identified as the competition that these firms face from more established foreign producers (Aiginger & Rodrik, 2020; Jackson & Jabbie, 2020; Jongwanich & Kohpaiboon, 2020). According to Rekiso (2007), Wu (2017), Li (2017) Jackson and Jabbie, (2020), Guisan, (2017) and Chang (2003), this vulnerability is a result of the lack of industrialisation and hence poor industrial performance (including below par manufacturing firms' output) from African countries. Opoku and Yan (2019) add that this phenomenon has culminated in failing domestic industries, continuously rising national debt and high poverty levels in the affected countries. Accordingly, Wu (2017) and Chang (2003) conclude that it is an impossible task for developing economies to develop new industries that are more competitive than those from developed economies, without some form of state intervention.

The infant industry protection framework has over the past decades been a subject of discussion as an ideal strategy for enhancing the size of certain industries and accelerating overall economic growth in developing countries (Greenwald & Stiglitz, 2006; Jackson & Jabbie, 2020). However, the ECA (2016) laments its low to non-existent implementation in African countries. At the same time, the shape of the global economic landscape has been evolving. A growing phenomenon of international fragmentation has resulted in intermediate inputs becoming a major share of global international trade, a scenario that has triggered discussions on the need for a recalibration of trade and development strategies in developing countries (Zhang, 2020). While imports in the form of final goods that compete against domestic output from vulnerable firms in developing economies remain undesirable for the survival of such firms (Strange, 2020), tariffs on imported international fragmentation-induced intermediate inputs mean that such vital inputs become more costly and hence less accessible to the already vulnerable firms.

The reduction of tariffs on imported intermediate inputs that are utilised by firms within an infant industry protection framework could undeniably result in easier accessibility to such inputs. Nonetheless, the impact of such a scenario on the flow of exports from the protected vulnerable firms remains an open question.

This thesis therefore formulated and evaluated the effectiveness of an infant industry protection framework that adopted imported international fragmentation-induced intermediate inputs as the focal point of integration into the international fragmentation system. The rest of this chapter discusses the infant industry theory as the theoretical anchor of this thesis, the infant industry protection framework, South Africa's electrical and electronic manufacturing industry as an infant industry, arguments for infant industry application, conventional mechanism of infant industry application and addresses some arguments against infant industry protection. This chapter also presents international fragmentation, the role of tariffs, imported international fragmentation-induced intermediate inputs, the role of exports in firm growth, the value of exports, technology transfer, industrial performance and overall economic growth in South Africa.

2.2 Infant industry theory

As an economic rationale for the protection of vulnerable firms, and according to Ravikumar et al. (2022), Andreoni and Chang (2019), Clark and Rosales (2022) and Levy (2009), the infant industry protection theory, generally referred to as the infant industry theory, states that governments should protect new industries against foreign, more established competitors until a time when they can fairly compete. Loosely stated, the theory underscores industrialisation through firm protection. An infant industry is described as nascent, uncompetitive, vulnerable to international competition and with less productivity than global standards in the particular industry, due to newness while still possessing the potential to innovate and develop (Levy, 2009; Slaughter, 2004). Alleyne et al. (2022) add that if the infant industry protection framework is effectively applied, it can form part of a powerful internationalisation strategy. The infant industry argument has over the years been examined both in theory and practice by scholars such as Saure (2007), Das and Srinivasan (1997), Dozin and Vamvakidis (2004), Kaneda, (2003), Leahy and Neary (1999), Lee (1997), Luzio and Greenstein (1995), Melitz (2005), Miravete (2003), Ohyama et al. (2004), Ho (2013) and Norman and Stiglitz (2012). According to the infant industry theory, the development and upgrade of vulnerable firms' inferior capability to produce (productive capabilities) is the epitome of economic advancement (ECA, 2016).

The infant industry theory was conceived by Hamilton (1791), inspired by the desire to make America a dominant nation. Ho (2013) and Mustafa (2020) assert the widely held belief that Hamilton was inspired by Smith's (1776) work, The Wealth of Nations, which covers a wide range of topics including both open and restrictive trade between countries. In his seminal report, The Report on the Subject of Manufactures, presented to the United States House of Representatives on December 5 in 1791, Alexander Hamilton bemoaned the competition faced by newly established American manufacturers from the long-matured industries of other countries, particularly European countries. In an effort to counter this obstacle, Hamilton (1791) proposed protection of domestic producers through taxes and quantity restrictions on imports, reallocation of domestic labour to these industries, subsidies and policies that promoted capitalisation and development of the specific disadvantaged vulnerable firms. Andreoni and Chang (2019) and Chang (2011) concur by indicating that the initial argument for the infant industry theory did not just motivate for tariffs but also for government investments in infrastructure, as witnessed in some modern Asian economies. Perhaps not surprisingly, and as proof that infant industry protection can indeed be instrumental to economic development, the United States, where this theory was first developed and applied has since economically advanced to become the greatest economy on the globe today.

The infant industry theory was later modified by Friedrich List (1885) who argued that the protection must be temporary, and focus must only be on key sectors of an economy (Chang 2011). Hamilton (1791) and List (1885) asserted that the natural course of things as depicted in comparative advantage within the free trade phenomena is not sufficient to create industrialization in a developing country whose target is to reach the developmental level of advanced countries. Hamilton and List advocated for both trade and non-trade policy interventions as a way of assisting infant industries (Ho, 2013).

With reference to the time frame of protection, proponents of the infant industry protection theory (Cheng et al., 2019; List, 1885; Melitz, 2005) merely indicate that such protection should be temporary and maintained until the industry matures or a reasonable period. It can be argued that the time required for such government intervention may be contingent on the policy structure, amount of support, the magnitude of commitment (from both government and industry) and the specific state of the concerned industry, such as the existing infrastructure to support growth and development. Lin and Chang (2009) and Wade (2014) suggest that some cases that have become synonymous with successful infant industry state intervention can be used as standards for the evaluation of approximate, expected infant industry protection timeframes. The authors proceed to draw special attention to Korea's chemical industry from the 1960s to the 1970s and its semiconductors industry from 1983 to 1993 (the time Samsung became the world's biggest chip producer) as well as Japan's steel, auto and ship industries from the late 1950s to the 1960s, as examples of such cases. The cases reflect the approximate duration that these protection strategies took for Korea and Japan; economies as small as six percent and 19 percent the size of the United States economy (at the time), respectively (Lin & Chang, 2009; Wade, 2014).

In advancing the infant industry theory, John Stuart Mill (1848) and Charles Francis Bastable (1921) added conditions to include learning effects and the need for cumulative benefits to outweigh the cumulative costs in the self-named Mill-Bastable Test (Melitz, 2005). Melitz (2005) acknowledges that infant industry protection as a growth strategy has been accepted by economists over the years. Other studies on the infant industry theory include Wade (2003) and Lall (2003) in a symposium on infant industries, Raffer (2020) who evaluates the relevance of exchange rates on trade flows while comparing infant industry protection to the Dutch disease and Xu (2006) who investigates the relationship between the import tariff rate and maturity of a protected infant industry. Xu (2006) develops an infant industry protection model under a trade policy negotiation scenario and finds that such protection can be a powerful tool for less developed economies in trade talks with more developed economies. The author uses the model to explain China's tariff offers to the WTO from the onset of its WTO entry negotiations in 1986.

As one of the modern proponents of the infant industry theory, Melitz (2005) develops a welfare maximising model based on an infant industry that is experiencing dynamic learning effects while showing that quotas induce higher welfare levels than tariff imposition. However, notably, the author applies learning effects in conjunction with trade restrictive policies in the form of quotas and tariffs.

Since the Mill-Bastable test, several scholars have applied the infant industry theory based on learning effects. Such research includes Anderson and Schmitt (2003) and Bagwell and Staiger (1990) who add import quotas as quantitative restrictions and find that such non-tariff barriers are more effective when compared to certain tariff conditions. Bardhan (1971) takes on a simple dynamic model of learning by doing in an open economy while Clemhout and Wan (1970) use the same principle on a group of industries and find that learning alone is not adequate in protecting vulnerable industries. Krugman (1987) goes on to include both domestic and foreign industries and cautiously points out that while a gradual process of infant industry protection can succeed in making some industries competitive, extra care in such policy prescription should be taken especially with regards to imperfectly competitive firms. While all the reviewed research studies allude to infant industry protection, it is vital to note that these studies assume trade restrictive strategies such as quotas and tariffs and they do not necessarily assume an Afr country context.

This thesis contributes by proposing an integration of infant industry protection into international fragmentation by removing tariffs from imported international fragmentation-induced intermediate inputs in an African country, specifically within the electrical and electronics manufacturing industry.

2.3 Infant industry protection

2.3.1 Overview

Infant industry protection is defined as policy interventions that assist infant industries overcome an initial growth handicap resulting from extreme competition from seasoned foreign firms (Schott, 2016). It is a subset of industrial policy, that is, measures that reallocate resources across sectors while driving industrialisation (Andreoni & Chang, 2019; Shikur, 2020). Industrialisation in turn refers to the application of industrial policies in the growth and development of industries that build a nation's economy (Parada, 2018). Infant industry protection policies encompass both protection and promotion tools (Togo, 2010) designed to promote and advance new economic enterprises (Lane, 2020). The protection framework attempts to unlock already existing potential but latent resources that currently cannot possibly be utilised, because of significant limitations to other sections of the production chain (ECA, 2016). Such a process involves aligning two strands of policy measures namely, trade policies (such as tariffs and non-tariff measures directly on imports and exports trade) and non-trade policies (such as those that pertain to skills, training, infrastructure development and financial investments) (Andreoni & Chang, 2019; Krugman 1987; Melitz, 2005).

It goes without saying that the initial and very important step of the infant industry protection framework application is the identification of an infant industry that requires such protection. This research identifies electrical and electronic manufacturing in South Africa as a vulnerable industry that requires protection, as detailed in the following section.

2.3.2 Electrical and electronic manufacturing in South Africa as an infant industry

The task of identifying an infant industry with the potential to grow and mature within the anticipated time frame has arguably been one of the major challenges in supporting the infant industry protection argument. The electrical and electronic manufacturing industry in South Africa arguably fits into the infant industry category in the sense that it exhibits potential for innovativeness, growth and product diversification (African Development Bank [ADB], 2019). The industry is nonetheless vulnerable and is suppressed by the much cheaper and abundant imported competing goods from Asia and developed countries, in a situation that does not provide adequate opportunities for South Africa to produce its medium to high technology goods to compete with the imports (Mutambara, 2017). Scholars such as Ravikumar et al. (2022) suggest that there are many infant industries in developing countries, however, the challenge lies in choosing industries that deserve protection. The scholars proceed to argue that the protection framework and evaluation criteria should pass the Mills-Bastable test, which requires the protected industry to eventually survive without protection and the future benefits to exceed the present cost of protection.

Torreggiani and Andreoni (2019) contend that cheap imports and competitive pressure from more advanced countries such as China still threaten the survival of manufacturing firms (such as electrical and electronic manufacturing firms) in South Africa. The influx of Chinese imports into other less technologically capable developing countries is seen as a threat to the depth and breadth of manufacturing industry development in the importing countries (Kaplisnky, 2008; Lall & Albaladejo, 2004; Lall et al, 2005; Torreggiani & Andreoni, 2019). Andreoni (2011) also argues that productive capabilities (that can be costly and time consuming to acquire) can only be accumulated over time in a rather uncertain way and therefore the requirement to protect such promising and potentially innovative industries from international competition. Productive capabilities are defined as individual and shared skills together with the expertise required by firms to adapt as well as make internal developments across various organisational and technological functions (Andreoni, 2014; Chang et al., 2013).

As an example of some level of potential innovativeness among many other cases, South Africa through the Cape Peninsula University of Technology managed to build its own nanosatellite (a small satellite weighing 10kg) named ZACube-1 in 2013 and subsequently sent a second nanosatellite (named ZACube-2) into orbit in 2018 (Wild, 2018). Such technical developments within South Africa have important interlinkages with the electrical and electronic manufacturing industry. Andreoni and Chang (2019) underscore the dynamic nature of the manufacturing sector; a theme that was in fact partially the basis of the infant industry theory. It can be argued that the electrical and electronic manufacturing industry is a very dynamic manufacturing industry within South Africa’s economy particularly because of its important interlinkages with technologically advancing sectors such as the Information and Communication Technology (ICT) sector, the Automotive sector, the continuously growing consumer electronics market (Gillwald et al., 2019), and electrical and electronic goods foreign markets that have generally shown a huge potential for expansion over the past few years (JEITA, 2020). Such growth potential has also been documented in other studies. For instance, the International Trade Administration Commission (ITAC, 2014) identifies South Africa’s electrical and electronic manufacturing industry as an emerging performing export industry, that is, the industry has a falling share in South Africa’s total exports despite a growing world market of electrical and electronic goods. While the electrical and electronic manufacturing industry shows promise for future expansion, South Africa remains a net importer of this industry’s products, with an import to export ratio of 4.7, whereby most imports are from China (ITAC, 2014).

Protecting manufacturing firms within the electrical and electronic industry implies assisting them to develop, grow bigger in size and become more competitive. A firm’s size is positively related to its tendency to export and accordingly, large manufacturing firms engage in economies of scale, are more likely to adapt to exporting and are more capable of augmenting resources while taking up risk when compared to smaller firms (Bernard & Jensen, 2004; Karam & Zaki, 2020). Meanwhile, Bernard and Jensen (2004) and Karam and Zaki (2020) conclude that smaller, growing firms have higher levels of the propensity for innovativeness and are therefore more likely to be more successful in exporting when compared to old firms.

The electrical and electronic manufacturing industry is continuously evolving and consistently presents a growth and development opportunity for the manufacturing sector and South Africa’s economy as a whole; however, firms in this industry remain at a disadvantage since they have always been lagging the leading manufacturers from more technologically advanced economies. Over the past years, imported small electrical appliances such as stoves, irons, kettles and microwaves have accounted for the bulk of domestic consumption in South Africa (InvestSA, 2020). Local manufacturers such as Nu World and Amalgamated Appliances have faced extreme competition from these imports such that they have continuously scaled down on production (Flatters & Stern, 2008). In one of the many examples of the collapse of domestic manufacturing firms, South African electronics manufacturing firm, Tedelex Manufacturing (that had television sets as one of its major products), shut down operations citing cheap imports from the East as the reason for its failure to survive ("Tedelex Shutdown", 2010).

It arguably becomes clear that the lack of appropriate policy alternatives has resulted in limited expansion and development of the electrical and electronic manufacturing industry to date. This thesis contributes by proposing an infant industry protection framework that is integrated into the international fragmentation system through international fragmentation-induced intermediate inputs. The next section discusses the rationale behind the adoption of infant industry protection.

2.3.3 Arguments for application

When it comes to the survival prospects of vulnerable firms, Melitz (2005) presents a scenario that confronts developing countries the most: no industry protection, leading to the extinction of vulnerable emerging firms followed by absolute reliance on imports, or industry protection potentially leading to a high probability of survival and maturity of such firms. Jackson and Jabbie (2020) and Opoku and Yan (2019) firmly stress that producing firms in African economies do not have the competitive edge that foreign producing firms from more developed countries possess. The catastrophic outcome as would most likely be expected and as Brenton et al. (2010) highlight, is the low survival rate of such vulnerable producing firms coupled with dwindling export flows from the developing economies, while some of the firms cease exporting altogether, in no time at all. Dang and La (2020) also contend that domestic firms require protection from competing imports to enable them to meet market demands more competitively than foreign suppliers.

A developing country will never know its full potential until it engages in new development options and accordingly, the infant industry protection framework aligns itself with the procurement of resources and abilities that are inappropriately deployed, hidden or scattered (Andreoni & Chang, 2019; Hirschman, 1958). Lin (2012) also recommends that developing economies should not just hang onto the prevailing economic pattern of comparative advantage (that underlies free trade) but must anticipate future patterns and as such promote and develop industries that will align and fit into such future industrial growth patterns.

Suwanprasert (2017) finds that in cases of inefficient labour markets in a small open economy, trade protection can improve welfare. Juhasz (2018) claims that trade protection based on the infant industry protection argument can indeed improve the competitiveness of the targeted industry, however, the author argues that there remains a question of whether the industry would still have developed to equivalent proportions without trade protection. Aiginger and Rodrik (2020) argue that there is a need for enterprising state assistance policies capable of enhancing and modernizing Sub Saharan and Latin American economies beyond their prevailing free trade setting. Ultimately, Stiglitz (2006) suggests that developing economies require time and appropriate policies to promote infant industries in a fashion similar to the now developed economies centuries ago. Contrary to simultaneous investments across all sectors of an economy, an effort directed at protecting one industry generates external economies in the industry, which subsequently leverages and stimulates growth in other sectors (Saliminezhad & Lisaniler, 2018). Similar sentiments on such auspiciousness of the infant industry protection framework are echoed by scholars such as Cohen and Delong (2016), Chang (2007) and Reinert (2005). The mechanisms by which infant industry protection has traditionally been applied both in theory and practice are presented in the following section.

2.3.4 Mechanism of application

Following the process of infant industry identification, the selected infant vulnerable industry will therefore deserve priority for protection from the state (Andreoni & Chang, 2019; Cohen & Delong, 2016). Infant industry protection is mostly discussed in economic literature as an isolated firm protection and growth strategy, such as in work by Kaneda (2003), Leahy and Neary (1999) and Ohyama et al. (2004). In other instances, infant industry protection is presented as a necessary early step within the broader industrial policy framework (Andreoni & Chang, 2019; Dozin & Vamvakidis, 2004; Miravete, 2003; Mukherjee, 2012). In either case, some scholars have to date focused on infant industry protection with emphasis on high tariffs and huge quantitative restrictions through high import quotas on final imported competing goods while simultaneously paying much lesser attention to non-trade policies.

For instance, Juhasz (2018) models quotas and high tariffs on imported final products in an infant industry framework, with results indicating increased exports. Similarly, Harris et al. (2015), and Blonigen (2016) demonstrate a positive impact of tariffs in the long run, on firms in an infant industry setup. However, Blonigen (2016) further claims that a one standard deviation increase in quotas and tariffs on imported competing final goods results in a 1.2% decrease in export competitiveness of downstream producing industries within the first few years of such protection policy implementation. On the contrary, Okamoto and Sjoholm (2000) show negative productivity under infant industry protection policies. Melitz (2005) undertakes a welfare maximising model of the infant industry protection framework in the presence of dynamic learning effects and concludes that import quotas induce higher welfare than tariffs on imported competing goods.

Other scholars have placed more emphasis on non-trade policies. With high import tariffs and non-tariff trade policies on final goods already assumed, Krugman (1987), in what he calls an exploration paper, discusses an infant industry of selected sectors that learn by doing over time and concludes that the setup can be beneficial in expanding the market share of a wide range of industries that eventually make an economy more competitive. Feenstra and Lewis (1991) theoretically model protection that incorporates quotas and tariffs on imported goods and obtain welfare growth for the home country while Melitz (2005) accentuates domestic firms' dynamic learning effects based on Charles Francis Bastable's (1921) Mill-Bastable test. Xu and Cao (2019) and Mazzucato (2013) emphasise human capital, innovation and, research and development as paramount to new firm protection and growth. Likewise, Criscuolo et al. (2019) investigate high subsidies on both small and big firms and find a positive effect on production that also increases employment creation. The authors reveal that a 10-percentage point increase in investment subsidies on both small and big firms results in increased productivity that translates to a 10% increase in manufacturing employment, but only in small firms.

Kalouptsidi (2018) elegantly models industrial investment subsidies on the Chinese shipbuilding industry and finds that the intervention reduced shipyard costs by 13 to 20%. Other studies that are aligned to non-trade policies such as Anderson and Schmitt (2003), Bagwell and Staiger (1990), Bardhan (1971) and Wan (1970), all discussed earlier in Section 2.2, neither focus on imported intermediate inputs nor an African country context. Table 1 summarises some of the studies that relate to infant industry protection.

Table 1: Summary of studies on infant industry protection

Author	Aim of study	Method/approach	Results/conclusions
Juhasz (2018)	Impact of protection measures on exports	Difference in difference estimator with continuous treatment intensity. Quotas and high tariffs on imported final products.	Increased exports from the targeted sector. Temporary infant industry protection had a large and positive impact in both the short run and the long run.

Author	Aim of study	Method/approach	Results/conclusions
Harris et al (2015)	Impact of high import tariff policy on some but not all Canadian manufacturing industries	Treatment intensity and difference-in-differences methods. High tariffs on imports using an industrialization organisation model and a learning by doing model	Positive impact in the long run: faster growth in output and productivity on protected industries
Okamoto and Sjoholm (2000)	Examine the effect of infant industry protection on Indonesia’s automotive industry	Fixed effects regression model. Tariff and non-tariff barriers on finished imported automotives. Dynamics of different subsectors’ productivity performance	Negative impact on productivity in the long run. While the government may have implemented reasonable protection measures, other factors (subject to further research) may have impacted negatively on the industry.
Melitz (2005)	Develops and analyses a welfare maximizing model of infant industry protection	Quantitative model of protectionist policies. Quotas and import tariffs on imported competing final goods. The domestic infant industry enjoys dynamic learning effects	Import quotas induce higher welfare than import tariffs
Blonigen (2016)	To determine the effect of industry protection on targeted sectors and downstream industries	Regression model – coefficient estimates from long differences. Data from major steel producing countries. Implementation of quotas and tariffs on competing imported final goods.	Positive impact on targeted sectors in the long run. However, average downstream sectors experience a decline in export performance within the first few years.
Miravete (2003)	Investigating learning by doing effects under a time consistent tariff protection policy	A dynamic equilibrium model that incorporates Open Loop Equilibrium, Static Nash Equilibrium and Markov Perfect Equilibrium	Learning effects in conjunction with time consistent tariff policy can make an infant industry competitive
Criscuolo et al. (2019)	Investigating the impact of investment subsidies on firm growth including job creation	Investment subsidies on both big and small manufacturing firms using regression discontinuity.	A 10-percentage point increase in maximum investment subsidies results in a 10% increase in manufacturing employment.

Author	Aim of study	Method/approach	Results/conclusions
Kalouptsidi, (2018)	Determining the impact of protection in the form of subsidies to the Chinese shipbuilding industry. Assesses the resulting production reallocation across countries	Subsidy detection method. Industrial investment subsidies on the Chinese shipbuilding industry.	Chinese shipbuilding shipyard costs were reduced from 20% to 13%. The result was significant worldwide ship production reallocation, with Japan losing the most substantial market share.

Source: Author's compilation.

As illustrated in the aforementioned literature, infant industry protection has almost by definition revolved around high tariffs and high quantitative restrictions of final goods imports that compete against domestic goods, combined with forms of non-trade government support policies. However, the current global wave of international fragmentation has induced high trade volumes of intermediate inputs that have surpassed the total share of final goods in global trade (Franco-Bedoya & Frohm, 2020). Literature has up to now failed to address a seamless integration of the infant industry protection framework into that of the international fragmentation system using international fragmentation-induced intermediate inputs as the main lever for stimulating export flows. While the traditional infant industry protection approach has some criticisms of its own, what remains a material question is how such a protection framework can be seamlessly integrated into the contemporary international fragmentation system.

This thesis fills a gap in the literature by integrating an infant industry protection framework into international fragmentation. This entails improving and maintaining the global presence of the infant industry while placing similar emphasis on government policies that are aimed at supporting the industry's growth. The studies mentioned thus far in this section all apply isolation strategies that often result in extended periods of restricted trade between the target industry and the rest of the world. Furthermore, none of the studies in Table 1 focus on infant industry protection in the context of African countries. The next section discusses some of the criticisms against the infant industry protection framework.

2.3.5 Addressing arguments against infant industry protection

Slaughter (2004) states that a major criticism of infant industry protection is that it shuts out knowledge gains, such as embedded technology knowledge gains, by restricting the importation of goods from abroad. This thesis addressed this criticism by defining a framework that promotes the importation of goods, however in the form of technology intensive international fragmentation-induced intermediate inputs, thereby improving embedded technology knowledge transfer to the domestic manufacturing firms.

Another major argument against infant industry protection is the consumer cost of protection argument which maintains that protecting industries, particularly through high import tariffs generally increases the price that consumers must pay for goods. Panagariya (2011) maintains that such a cost of infant industry protection at the onset is not justifiable. However, Irwin (2009) and Stefan (2012) reject this and argue that jobs created from protecting local industries are more important than consumer welfare in political and policy economics. If one must compare a scenario of saving a few hundred jobs to a scenario of consumers saving a few hundred dollars in income; the policy of protection is almost always likely to prevail (Irwin, 2009; Stefan, 2012).

However, it remains imperative to iterate that this thesis formulated an infant industry protection framework that was integrated into international fragmentation through a reduction of tariffs on imported international fragmentation-induced intermediate inputs. The traditional infant industry protection-type high tariffs on imported final goods were not assumed. This framework therefore at least reduces or eliminates the consumer cost of protection since the minimal tariffs on imported final goods will result in low prices for the consumers. The next section discusses international fragmentation and how it could play an important role in the survival of infant industries in African countries.

2.4 International fragmentation

The global economic platform has constantly morphed over the past decades. Goods exports and imports as a share of the global Gross Domestic Product (GDP) have risen from 27 % in 1970 to 58 % in 2018; a period during which international fragmentation processes and intermediate inputs trade have significantly expanded (Franco-Bedoya & Frohm, 2020). Deardorff (2001) defines fragmentation as the division of a production activity of a single product into multiple stages that are executed at separate locations while Njike (2020) defines international fragmentation as the splitting up of the production process of a good across countries such that the good (or part of) crosses the border of a country many times before it reaches the completion of its manufacture and its final market destination. Similarly, Gorg (2000) identifies international fragmentation as trade in fragmented goods between countries.

International fragmentation generally encompasses the segmentation of production processes, creation of separate independent operations for a product resulting in the proliferation of global intermediate inputs trade (Gaulier et al., 2020). In such a scenario, firms in different countries concentrate on certain tasks along stages of production rather than undertaking the whole production process up to a final good (Baldwin, 2017). Krugman (1995) also identifies this phenomenon of slicing up the value chain and breaking up production into geographically separated steps as a completely new aspect of trade that threatens to dominate the global economy. Torreggiani and Andreoni (2019) stress that such a type of international trade is potentially a determinant of manufacturing firms' dynamics such as growth and development or decline and extinction.

In their contribution to the discussion on international fragmentation, Hummels et al. (2001) and Fally (2011) argue that international trade has recently been associated with a large growth in intermediate goods trade and has made possible new avenues to disperse production across countries. Timmer et al. (2013) accord to this view by stating that the increase in intermediate inputs trade across different countries over the last few decades has been a result of fragmented production processes.

An abundance of literature exists on intermediate inputs (Bas & Strauss- Kahn, 2014; Chevasuss-Lozza et al., 2013; Edwards et al., 2018; Feng et al., 2016; Okafor, 2020). However, these studies and many others do not address intermediate inputs in the context of vulnerable firms within an infant industry protection framework in African countries. Easier access to intermediate inputs through international fragmentation arguably presents a survival and growth opportunity for vulnerable high technology firms in developing economies. The rationale behind this argument is that easier access to imported intermediate inputs can potentially result in reduced production costs, which can arguably be translated into competitively priced final goods for the export markets. Shin et al. (2012) and Giusti et al. (2020) argue that sources of innovation have become globally scattered, resulting in firms looking beyond their geographic boundaries in an attempt to acquire and integrate into other firms' technologies. It can be argued that this assessment is accurate with respect to intermediate inputs in the context of international fragmentation and vulnerable firms that seek to develop a competitive advantage over their more established foreign competitors.

Andreoni and Chang (2019) argue that the challenge of underdevelopment in developing countries can possibly be solved by promoting manufacturing firms through economies of scale.

Even so, the authors do not identify any specific mechanism through which such economies of scale could be generated. International fragmentation is a source of a potentially cost-effective flow of intermediate inputs (Buckley et al., 2020) that could arguably be central to the survival of firms that are vulnerable to foreign competition in African countries. It is therefore in this interest that this thesis pivots on imported international fragmentation-induced intermediate inputs to integrate the infant industry protection framework of vulnerable firms into the international fragmentation system.

Collier and Venables (2007) argue that African countries' trade priorities need to be aligned with fragmented tasks of international trade if they are to catalyse the growth of their manufactured exports. This, in essence, would include utilizing imported intermediates that are a result of international fragmentation. Similarly, Rahardja and Varela (2015) find that Indonesian firms that utilise imported intermediate inputs show faster growth with respect to output, value addition and higher-paying job creation. According to Collier and Venables (2007), the global phenomenon of international fragmentation offers huge potential for the survival and growth of manufacturing firms in African countries because it is much simpler to develop capabilities in specific tasks of production than in all stages of production including the manufacture of intermediate inputs. Del Prete et al. (2017) concur by stating that firms in African economies no longer need to possess all the capacity required for performing all production steps.

International fragmentation continues to play an important role in technologically advanced production processes in some developing countries in Asia, resulting in very significant improvements in their export performance, technological upgrading and general economic welfare (Lall et al., 2010). Such experiences raise expectations on the possibility of implementation, and the probability of success of such a fragmentation system in African countries. Furthermore, high technology industries such as the electrical and electronic manufacturing industry in South Africa, potentially possess characteristics that favour integration into international fragmentation. Some of these characteristics that are identified by Lall et al. (2010) include technical divisibility of the stages of production, significant production cost reduction by shifting to low wage regions, and lower transportation costs that result from a high value-to-weight ratio of intermediate components or final products.

According to Deardorff (2001), international fragmentation is a result of the increasingly competitive global economy that has compelled firms to seek beyond their country frontiers to reduce costs. Gasiorek et al. (2020) and Kowalski et al. (2015) state that one key export stimulus for manufacturing firms is access to competitively priced and reliable imported intermediate inputs while Lopez (2006) also suggests that exporting firms could increase their likelihood to survive by importing such intermediates. To eliminate some disadvantages in factors of production, developing countries, therefore, need to exploit imported intermediate inputs through some form of integration into global value chains (Kowalski et al., 2015).

While mere integration into such a system may increase firm exports by way of reduced production costs and increased productivity (Gasiorek et al., 2020), the complete elimination of import tariffs on intermediate inputs, in addition, could potentially provide a fundamental turnaround stimulus to rescue challenged and vulnerable firms. This stimulus assimilated into an infant industry protection framework, could arguably provide an important contribution to literature and industrial policy aimed at improving the survival rate of vulnerable firms in developing economies. Imported international fragmentation-induced intermediate inputs and their potential role in enhancing the survival of vulnerable manufacturing firms in African countries are further discussed in the following section.

2.5 Imported intermediate inputs

Intermediate inputs refer to components that are used up in the production process. According to the United Nations (UN, 2018), parts and components are defined under the Broad Economic Classification (BEC) Rev.5 as specified intermediate inputs because they are highly industry specific and cannot be used generically across industries.

According to the WITS (2020) database and as shown in Table 5, page 55 of this thesis, South Africa's tariff structure on imported electrical and electronic intermediate inputs is based on Most Favoured Nations tariff rates (MFN) and applied tariff rates. MFN rates are the maximum and therefore most restrictive rates that WTO members can impose on each other whereas applied tariff rates represent the actual duties that are charged on imports (WTO, 2022). While South Africa sources its electrical and electronic components from a wide spectrum of European, American and Asian countries such as Germany, France, USA, Malaysia, Thailand and France (Banga & Balchin, 2019), China remains one of the biggest source regions for such intermediate inputs where the applied import tariff rates are mostly equivalent to the MFN tariff rates (WITS, 2020). Trade agreements such as Regional Trade Agreements (RTAs) tend to affect a country's overall integration into global trade and value chains, however, trade data from WITS (2020) indicates that South Africa does not source its electrical and electronic intermediate inputs from regional trade blocs such as the Southern African Development Community (SADC) and the Southern African Customs Union (SACU), because of a lack of production capabilities from the regions' member countries. Kowalski et al (2015) note that countries that participate in trade agreements such as RTAs are more likely to impose lower import tariffs because of the tariff liberalisation that is associated with such trade agreements.

While South Africa has trade agreements in various trade blocs, the country does not have any specific trade agreements with countries from which it mainly imports electrical and electronic intermediate inputs. For instance, import tariffs on electrical and electronic intermediate inputs from China, one of the main sources of such imports, are imposed at the WTO's MFN tariff rate as shown in Table 5, page 55. Stern and Ramomkolowan (2021) claim that South Africa's future growth is likely to be affected by the extent of manufacturing industries' access to competitively priced inputs. The authors mention the unconducive policies concerning manufacturing firms' imported inputs access, which have negatively impacted their growth and development.

Edwards and Jenkins (2015) highlight that the importation of technology-laden intermediate inputs by South Africa's manufacturing industries may result in increased output per worker. The authors associate this increased output with the labour-saving nature of the technology that is embodied in these imported inputs.

Importation of intermediate inputs promotes technology diffusion and learning spillovers into the importing country (Acemoglu, 1998; Baldwin & Yan, 2014; Keller, 2004). Global trade data shows that a much larger share of imports is consumed by the manufacturing sector when compared to other sectors such as the agricultural sector while intermediate inputs into manufacturing represent the largest share of the total imports (Aguiar et al., 2016; Narayanan et al., 2015). Data from Aguiar et al. (2016) for the years 2004, 2007 and 2011 shows that the values of intermediate imports as a share of global imports were 63.72%, 65.37% and 66.63% respectively while the percentage of manufacturing intermediates as a share of total intermediate imports stood at 53.3%, 51.2% and 50.6% for the respective years. It is therefore undeniable that imported intermediate imports play a hugely significant role in manufacturing processes, particularly in high value and technology enhanced processes.

A plethora of studies assess the use of intermediate inputs within the trade liberalisation context. An example is Lopez (2006), who investigates the relationship between the importation of intermediate inputs and the probability of plant survival from a trade liberalisation perspective across the whole manufacturing sector in Chile by observing data on firms that continue to exist or stop existing after a few years. The author finds that plants that import are more likely to survive than those that do not. However, the study by Lopez (2006) does not investigate the cost effect of imported intermediate inputs (changes in intermediate input prices) on plant survival, nor does it focus on vulnerable less competitive industries within the manufacturing sector. Similarly, studies that evaluate the link between intermediate inputs and firm productivity (Amiti & Konings, 2007; Gopinath & Nieman, 2014; Halpern et al., 2015; Yu, 2015) do not progress as far as addressing the link between such inputs and firm exports. Those that address firm exports, for instance, Feng et al. (2016), find that increased expenditure on imported intermediate inputs is positively correlated to export performance. Likewise, Edwards et al. (2018) investigate the effect of consistent access to imported intermediate inputs across all manufacturing firms in South Africa and their assessment shows a positive relationship between export performance and consistent access to intermediate inputs.

To contribute to the literature, this thesis focuses on vulnerable firms in a specific industry (electrical and electronic manufacturing) in South Africa, using the infant industry protection argument as the theoretical approach. Furthermore, this research concentrates on imported intermediate inputs tariff reduction whereas Feng et al. (2016) for instance, focus on increased expenditure on imported intermediate inputs while Edwards et al. (2018) pay attention to consistent access to such inputs regardless of the inputs' cost effect.

Nonetheless, it can be argued that it remains generally acceptable within trade literature and policy circles that the importation of intermediate inputs potentially plays a significant role in the survival and performance of manufacturing firms as well as in the general economic growth of the concerned countries. It is therefore not unreasonable to suggest that if infant industry protection strategies are to be promoted within manufacturing, then imported intermediate inputs can be a focal point around which these strategies can be modelled. Chevasuss-Lozza et al., (2013) argue that although it may appear rational that a cut in input tariffs is followed by increased exports for impacted firms, in reality, this is much more complex since different industries' productivities vary significantly, hence this concept requires specific scrutiny. Furthermore, it can be argued that resource allocation inefficiencies or resource constraints in other sections of production may distort the seemingly straightforward relationship between tariffs and exports.

While the impact of imported inputs tariff cuts on the domestic sectors that produce similar inputs has been widely studied, the impact of these tariff cuts on the final goods producing sectors that utilise such inputs remains poorly researched (Amiti, 2000; Chevasuss-Lozza et al., 2013;

Goldberg et al., 2009) let alone within an infant industry setup. Even so, Kowalski et al. (2015) note that Eastern and Southern African countries still impose some of the highest tariffs on imported intermediates (see Table 6). Moreover, South Africa in particular, imposes a higher level of tariffs on all imports in general when compared to other middle-income economies such as Egypt, Chile, Colombia, Mexico and Indonesia (Draper et al., 2018). This is in accord with claims in an electronics report by Van de Groenendaal (2016) that imported input tariffs combined with the relatively cheaper competing final goods imports could be to blame for the poor performance of domestic electrical and electronic manufacturing firms in South Africa. Draper et al. (2018) also indicate that even though South Africa has generally reduced its applied tariff rates over the past years, these tariffs remain above those of the majority of other middle-income countries and significantly higher than those of advanced countries. The following is therefore hypothesised:

H1: Elimination of import tariffs on international fragmentation-induced intermediate inputs positively impacts the value of South Africa's electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

The Multi Region Input Output (MRIO) version of the GTAP database, adopted for this research, identifies tariff inclusive trade values of commodities by end use (Carrico et al., 2020). This makes it possible to trace intermediate inputs from the source region to the destination region and agent at tariff inclusive market prices, in this case, from the Rest of the World to South Africa's electrical and electronic manufacturing industry. Carrico et al. (2020) derive the estimates for the GTAP MRIO database tariff inclusive trade flows according to the following equations:

$$SHRM_{c,u,s,d} = \frac{TVM_{c,u,s,d}}{\sum_u TVM_{c,u,s,d}} \quad (1)$$

$$VIUMS^0_{c,u,s,d} = SHRM_{c,u,s,d}\, VIMS^0_{c,s,d} \quad (2)$$

Where $SHRM_{c,u,s,d}$ borrowed from Market Access Map (MAcMap), represents the share of tariff inclusive trade value of a commodity *c* from region *s* to region *d* for use by importing agent *u*. $TVM_{c,u,s,d}$ is the tariff inclusive trade value. In equation (2), the share is applied to bilateral trade data, $VIMS^0_{c,s,d}$, from the standard GTAP database. Subsequently, an estimate of the tariff inclusive value, $VIUMS^0_{c,u,s,d}$, for the GTAP MRIO database is obtained.

The possibility of firms having greater access to imported intermediate inputs, because of tariff reduction, arguably raises the prospects of such firms adopting different varieties of imported intermediate inputs to diversify their final products. Different scholars (Abou Hamia, 2022; Keller, 2021; Sharma & Mishra, 2022) acknowledge that imported intermediate inputs, specifically in high technology industries, are associated with the transmission of technological information from the source region to the destination region. The high technology intermediate inputs, such as transistors and electronic chips that are used by South Africa's electrical and electronic manufacturing firms, are imported because of their lack of availability domestically. It is not unreasonable to suggest that the technological information that is embedded in either the homogenous inputs or varieties of inputs becomes more accessible as the high technology intermediate inputs become more accessible to the electrical and electronic manufacturing industry in South Africa. The concept of technology transfer through imported high technology commodities is discussed in the next section.

2.6 Technology transfer

In line with various studies discussed in this section, this thesis presents technology transfers or technology spillovers from the exporting region to the importing region. International technology transfers, widely discussed in literature as international technology spillovers (technology benefits gained from other countries without any financial compensation), that exist in trade flows are documented by Pandey et al. (2022), Byun et al. (2020), Van Meijl and Van Tongeren (1999), Das (2019), Deng et al. (2020), Liu and Fan (2020), Coe et al. (1995), Gerlagh and Kuik (2014) and Hubler (2011) who describe this type of knowledge transfer as either embodied or disembodied. Van Meijl and Van Tongeren (1999) further demonstrate how this important aspect of learning effects is incorporated into GTAP modelling.

According to Van Meijl and Van Tongeren (1999) and Coe et al. (1995), embodied spillovers are transferred from one country to the importing country as part of the traded product (leading to imitation or further development of the product) and they exist in both final products and intermediate products while disembodied spillovers are not directly connected to any trade flows, for example, international journals, conferences on technology matters and patents. Somwaru (2013), Helpman and Grossman (1991) and Romer (1994) argue that technology transfer increases the rate of learning by firms from imports, increases labour productivity and subsequently results in an increase in output. According to Datta and Mohtadi (2006), an increase in the importation of intermediate inputs leads to an accumulation of technological knowledge hence the growth of the importing country's knowledge base.

Yu et al. (2022) refer to modern global technology transfer as the knowledge economy and acknowledge that lesser developed countries can catch up through learning and imitating. However, the authors emphasise that the catch-up process can only be successful if the recipient countries possess the desirable levels of other important factors such as absorptive capacity, economic environment and human capital.

This thesis presents a developing country design of an infant industry protection framework that is integrated into the international fragmentation system through international fragmentation-induced intermediate inputs. This infant industry protection framework assumes that firms within the industry gain knowledge that is embodied in the imported intermediate inputs while government, in conjunction with the industry, provides institutional skills training to optimise the acquisition and adoption of the knowledge in firm survival, growth and development. Effectively, this thesis establishes what happens to the recipient region and sector when information is transmitted from a more advanced region and sector. To achieve this, the value of exports from the knowledge receiving sector was evaluated.

Other studies such as Das (2019) and Van Meijl and Van Tongeren (1999) have adopted GTAP modelling with respect to technology transfer by assuming that technology is transferred via intermediate inputs trade from the source region to the destination region. However, this research was carried out with a few deviations as discussed in the following paragraphs.

Das (2019) and Van Meijl and Van Tongeren (1999) place a major focus on total factor productivity to determine technology induced gains whereas this research places a major focus on the value of exports as a measure of technology induced gains by the domestic industry. The approach by Van Meijl and Van Tongeren (1999) is to adopt an absorptive capacity index and a structural similarity index. The efficient transfer of technology from one region to another is assumed to depend on the ability of the recipient country to absorb the technological knowledge (Van Meijl and Van Tongeren, 1999). The authors proceed to define this ability to absorb knowledge as absorption capacity, which is principally based on the human capital, whereby the transfer of knowledge is most efficient in cases where the destination region has more human resources than the source country. While other factors such as capital, infrastructure, substitution elasticities or trade distortions partly determine the ability of the destination region to absorb technological knowledge, it can be argued that human capital plays a hugely significant role in this regard.

Lucas (1988) emphasises the importance of human capital in technology transfer by referring to technological differences as differences in the knowledge of particular people.

This thesis modelled an infant industry protection framework through which skilled labour abundance is attained through government sponsored training programmes. Absorption capacity is not specifically modelled in this research, but rather, an abundance of skilled labour is assumed, to enhance the survival, growth, and development of vulnerable firms. This did not undermine the results of this thesis in any way, because the objective has been to evaluate the effectiveness of an infant industry protection policy framework, whereby an industry-led and government sponsored skills training programme within the electrical and electronic manufacturing industry forms part of the protection framework.

Van Meijl and Van Tongeren (1999) in their nine-region aggregation study, adopt a structural similarity index whereby the similarity between North America and the Rest of the World is prescribed as 0.369, between North America and China as 0.495, between Argentina and China as 0.875 where the Rest of the World includes South Africa. In contrast, this research models two regions, South Africa and the Rest of the World. The Rest of the World region is made up of widely structurally dissimilar countries that are nonetheless sources of intermediate inputs for South Africa's electrical and electronic manufacturing industry. An estimation of a structural similarity index between South Africa and the Rest of the World would therefore become highly inaccurate. Because of the high regional aggregation, this parameter is not specifically modelled in this research.

According to Das (2019), the model shock that initiates technical change can be described as a percentage technical progress in the more technologically advanced source region. Logically, and as Van Meijl and Van Tongeren (1999) state, the destination region will not gain if there are no trade flows from the region of origin. With the appropriate conditions in place in the destination region, it is therefore anticipated that a positive technical change in the region of origin will result in increased productivity in the destination region because of the trade linkages between the two regions. It is also anticipated that such a gain could result in a change in the value of exports from the manufacturing industry that utilises the imported technology embedded inputs. Van Meijl and Van Tongeren (1999) proceed to claim that the size of the trade flows between the origin and destination regions significantly impact the amount of knowledge transferred, to the effect that the quantity of imports corresponds directly to the amount of knowledge transferred. It is therefore not unreasonable to assume that policy frameworks that increase the quantity of imported international fragmentation-induced intermediate inputs should theoretically be expected to result in an increase in the amount of knowledge received by the destination manufacturing industry.

It can be argued that technology spillovers result in learning effects in the recipient industries. Different scholars including Hausmann and Rodrik (2003), Melitz (2005), Deng et al. (2020) and Young (1991) demonstrate that firms can experience a decline in production costs while realizing productivity gains from a learning process that is based on technology spillovers. Protection of vulnerable less competitive firms is believed to buy them sufficient time to learn by doing while achieving productivity gains and economies of scale whereby the gains are much bigger in knowledge intensive industries (Slaughter, 2004) such as the electrical and electronic manufacturing industry. Kogan et al. (2016) describe these learning effects as a learning by doing process in which the production experience gained with time eventually leads to a reduction in the cost of production. In such instances, economies of scale arise from learning by doing where the cost of production declines as production experience increases (Kogan et al., 2016). Miravete (2003) also attests that learning by doing is a source of marginal cost reductions. It can therefore be further argued that firm protection strategies such as the creation of easy access to knowledge embodied imported intermediate inputs (that enable technological knowledge spillovers) can potentially contribute to a successful learning by doing process.

The generalised presentation of technology flow through intermediate inputs for this thesis is given in Figure 1 where the source region (SR) is the Rest of the World, and the destination region (DR) is South Africa. The rest of the world is an aggregation of regions and countries of the world except South Africa (see Table 16).

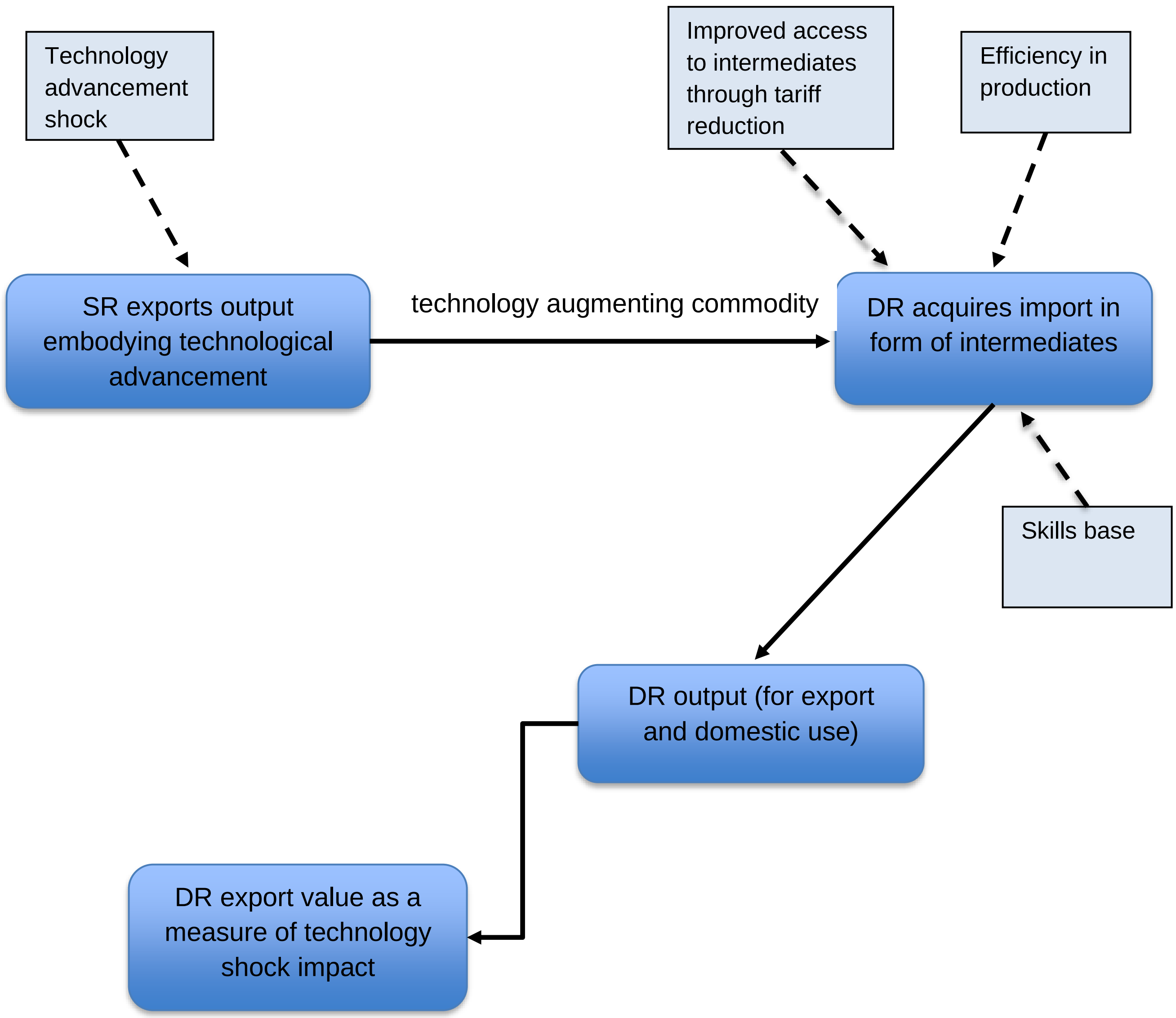

Figure 1: Schematic diagram of technology flow

Source: Author.

Several studies (Boler et al., 2012; Coe et al., 1995; Hayami & Ruttan, 1985; Van Meijl & Van Tongeren, 1999) integrate technology spillovers into production processes in countries that import intermediate inputs and find positive productivity effects. These studies, however, do not focus on export flows from the technology receiving countries. Nonetheless, they demonstrate a positive impact of technology spillovers on the recipient sectors' productivity in the destination region.

This thesis specifically focuses on exports from the electrical and electronic manufacturing industry in South Africa. Considering the assumption that tariff reduction increases access to imported intermediate inputs, and the concept of technological transfer through such inputs, the following is therefore hypothesised.

H2: Technology transfer through intermediate inputs enhances the positive impact of imported international fragmentation-induced intermediate inputs tariff reduction, on the value of South Africa's electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

This thesis examined technology transfer in the form of the embodied technology transfer concept as defined by Van Meijl and Van Tongeren (1999) and Coe et al. (1995), that is, the transfer of technology in the physical presence of imports. The learning effects gained through the importation of international fragmentation-induced intermediate inputs provide an opportunity for vulnerable firms that lack adequate research and development facilities, to learn by adopting intermediate input-bound knowledge. While the reduction in imported intermediate inputs tariffs made such inputs more readily available to less competitive and vulnerable firms in the electrical and electronic manufacturing industry, a constraint in terms of skilled labour (required for effective adoption of technological knowledge) was also anticipated. The infant industry protection model specification in this thesis assumed an industry led (government assisted) initiative through skills training in industry and institutions of higher education hence alleviating the skills shortage constraint. The next section discusses the significance of tariffs in infant industry protection.

2.7 Tariffs

Import tariffs are defined as taxes that are imposed either on the quantity of imports, for example, as a fixed dollar amount on a unit quantity of imports or as *ad valorem* tariffs, that is, as a percentage of the import value that includes trade margin costs (Burfisher, 2016). Tariffs are the most used industry protection policy, and they are generally preferred over quotas (non-tariff barriers that have the effect of changing the quantity of goods traded) because they generate income for the imposing country (Mahdi & Michalek, 2016; Miravete, 2003). In such industry protection strategies, the policies are designed to increase the tariff rates, as an alternative to imposing import quotas.

Chang (2011) posits that while a fair amount of literature theoretically postulates that quotas yield more favourable results than tariffs, practically, tariffs have been shown to be easier to administrate. For this reason, a government may choose to implement the less administratively exhausting tariffs (Chang, 2011). Similarly, Andreoni and Chang (2019) suggest that because of their inferior administrative functions; developing countries will most likely prefer tariff protection since the tariffs are much easier to collect.

Nonetheless, high tariffs that are typical of infant industry protection mean that domestic consumers end up paying more for imported goods (Qadir, 2020) while alternative policies such as quotas also have negative effects such as directly shutting out knowledge gains that are embodied within imports, particularly in technology intensive goods (Simachev et al., 2016). Furthermore, high tariffs potentially incite retaliation from the advanced exporting countries (Dosi et al., 2020). However, to attenuate the propensity of some economies to unduly increase import tariffs, the WTO policing was designed to encourage tariff reduction (Koopman et al., 2020).

Import tariffs on intermediate inputs are highly significant in international fragmentation systems, specifically because they tend to accumulate in scenarios where the concerned intermediate inputs cross country borders several times (Farole, 2016). Since tariff rates directly impact the price of intermediate inputs, the manipulation of tariff rates can therefore be considered as an indirect way of controlling the flow of intermediate inputs.

In summary, any possible negative impacts of tariffs, such as the cost burden to consumers, administrative challenges, reduced knowledge transfers and retaliation from source regions are eliminated in a protection strategy that emphasises the elimination of tariffs as a part of the policy framework. This thesis, which integrates the infant industry protection framework into the international fragmentation system therefore reduces the cost burden to the three concerned agents, namely firms, households and government. To evaluate the effectiveness of the protection framework on the vulnerable manufacturing industry, the value of final goods exports was examined. The following two sections focus on the significance of final goods and manufactured exports in industry and manufacturing.

2.8 Final goods and their role in industry and manufacturing

This section discusses the role of final goods (both exports and imports) towards the development of industries. It is also vital to note that this research observes only the final goods exports from South Africa’s electrical and electronic manufacturers as the dependent variable.

A long-standing argument for infant industry protection is that cheaper imports that compete against domestic goods output are generally not sustainable in the long run because such competition eventually destroys the local industries (List, 1841; Raffer, 2020; Roberts, 2003). It is therefore not surprising that the infant industry protection argument has traditionally pivoted around the imposition of high tariffs on imported competing goods, to reduce the consumption of such imports. Imported medium to high technology final goods such as electrical and electronic goods appear to be a double-edged sword. Despite their purported undesirable competing nature, Fracasso and Marzetti (2015) argue that imported final goods are an important mode of embedded knowledge transfer into importing countries, particularly those countries that have limited research and development facilities to initiate their own innovative projects in manufacturing processes.

On the other hand, exports have been found to play an important role in manufacturing sectors and the general economic performance of developing countries. Gries and Grundmann (2020) investigate data from a sample of 75 developing economies for the period 1970 to 2005 and find that manufactured exports positively drive the diffusion of the countries' productivity capacity because such countries can compensate for domestic demand shortages through sales to the larger international markets. Among many other scholars, Belkania (2020) argues that manufactured exports from developing countries enhance economic growth to a larger extent when compared to primary goods exports. The next section delves into the relevance of manufactured exports to both firm and country level growth and performance.

2.8.1 The role of manufactured exports

Exports are an important source of foreign exchange required for financing imports, allow exploitation of economies of scale through bigger market access, boost employment and are essential for an economy's growth and development (Grossmann & Scheufele, 2019; Pieterse et al., 2016; Takii, 2019). Matthee et al. (2018) find evidence that South Africa's exporters generally behave similarly to exporters in other countries where comparable studies have been undertaken. For instance, with reference to both Africa and South Africa, exporters are generally over 200% larger and reflect 50% more capital intensity than non-exporters (Matthee et al., 2018; Van Biesebroeck, 2005). Karam and Zaki (2020) demonstrate that exports are a reliable indicator of firm performance by evaluating manufacturing firms' exports from the Middle East and the North African region. Evidence that exporters are more productive than non-exporters of the same size in the same industry has led to a consensus that exporting has a positive impact on firm productivity (Le & Valadkhani, 2014). Cieslik et al. (2015) also find evidence of a strong positive relationship between firm productivity and exporting. However, Brenton et al. (2010) stress that the low survival rates of developing countries' export flows are a result of a lack of follow up policy strategies once firms enter export markets. It is therefore not unreasonable to argue that thriving exporters require more than just entry into foreign markets; they also need to consistently maintain a sustainable level of exports.

Increased exports stimulate capital formation because firms can generate sufficient gains to purchase imports in the form of both intermediate goods and capital equipment (Belkania, 2020). Several studies, including Tanaka (2017), Bustos (2011), Trefler (2010), Ahmad et al. (2018), Lam (2013) and Freund and Rocha (2011) have suggested that exports induce important changes in firm behaviour that include economies of scale, higher varieties of products and higher quality products for richer export markets when compared to firms that only sell to domestic markets. Bastos et al. (2018) also confirm that higher export flows induce economies of scale. Exports contribute directly to employment creation and according to the IDC (2017), 2.53 million jobs (an equivalent to 21.4% of total jobs) within the South African economy in the year 2016, were either directly or indirectly linked to exports, a figure that has tremendous potential to rise if export growth enhancing strategies are implemented.

Furuoka (2018), Awokuse and Christopoulos (2009) and Salim and Hossain (2011) suggest that there has been a significant positive relationship between exports and economic growth in some Asian developing countries such as Taiwan, Japan and South Korea, and this has resulted in high credence to claims that exports play a major role in stimulating firm and country economic growth. On the contrary, evidence from African countries has sadly been unappealing. Africa's share of global exports declined by half in the 30 years from 1980 to 2010, at the same time Sub-Saharan Africa's merchandise exports (as a share of global merchandise exports) fell from 1.6% to 0.8% (Freund & Rocha, 2011). Similarly, Edwards (2021) states that South Africa's exports rose by a mere 3% from the year 2008 to the year 2019 while imports surged 17% during the same period. While manufacturing has been the main source of firm exports and economic development in developing countries (Gault & Zhang, 2010; Lall, 2005), the manufacturing value added from Africa fell from 1.2% to 1.1% of the global manufacturing value between the year 2000 and the year 2008, and Africa's GDP has followed a downward trend since the 2000s (Mijiyawa, 2017).

Also notable are South Africa's goods exports to traditional markets such as Europe, China and America which declined for the period 2010 to 2016 (IDC, 2017). While a significant portion of scholars and policymakers have shown tremendous interest in the relationship between exports and firm growth or general national economic growth, African countries have surprisingly received less than expected attention in these academic discussions (Ee, 2016).

It can be argued that policy measures aimed at enhancing exports could play a fundamental role in reviving the survival prospects of the electrical and electronic manufacturing firms in South Africa. As such, the objective in this thesis was to formulate and evaluate (by observing the value of exports) an infant industry protection framework that was integrated into the international fragmentation system. The following section justifies the choice of export value as an export performance indicator and dependent variable for this thesis.

2.8.2 The value of exports

Economic measures of export performance such as export profitability, sales growth of exports and export intensity are more frequently used when compared to non-economic measures such as an export goal or satisfaction achievement because the former can quantify the value gained by firms through changes in production activity (Chen et al., 2016; Edeh et al., 2020; Ruzekova et al., 2020). A quantifiable economic measure is required to conduct a meaningful policy analysis study that involves goods imports and exports.

The value of exports was the preferred export flow indicator and dependent variable in this thesis because of its capability to reflect price effects as well as potential profitability to the vulnerable industry that engages in the use of international fragmentation-induced intermediate inputs. For instance, adopting the total quantity of units sold as a dependent variable could be misleading in cases where a lesser quantity of high value products is worth more than a higher quantity of low value products.

2.9 Conclusion

This chapter discussed the infant industry protection framework, its theoretical background and traditional mechanisms of application, the common criticisms against the traditional mechanisms of infant industry protection framework application and South Africa's electrical and electronic manufacturing industry as an infant industry. The chapter also discussed international fragmentation, international fragmentation-induced intermediate inputs and the potential role of such inputs in enhancing the survival and growth prospects of electrical and electronic manufacturing firms in South Africa. The reviewed studies indicated that the costs associated with the implementation of the traditional infant industry protection framework make it less suitable for application in resource constrained African countries. The chapter also outlined the designed integration of the infant industry protection framework into the international fragmentation system, at the same time addressing criticisms against the conventional mechanisms of infant industry protection application. Aspects of the integration process, such as the technology transfer, tariffs, final goods and their role in manufacturing, and the value of exports were also discussed.

Fundamental to the choice and adoption of appropriate policies for infant industry protection and its integration into international fragmentation, is the general economic performance and the level of development of the concerned country. This is important in assessing the viability and meaningfulness of the implementation of the concerned policies, based on countrywide resource endowments and other relevant factors. The next chapter, therefore, discusses the African country context, South Africa as a developing country and South Africa’s electrical and electronic manufacturing industry.

Chapter 3: African countries and South Africa as a study context

3.1 Overview

The formulation and adoption of policies that pertain to the infant industry protection framework arguably entail an awareness beyond the targeted industry. It also requires comprehension of the concerned country in terms of its economic performance and general global economic positioning. This chapter focuses on the African country context, South Africa as a developing country and South Africa's electrical and electronic manufacturing industry. Sections in this chapter are presented in the following order: African countries as a region of interest, the significance of manufacturing to African countries and a comparison of their economic performance to other emerging economies, potential growth opportunities for electrical and electronic manufacturing in South Africa, the tariff structure in South Africa's electrical and electronic manufacturing industry, industrial performance and overall economic growth in South Africa, as well as government policy towards the electrical and electronic manufacturing industry.

3.2 African countries as a region of interest in the study

This section details the general similarities among African developing countries. It also discusses the practicability of integrating an infant industry protection framework into the international fragmentation system within an African country context. In this thesis, the terms country and economy are used interchangeably as delimited by the World Bank (WB, 2020) to refer to a territory where authorities declare separate economic statistics.

The World Bank and the United Nations (UN) generally stratify countries of the world into three classes of low income, middle income (low middle income and high middle income) and high-income countries (United Nations Conference on Trade and Development [UNCTAD], 2020; WB, 2020). The UN's World Economic Situation and Prospects (WESP, 2020) further groups the low-income and middle-income economies into the developing country category while the high-income economies comprise the developed country category. According to the WESP (2020), South Africa is classified as an African economy. Fal'tsman (2020) states that developing economies have historically lagged the developed world in terms of economic development by an ever-increasing gap. The developing economies, therefore, need to implement novel and more competitive economic growth strategies if they are to catch up with the developed economies (Fal'tsman, 2020).

Conventionally, African countries have heavily relied on the importation of manufactured goods (including high technology goods) rather than developing domestic manufacturing firms to global level production capacity and competitiveness, hence arguably suppressing any potential growth and development of such domestic manufacturing firms, as demonstrated by Torreggiani & Andreoni (2019). The authors show that an increase in Chinese manufactured imports into South Africa coincided with a decline in the domestic manufacturing sector output for the period from the year 2002 to the year 2017. During this period, evidence from Torreggiani and Andreoni (2019) points to the fact that China's import penetration rose from 1.45 % to 8 % while the fraction of domestic manufacturing output in total output dropped from 33.4% to 23.9%.

According to Edwards and Jenkins (2015), the effects of the growth of final goods trade with China, for instance, have been undesirable for South Africa's manufacturing sector with some industries calling for protection from imports from China. Then president of South Africa Jacob Zuma, in his address at the Forum on China Africa Cooperation (FOCAC) in 2012 went on to highlight that such unequal trade was unsustainable (Edwards & Jenkins, 2015). While China was the centre of focus, it is undeniable that other Asian and developed countries have practiced such unequal trade with African countries. The tendency has been to protect South Africa's manufacturing sectors by focusing on the balance and check on the imported competing final goods as shown in studies by Morris & Reed (2008) and Edwards and Jenkins (2015).

However, there is a scarcity of studies that analyse the protection of South Africa's manufacturing industries by focusing on international fragmentation-induced imported intermediate inputs that are utilised by these manufacturing industries, especially from the infant industry protection perspective. This thesis fills this gap by concentrating on the formulation and evaluation of an infant industry protection framework that is integrated into international fragmentation with specific attention to the electrical and electronic manufacturing industry in South Africa. The next section examines the importance of manufacturing activities as a focal point of growth and development in African developing economies.

3.3 The significance of manufacturing to African economies

Manufacturing activities have been the driver of economic advancement in most of today's developed economies and only a handful have managed to develop in the absence of a strong manufacturing background (ECA, 2016). Weiss (2018) argues that manufacturing is vital to the transformation of countries from low-income status to high income status. Aiginger and Rodrik (2020) echo similar sentiments by affirming that for any country to overcome poverty or upgrade its income status, for example, from middle-income to high-income, it must improve its manufacturing activities. A high export level of manufactured goods has been found to have an even more significant positive effect on economic growth, nonetheless, the story in relation to African countries has not been impressive (Guisan, 2017; Opoku & Yan, 2019). Furthermore, the International Labour Organisation (ILO, 2014) maintains that in the context of developing economies, manufacturing firms that export provide the most stable formal jobs that are subject to minimum wage legislation.

Manufacturing industries are the major origin of the modern economic world's technology driven growth efficiency because their output can be applied as input into agriculture, services, information technology and other sectors (Andreoni & Chang, 2016; Chang et al., 2013). Scholars such as Shen et al. (2007) and Mijiyawa (2017) equally stress that manufacturing firms are key customers of the banking, transport, insurance and communication services, while potentially inducing strong spillover effects to other economic sectors of a country. Andreoni and Chang (2016) therefore conclude that a weak manufacturing foundation eventually leads to a slump in the quality and growth of such services. With respect to South Africa, the manufacturing sector's share of GDP stood at 13% in the year 2017, a decline from approximately 19% in the year 2000 (DTI, 2018).

There has been a contentious comparison of the rate of growth and development between African countries, Asian developing countries and other emerging economies, especially for the period spanning a few decades through to the beginning of the 21st century. For instance, Yong (2017) indicates that the manufacturing value added in Southern Africa fell from 16.7% in 1990 to 11.2% in 2015 whereas developing Asian countries and Europe registered an increase from 16.5% to 25.5% and from 14.8% to 15.2% respectively, in manufacturing value added to GDP from 1990 to 2015. Stiglitz (2017) contributes to this argument by pointing out that the East Asian bloc experienced simultaneously high levels of development and economic growth along with increased manufacturing activity while African economies suffered poor growth and lower manufacturing activity.

The Competitive Industrial Performance (CIP) index score for the year 2015 and the year 2017 ranks South Africa lowest amongst BRICS member countries (United Nations Industrial Development Organisation [UNIDO], 2020) as presented in Figure 2. The CIP index measures the capacity to produce and export manufactured goods, technological deepening and upgrading as well as world impact (UNIDO, 2020). A higher CIP index score indicates that a country's manufacturing industries are more competitive. The CIP index score for South Africa decreased by 0.004 from 0.072 in the year 2015 to 0.068 in the year 2017. China in comparison, has a much higher CIP index score that dropped slightly from 0.401 in the year 2015 to 0.3687 in the year 2017. Figure 2 not only reflects that South Africa lags in manufacturing competitiveness but perhaps also highlights the need to exploit opportunities, particularly in relation to technological advances, for example, in the electrical and electronic manufacturing industry. Literature suggests that the manufacturing sector when compared to other sectors such as mining and construction, has the highest opportunities for growth, job creation and welfare improvement in African developing countries, and has historically been a vital source of innovation and technology diffusion in developing countries (Gault & Zhang, 2011; Lall, 2005; Mijiyawa, 2017).

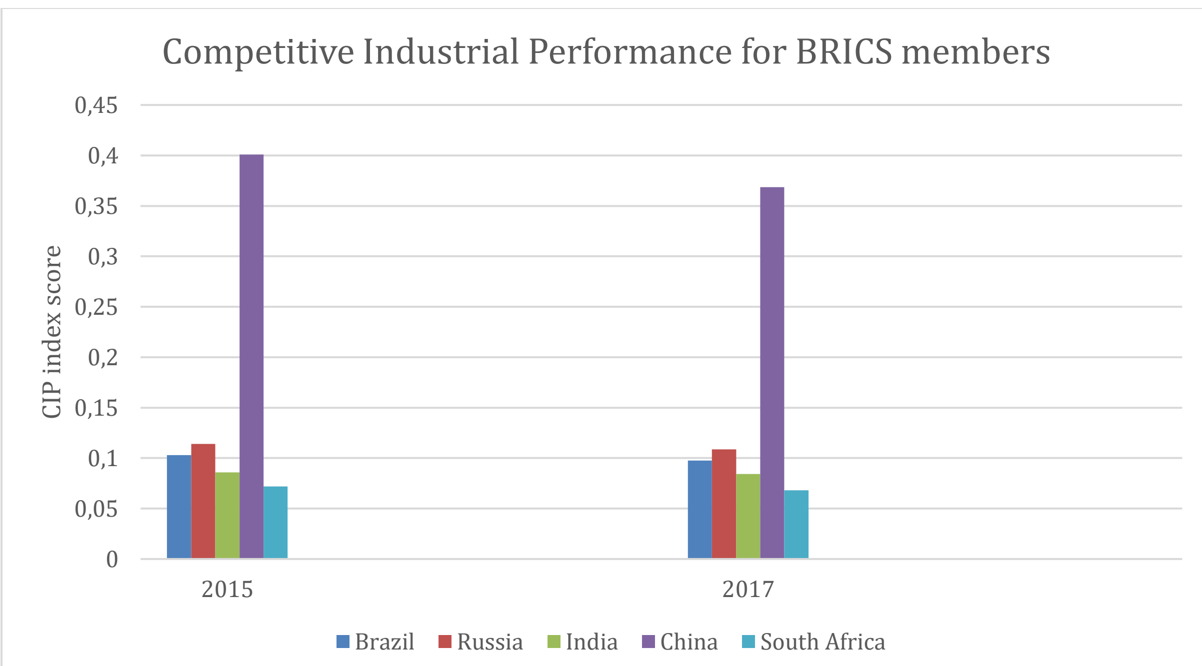

Figure 2: CIP index for BRICS members for the years 2015 and 2017

Source: UNIDO (2018, 2020).

With the emergence of international fragmentation, Andreoni and Chang (2016) acknowledge that countries have come to identify manufacturing firms as the principal contributor to technology driven productivity growth. According to the authors, manufacturing has in fact made the modern world, due to its higher adaptability to a variety of economic activities when compared to other sectors like agriculture, whose productivity increase is curbed by natural factors such as soil, climate, time and space. Mijiyawa (2017) critically alludes to the fact that African governments should not expect this technology driven productivity growth to happen autonomously but should rather proactively instigate drivers of transformation. Parada (2018) argues that real transformation through successful manufacturing industries relies on selecting and protecting the appropriate firms for production while taking new risks with new projects of great potential, for instance, the production and exportation of potato chips is different from the production and exportation of electronic microchips. Even the current developed nations did not experience simultaneous growth in all sectors of their economies but began by growing small promising industries (mostly manufacturing industries) inside their borders (Hirschman, 1958; Parada, 2018; Saliminezhad & Lisaniler, 2018).

It is with the above consideration that this thesis contributes to the literature by integrating an infant industry protection framework of the electrical and electronic manufacturing industry into the international fragmentation system through the adoption of international fragmentation-induced intermediate inputs. The following section focuses on electrical and electronic manufacturing in South Africa.

3.4 Potential growth opportunities for electrical and electronic manufacturing in South Africa

This section presents the general types of products from the electrical and electronic manufacturing industry, in addition to the examples of various innovation projects (as discussed earlier in Chapter Two, Section 2.3.2). It also positions South Africa globally while identifying existing opportunities and potential for growth in its electrical and electronic manufacturing industry. This section further focuses on the total output from South Africa’s electrical and electronic manufacturing industry, which falls far short of the general average global production standards and domestic demand.

According to the DTI (2022), firms in the electrical and electronic manufacturing industry manufacture products that generate, distribute and use electrical power whereby the subsectors include consumer electronics, electronic products such as automotive parts, power electronics and electrical products. Table 2 summarises the composition of the electrical and electronic manufacturing industry based on the type and usage of the products made. However, Table 2 is not exhaustive of all the different products produced by the industry. It merely highlights the areas of manufacturing specialisation and their major products.

Table 2: Electrical and electronic manufacturing firms by manufacturing specialisation

Manufacturing specialisation	Household appliance	Electrical equipment	Electric lighting equipment	Other electrical equipment
Products	electrical appliances	electric motors, generators, transformers, switchgear apparatus etc	electric lamp bulbs, lighting fixtures etc	devices for storing electrical power (e.g., batteries), for transmitting electricity (e.g., insulated wire), and wiring devices (e.g., electrical outlets, fuse boxes, and light switches) etc

Source: DTI (2017,2022) and Dun & Bradstreet website (2022).

The global market for electric lighting equipment such as Light Emitting Diodes (LED) lighting systems is predicted to expand in the coming years (Paucek et al., 2020). According to the International Distribution of Electronics Association (IDEA, 2019) and Yole Development (2017), the use of LED lighting in horticultural greenhouses is expected to grow at an average annual rate of 15%, whereas indoor and vertical farming applications in indoor horticulture are expected to grow at an average annual rate of 35% from the year 2022 to the year 2027. According to the study, this translates to an increase in LED consumption from US$ 400 million in 2022 to US$ 700 million in 2027, in a market that had already reached a value of US$ 3.8 billion in the year 2017.

Concerning medical devices trade, Hu et al. (2022) report that the total global volume of medical devices trade from the year 2001 to the year 2020 shows an upward trend, however, the main exporting countries have remained the same. This group of exporting countries includes the United States, China, Germany, Japan, China, France, Switzerland and Ireland (Hu et al., 2022). The lack of new entrants into the expanding medical devices export market probably reveals that there could be an opportunity to be exploited by electrical and electronic manufacturing industries in African countries. Some of South Africa's prominent manufacturing firms (and their output specialisation) that comprise the electrical and electronic manufacturing industry are presented in Table 3. The table also identifies specific firms that could benefit from the current global opportunities, for instance, Minoan Medical, could benefit from tapping into the global wave of increasing medical devices trade.

Considering all the global trends discussed above, it can be argued that South Africa's electrical and electronic manufacturing industry should take advantage of these prevailing conditions to grow, develop and sustain the survival of its manufacturing firms.

Table 3: Selected electrical and electronic manufacturing industries in South Africa

Company name	Number of employees	Output specialisation
SAAB Grintek Defence	700	Manufactures electronic equipment for the aviation and marine defence industries.
Kwikot	650	manufactures geysers in South Africa.
Fresenius Kabi Manufacturing South Africa	580	manufactures medical devices.
Altech UEC SA	457	Designs and manufactures set-top boxes and other electronic products Imports, designs, manufactures and installs ICT, air traffic management and defence products, including software and services; manufactures decoders.
CZ Electronics Manufacturing	300	Manufactures electronic assemblies for the defence, utility metering, vehicle tracking, data acquisition and telecom industries with printed circuit boards, TV components and set-top boxes.
Home of Living Brands	250	Manufactures and markets household appliances, including televisions, audio and visual products, and aerial and satellite equipment, mostly under licence.
Minoan Medical	206 (Group)	Subsidiaries manufacture medical stand devices, specialising in vascular technology, as well as distributing imported products.
Drager South Africa	141	Manufactures and imports medical and safety products and equipment such as monitors and incubators for South Africa and other African countries.

Company name	Number of employees	Output specialisation
Current Automation	67 (Head office)	In addition to importing data processing and other machinery, manufactures solar components and installs off-grid and grid systems.
UNIVA	250	Stoves
Whirlpool	930	Freezers, fridges and washing machines

Source: DTI (2017, 2022) and Dun & Bradstreet website (2022).

Similarly, household appliances and other product types listed in Tables 2 and 3, present further opportunities for the growth and development of South Africa's electrical and electronic manufacturing industry. These are discussed in the following paragraphs.

In 2018, the value of manufactured products from the electrical and electronic (electrical machinery, household appliances, radio, television & communication apparatus, optical and other equipment) manufacturing industry as a share of the total value of manufactured goods from South Africa's manufacturing sector was approximately 3.5% (Statistics South Africa [StatsSA], 2019). Figure 3 shows that the electrical and electronic manufacturing industry's share of manufactured output relative to the other 8 industries is quite low. It is only slightly higher than the glass and other non-metallic products as well as the textiles and apparel industry output which contribute 3.2% and 2.3% respectively. Table 3 reflects that there is room for growth and development in the electrical and electronic manufacturing industry, particularly in cognisance of studies by Hu et al. (2022) and Paucek et al. (2020) that show that there is a continuous average global growth in sections of this industry.

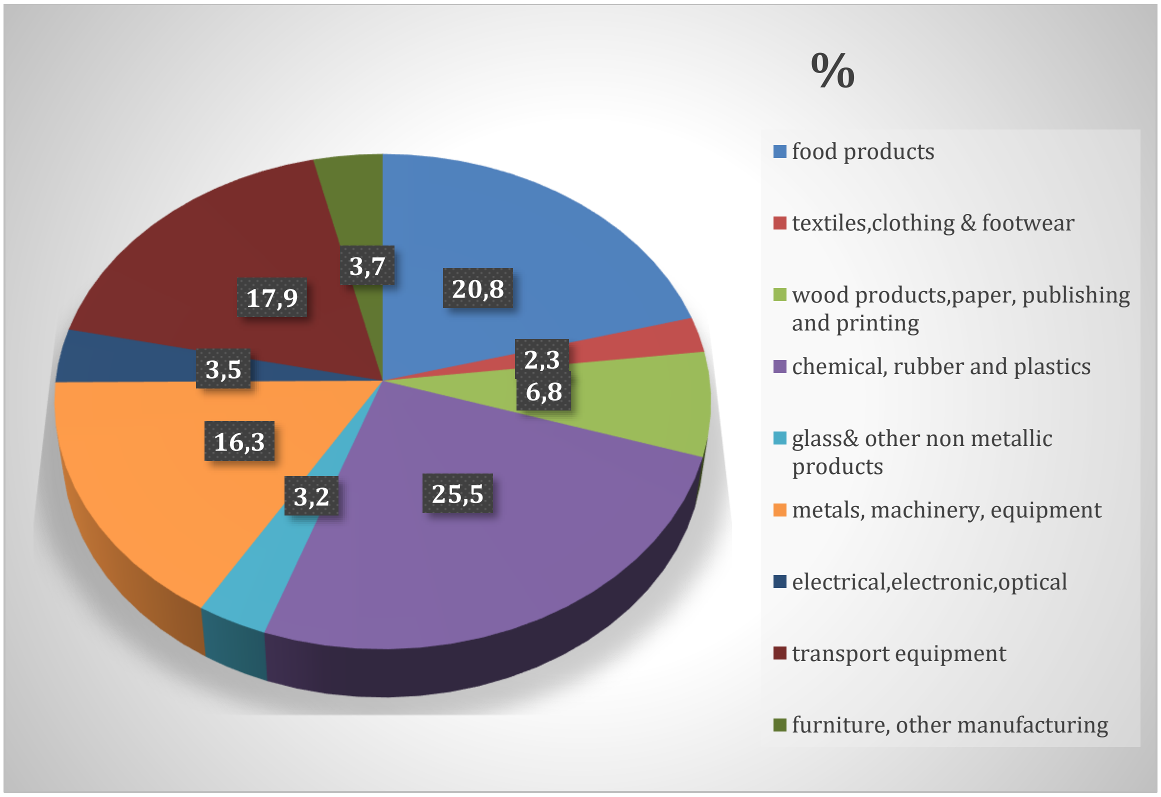

Figure 3: Percentage sector output as a share of total manufacturing output for 2018

Source: StatsSA (2019).

InvestSA (2020) reveals that South Africa remains heavily reliant on the importation of consumer electronics, having imported 60% of total consumer electronics into Africa during the year 2018. However, the IDC (2017) reports that the electrical and electronic manufacturing industry in South Africa remains reliant on exports for its growth and development. The high percentage of consumer electronics imports (InvestSA, 2020) reveals the high vulnerability of South Africa's manufacturers of such goods. This translates to the need for strategies to sustain the survival and growth of this particular domestic manufacturing industry. Based on the IDC (2017) report, one such strategy is a policy framework that improves the value of exports from the industry. The industry has consistently shown a potential for positive growth over the past few years and such growth prospects are now brighter because of its strong linkages with the electricity generation sector, technology sector and the heightening global technology advancements, such as the Fourth Industrial Revolution (4IR) (ADB, 2019).

On the global front, the global electronics and information technology sectors' production output is generally predicted to keep increasing in the backdrop of an ever-rising demand for electronic devices for use in remote information technologies (JEITA, 2020). On the contrary, South Africa's electrical and electronic manufacturing industry remains with significant challenges and the survival of its firms is at risk. According to an industry report by Van de Groenendaal (2016), this is because of tariffs on imported intermediate inputs that result in a high cost of production compounded by the cheaper competing final goods imports from advanced western countries and Asian countries such as Japan, Taiwan and China.

Given the electrical and electronic manufacturing industry's low output (see Figure 3) compared to other industries, it is perhaps not surprising that data collected from the South African Revenue Service (SARS, 2022) shows that the share of exports from the industry in total exports is subsequently low. Figure 4 shows that the share of electrical and electronic exports in total exports from South Africa for the year 2018 is at approximately 2.57%, way lower than leading contributors such as metals and minerals, food and transport equipment industries.

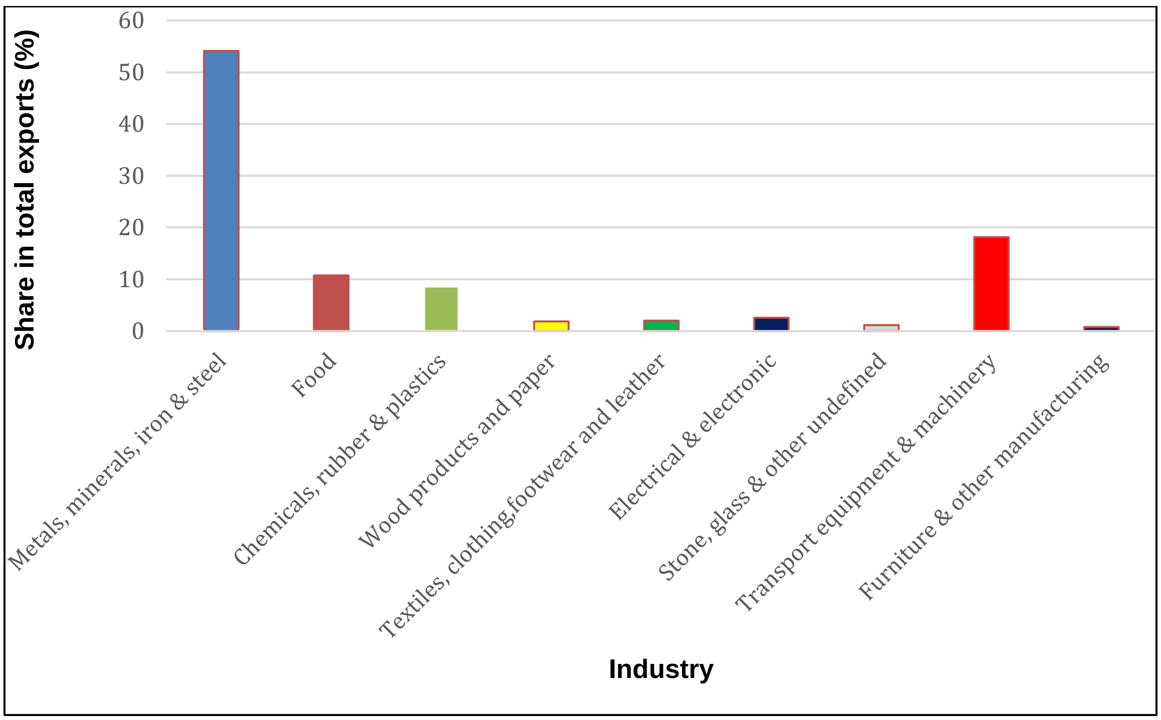

Figure 4: Share of industry exports in South Africa's total exports for the year 2018

Source: SARS (2022).

Based on the GTAP 10 database (2014 base year) and this study's aggregation, the share of electrical and electronic exports as a share of South Africa's total exports stood at 2.72%. The data shows a very slight decrease of 0.15% in the value of exports from the year 2014 to the year 2018. It is therefore reasonable to suggest that the GTAP 10 data, used in this study is fairly representative of the industry's size in South Africa's most recent economic data (before the outbreak of the COVID-19 pandemic).

A comparison of South Africa's electrical and electronic manufacturing industry performance against global trends also reveals some stark contrast between the domestic output and the general global output. On average, the annual total global output from the electrical and electronics manufacturing industry has shown an overall increase of 12.9 % from the year 2015 to the year 2018 (JEITA, 2020), most likely owing to the ever-expanding global market for such products. Despite the expanding global production in the electrical and electronics manufacturing industry during the period 2015 to 2018, as well as the generally growing demand for electrical and electronic products, a report by JEITA (2020) reveals that South Africa's electrical and electronic manufacturing industry had contrasting fortunes and arguably suboptimal total output with an overall 8% decline over the same period. A study by Draper et al. (2018) also reveals a decline in medium to high technology manufacturing exports from 39.8% to 21.3% of South Africa's total exports from the early 2000s to the year 2016.

South Africa's total revenue for consumer electronics only, in the year 2019 was subsequently not impressive when compared to main global players and peer African countries. Table 4 shows this comparison across the spectrum from global leaders to African economies.

Table 4: A comparison of consumer electronics total revenue for 2019 (in United States dollar terms) by country

Top Five Global Leaders	**Consumer Electronics Revenue (US$ Million)**
China	158 016
United States of America	74 316
Japan	15 954
Germany	15 535
United Kingdom	12 075
Selected African Countries	
Egypt	961.3
Nigeria	787.5
South Africa	764.0

Source: Statista (2020). Note: Consumer electronics are a significant subset of the electrical and electronic industry. Nonetheless, the projected growth of this industry in South Africa is set to decline through to 2023 partly because of the increased competition from foreign producers.

The gap between global production trends and domestic production trends in the electrical and electronic manufacturing industry highlights the policy and structural inadequacy with respect to the pertinent production and value chains in South Africa. Beyond just tariff reductions, this study, therefore, contributes towards attempting to solve the survival challenges facing South Africa's electrical and electronic manufacturing industry by empirically modelling an infant industry protection framework that is integrated into international fragmentation, using a CGE model.

South Africa's electrical and electronic manufacturing industry is reliant on imported intermediate inputs such as electronic microchips and transistors, but policy regulations concerning this value chain, as reflected in the WITS (2020) tariff data, are currently detrimental to the industry. Draper et al. (2018) highlight institutional challenges concerning tariff setting while the Association of Representatives for the Electronics Industry (2019) reports that the electrical and electronic industry in South Africa is falling short because the government has not removed trade barriers that negatively impact the firms in the industry. This is echoed by Flatters and Stern (2008) who claim that electrical and electronic manufacturing firms in South Africa have always faced import tariffs on their imported components while (ITA, 2021) adds that the importers have continuously been disadvantaged by the unnecessarily complex tariff schedule. According to Peterson and Thies (2014), domestic manufacturing firms that consume imported intermediate inputs are expected to be negatively impacted by any form of import duty particularly if the demand for these inputs is inelastic, since this scenario implies that the firms have no alternative but to meet the higher prices. In the same way, South Africa's electrical and electronic manufacturing industry operates at productivity and competitiveness levels that are below those of global standards, in the same industry, as identified by ITAC (2014) and because of its small size, it is subsequently a price taker with respect to its goods exports.

With reference to import tariffs, the electrical and electronic manufacturing industry is guided by umbrella trade agreements and general tariff regulations such as the MFN tariff rates, as shown in the WITS (2020) database. The next section further examines tariffs by focusing on the import tariff structure with respect to imported electrical and electronic intermediate inputs.

3.5 The tariff structure in the electrical and electronic manufacturing industry

Different tariff rates are imposed on various tariff lines of intermediate inputs imported into the electrical and electronic manufacturing industry in South Africa. The different tariff rates also vary according to the imported intermediate input source region. The baseline tariffs presented in the GTAP 10 database and utilised in this research represent the average value of tariffs as of the base year 2014. Aguiar et al. (2019) state that applied ad valorem tariffs at the 6-digit Harmonised System (HS6) level tariff structure were adopted in the construction of the GTAP 10 database. This study maintains the GTAP 10 database weighted average tariff rate of 2.91% for the year 2014.

As an indication of the most recent state of tariff application and the practical relevance of this thesis, an extract of the year 2018 tariff schedule on intermediate imports from China into South Africa is presented in Table 5. The 2018 ad valorem tariff rates were not applied in this study; however, their presentation serves to highlight South Africa’s prevailing tariff rates with one of its biggest trading partners in electrical and electronic goods. The year 2018 data is the most recent representation of the South Africa – China bilateral trade, free from any sources of bias such as the COVID-19 pandemic. A significant volume of electrical and electronic imports as well as other imports across all manufacturing sectors in general, into South Africa are from China (Edwards & Jenkins, 2015).

Table 5 shows the HS6 level classification and the ad valorem tariff rates for some of the imports into the electrical and electronic manufacturing industry in South Africa for the year 2018.

Table 5: An extract from the applied tariff schedule for the year 2018.

Reporter	Year	Partner	Tariff code and Product description	MFN Rate	Applied Tariff Rate	Total tariff lines	Traded
South Africa	2018	China	853990 - Lamps; parts of the lamps of heading no. 8539	15	15	1	yes
South Africa	2018	China	851680 - Resistors; electric heating, other than those of heading no. 8545	13.33	13.33	3	yes
South Africa	2018	China	850450 - Electrical inductors; n.e.s. in heading no. 8504	5	5	1	yes

Reporter	Year	Partner	Tariff code and Product description	MFN Rate	Applied Tariff Rate	Total tariff lines	Traded
South Africa	2018	China	853290 - Electrical capacitors; parts of the capacitors of heading no. 8532	7.5	7.5	2	yes
South Africa	2018	China	850870 - Parts	10	10	2	yes
South Africa	2018	China	851621 - Heating apparatus; electric storage heating radiators	20	20	1	yes
South Africa	2018	China	850490 - Electrical transformers, static converters and inductors; parts thereof	5	5	1	yes
South Africa	2018	China	851690 - Electro-thermic appliances; parts, of heating resistors, of water, space and soil heaters, hair-dressing apparatus, hand dryers, smoothing irons and other domestic appliances of heading no. 8516	13.6	13.6	5	yes
South Africa	2018	China	850990 - Electro-mechanical domestic appliances; parts for the appliances of heading no. 8509, with a self-contained electric motor	20	20	1	Yes
South Africa	2018	China	850710 - Electric accumulators; lead-acid, of a kind used for starting piston engines, including separators, whether or not rectangular (including square)	10	10	2	yes
South Africa	2018	China	850410 - Discharge lamps or tubes; ballasts therefor	10	10	1	Yes
South Africa	2018	China	850680 - Other primary cells and primary batteries	12	12	5	Yes
South Africa	2018	China	853090 - Signalling apparatus; parts of safety, traffic control equipment for railways, tramways, roads, inland waterways, airfields, parking facilities, port instalments (excluding those of heading no. 8608)	5	5	2	Yes

Reporter	Year	Partner	Tariff code and Product description	MFN Rate	Applied Tariff Rate	Total tariff lines	Traded
South Africa	2018	China	850151 - Electric motors; AC motors, multi-phase, of an output not exceeding 750W	10	10	2	Yes
South Africa	2018	China	850450 - Electrical inductors; n.e.s. in heading no. 8504	5	5	1	Yes
South Africa	2018	China	852910 - Reception and transmission apparatus; aerials and aerial reflectors of all kinds and parts suitable for use therewith	10	10	3	Yes
South Africa	2018	China	851140 - Ignition or starting equipment; starter motors and dual purpose starter-generators, of a kind used for spark or compression-ignition internal combustion engines	7.5	7.5	2	Yes
South Africa	2018	China	851610 - Heaters; electric, instantaneous or storage water and immersion heaters	10	10	2	Yes
South Africa	2018	China	852352 - ‘Smart cards’	2.5	2.5	2	Yes
South Africa	2018	China	841891 - Refrigerating or freezing equipment; parts, furniture designed to receive refrigerating or freezing equipment	13.33	13.33	2	Yes
South Africa	2018	China	843120 - Machinery; parts of the machinery of heading no. 8427	5	5	2	Yes
South Africa	2018	China	842191 - Centrifuges; parts thereof, including parts for centrifugal dryers	7.5	7.5	2	Yes
South Africa	2018	China	841950 - Heat exchange units; not used for domestic purposes	15	15	1	Yes
South Africa	2018	China	853210 - Electrical capacitors; fixed, designed for use in 50/60 Hz circuits and having a reactive power handling capacity of not less than 0.5 kVAr (power capacitors)	5	5	3	Yes
South Africa	2018	China	853229 - Electrical capacitors; fixed, n.e.s. in heading no. 8532	7.5	7.5	2	Yes

Reporter	Year	Partner	Tariff code and Product description	MFN Rate	Applied Tariff Rate	Total tariff lines	Traded
South Africa	2018	China	853510 - Electrical apparatus; fuses, for a voltage exceeding 1000 volts	5	5	1	Yes
South Africa	2018	China	853620 - Electrical apparatus; automatic circuit breakers, for a voltage not exceeding 1000 volts	7.5	7.5	2	Yes
South Africa	2018	China	853921 - Lamps; filament, (excluding ultra-violet or infra-red), tungsten halogen	10	10	4	Yes
South Africa	2018	China	854099 - Valves and tubes; parts of the valves and tubes of heading no. 8540, excluding parts of cathode-ray tubes	5	5	1	Yes
South Africa	2018	China	853931 - Lamps; discharge, (excluding ultra-violet), fluorescent, hot cathode	17.5	17.5	2	Yes

Source: WITS (2020). *Note: n.e.s = not elsewhere specified*

The relatively high tariff levels shown in Table 5, when compared to import tariffs imposed in other regions of the world (see Table 6) impact negatively on the growth and performance of the electrical and electronic manufacturing industry, as confirmed by studies such as Kowalski et al. (2015) and Draper et al. (2018). Table 6 shows the applied tariffs for some imported electrical components and products for South Africa, compared to the same tariff lines for the United States. Applied tariffs refer to the actual tariffs that the WTO member countries impose on imports (WITS, 2020).

Table 6: Import tariff comparison

Year	Tariff code	Product	South Africa Applied tariff (% applied ad-valorem)	United States Applied tariff (% applied ad-valorem)
2018	850990	Electro-mechanical parts of heading no. 8509	20	0.00
2018	854012	Cathode ray tubes and parts there of	25	1.65
2018	851680	Electric heating resistors	20	0.00

Source: *WITS (2020). Note: tariff codes are based on the HS6.*

In comparison, developed countries tend to impose much lower tariffs, or no tariffs at all on imported components that are required for domestic production processes. Table 6 reveals the stark contrast between the tariff rates that South Africa and the United States imposed on the same product lines. While these two countries have very different sizes of economies, which possibly contribute to the large differences in their tariff structures, the tariff data arguably reveals that tariffs on imported intermediate inputs could still be reduced. Tariff reduction could improve the competitiveness of South Africa's electrical and electronic manufacturing industry on the global market. This argument is based on the assumption that tariff reduction could play a significant role in increasing the productivity of firms within the industry. The next section narrates the recent history of South Africa's economy and explains how the protection framework in this thesis could help sustain the survival of vulnerable firms while potentially improving the country's overall economic performance.

3.6 Industrial performance and overall economic growth in South Africa

South Africa's economic policy was characterised by a wide array of inward-looking strategies from the 1920s to the 1970s, biased towards exports in the 1980s, the introduction of the GEIS (Generalised Export Incentive Scheme) in the year 1990 and policies towards freer trade after the country joined the WTO in the year 1994 (Mabugu & Chitiga, 2009; Malefane & Odhiambo, 2017). An analysis by Fedderke (2018) shows that South Africa lost ground in terms of GDP per capita growth when compared to a group of 17 emerging markets (including Argentina, Turkey, Indonesia, Egypt, Malaysia and Thailand) in the six decades from the 1960s to the 2010s. According to Hausmann and Klinger (2008), South Africa had a poor GDP per capita growth in the 40 years leading up to the year 2008, with the year 2004 GDP per capita placed at only 40% higher than that in the year 1960 while Malaysia, for instance, had a 168% increase in GDP per capita over the same period. Similarly, exports per capita in constant dollar terms in the year 2004 were at the same level as in the year 1964, placing South Africa 50th out of 56 countries with a population of at least four million (Hausmann & Klinger, 2008).

Scholars such as Hausmann and Klinger (2008) and Pieterse et al. (2016) claim that South Africa's poor export performance in the past half a century of years has been a result of slow to non-existent structural transformation (switching from simple poor country goods to complex rich country goods). South Africa's main export lines have been concentrated in coal and mining, where the endowment has remained relatively stagnant while the population has exploded, resulting in reduced export per capita over the decades (Fedderke, 2018; Hausmann & Klinger, 2008; Pieterse et al., 2016). Rodrik (2008) contributes to this discussion by calling for the augmentation and diversification of non-mineral tradables, particularly in manufacturing, in a strategy that would certainly promote exports, economic growth and employment in South Africa. The electrical and electronic manufacturing industry has the potential to boost the country's export performance through innovative capabilities. However, studies such as Hausmann and Klinger (2008) and Pieterse et al. (2016) indicate that this manufacturing industry has been let down by the government's lack of initiative in growing its export base.

South Africa's economic policy structure reflects a highly distorted system of protection leading up to and including GEIS (that was later discontinued within three years of its existence) of the year 1990, with its share of world exports falling from 0.7% to 0.5% in the decade after the year 1994 (IDC, 2013; Power, 2008). In the same decade, from 1994 to 2004, South Africa's GDP per capita rose at a disappointing rate of approximately 1.2% per annum, a rate that only compares to Sub Saharan Africa and Latin America but is still much lower than that of South Asia and East Asia that show annual GDP growth rates of 1.1%, 0.8%, 3.7% and 6.2% respectively for the four regions during the same period (Edwards et al., 2015; Rodrik, 2008). This was against South Africa's increasing government spending from close to 18% to approximately 22.2% of GDP from the year 1995 to the year 2014 (Edwards et al., 2015).

Freund and Rocha (2011) add that the period post GEIS saw huge job losses. This is despite Zhou and Cuyvers (2012) identifying South Africa as a decent 14th of the top 20 major beneficiary developing countries from the European Union Generalised System of Preferences (EU GSP) in 2006, contributing 2.6% of the share of the total European Union (EU) imports. The EU GSP was modelled to boost exports of poor developing countries needing the benefits of trade, by implementing nonreciprocal tariff preferences in a bid to create export revenue for their development (Zhou & Cuyvers, 2012). The National Industrial Policy Framework (NIPF) and the subsequent Industrial Policy Action Plan (IPAP) introduced after 2007 to address among other issues, the unemployment challenge, and an effort to intensify the country's long term industrialisation path (DTI, 2007, 2011) have so far not been impressive in this respect. The rather unimpressive impact of the policies is observed in the continuously rising unemployment rate reaching 34.5% in 2022 up from 24.73% in 2012 (StatsSA, 2022) and subdued industrialisation (Torreggiani & Andreoni, 2022).

While Loewald (2018) and other studies highlight a positive relationship between export performance and GDP growth, what remains a quandary for South Africa is how to significantly improve its export flows and how much positive impact this can build on the GDP growth. In his paper on cumulative costs of protection for South Africa, Freytag (2011) asserts that trade protection reduces customers' choice but still proposes that certain types of protection for specific industries will potentially achieve gains. In addition, Anand et al. (2016) suggest that the probability of a small firm growing and transitioning into a much larger firm under the prevailing policy regime in South Africa is extremely small. Therefore, it can be argued that vulnerable manufacturing firms such as the electrical and electronic manufacturers fit into this category of firms that require tailor made policy measures. The electrical and electronic manufacturing industry forms a rather small but strategic part of the bigger industrial sector in South Africa. Strategic in the sense that it has the potential to grow, based on the general innovativeness and expansion of the global electronics sector while exhibiting important interlinkages with other sectors of the economy. Such industrialisation has contributed to the rapid growth of several economies around the world, particularly the Asian economies (Kozul-Wright & Poon, 2018).

Industrial output in South Africa over the past few decades has been subdued and so has the overall economic growth of the country. Figure 5 shows the significance of the general industrial production output growth rate when compared to the GDP real growth rate for the period 2008 to 2018. It is perhaps not coincidental that the GDP real growth rate appears to be contingent on the industrial production growth rate. It may also be argued that the poor overall economic growth during this period may have contributed to rising unemployment, with StatsSA (2022) and Alenda-Demoutiez and Mugge (2020) indicating a continuous increase in unemployment over the same period.

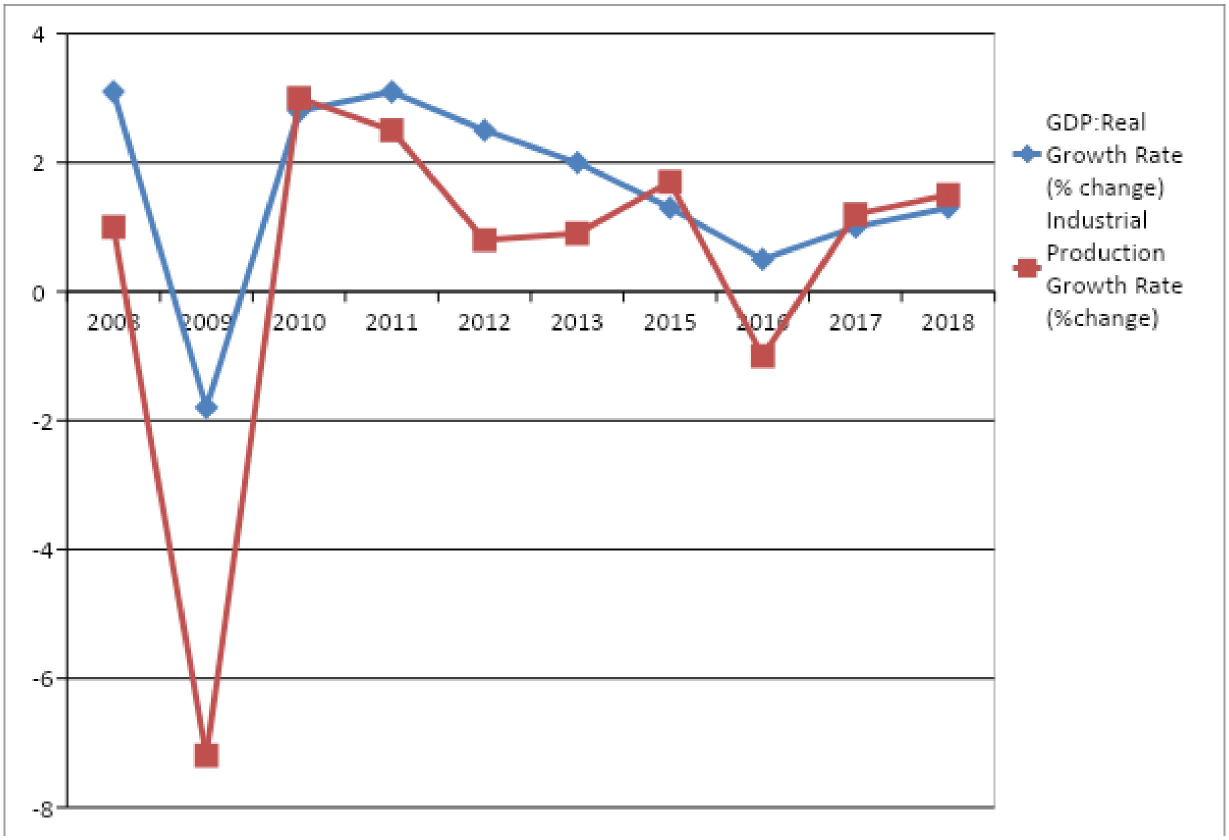

Figure 5: South Africa's industrial production growth rate compared to the GDP real growth rate for the period 2008 to 2018.

Source: World Bank (2019).

South Africa's disappointing industrial performance can arguably be improved through the adoption of manufacturing biased policies that enhance manufacturing output in industries that show potential for growth and expansion. According to (Torreggiani & Andreoni, 2022), examples of industries that possess potential for growth and expansion are high technology industries such as the electrical and electronic manufacturing industry. Furthermore, Andreoni (2016) notes that South Africa's industrial policies from the year 1990 to the year 2006 have only focused on a restricted set of manufacturing industries (automotive, steel and aluminium, paper and pulp, and chemicals) while the current National Development Plan (NDP) 2030 still focuses on a narrow range of industries such as metals, mineral processing and chemicals manufacturing.

To stimulate a more diversified industrial base for the economy, through promotion of the electrical and electronic manufacturing industry, this thesis formulated an infant industry protection framework that is integrated into the international fragmentation system. Such a strategy could potentially enhance the survival prospects of emerging, vulnerable firms, at the same time expanding the size and performance of the industry. This could in turn create leverage to stimulate output from other sectors thereby improving the general economic performance of the country. The next section discusses the government's policies towards the electrical and electronic manufacturing industry.

3.7 Government policy towards the electrical and electronic manufacturing industry

The supply of electrical and electronic products in South Africa particularly consumer electronics and machinery has remained largely dependent on imports from countries such as China (Torreggiani & Andreoni, 2022). The authors claim that the Chinese imports result in slower domestic sales, low employment growth and a high likelihood of collapse of domestic firms that do not engage in growth and development strategies. This would probably explain the government's approach over the past years, which attempts to create an improved manufacturing environment for manufacturing firms. According to the DTI (2009), the Customised Sector Programme (CSP) was created in 2008 to generate global industry awareness about South Africa's electrotechnical abilities.

Other government support initiatives include continuous programmes such as the Support Programme for Industrial Innovation (SPII) and the Small Enterprise Development Agency (SEDA) Technology Programme (STP). The programmes were designed to provide some form of innovation support to electrical and electronic manufacturing firms (DTI, 2014; SEDA, 2020). However, an assessment of the impact of these initiatives on the growth and development of the electrical and electronic manufacturing industry clearly shows that they are inadequate to effect positive change in the growth and development trajectory of the industry. For instance, studies and industry reports as recent as 2018 and dated as far back as 2008, indicate that the performance of South Africa's electrical and electronic manufacturing industry has been on a decline. Flatters and Stern (2008) state that the competitiveness and output of electrical and electronic manufacturing firms are negatively impacted by ineffective access to inputs, resulting in more than 80% of the domestic market relying on imported final goods.

The DTI (2018) data shows the total exports for the year from the electrical and electronic industry as equivalent to only 35% of South Africa's total imported electrical and electronic goods in rand value terms. This poor performance is despite the government initiative programme implementation dating back to as early as the year 2008. This can arguably be considered an indication that the initiatives implemented over the past years have fallen short. This study proposes a growth and protection strategy that considers the contemporary international fragmentation phenomenon, where the target industry is expected to benefit from enhanced access to imported inputs and technology spillovers.

3.8 Conclusion

The chapter discussed the African country context and South Africa in particular, as the study setting. The chapter evaluated South Africa’s electrical and electronic manufacturing industry as an industry that can potentially benefit from an infant industry protection framework. Other aspects that are pertinent to the proposed protection strategy, such as the tariff structure of the industry, industrial performance and overall economic performance in South Africa as well as government policy towards the electrical and electronic manufacturing industry were also outlined. In summary, the chapter evaluated the suitability of the electrical and electronic manufacturing industry and South Africa’s economic landscape for the adoption of an infant industry protection framework that is integrated into the international fragmentation system through international fragmentation-induced intermediate inputs. The next chapter details the methodology that was adopted in operationalising the integration of the infant industry protection framework into the international fragmentation system.

Chapter 4: Research design and methodology

4.1 Overview

This thesis, like other economic policy studies presents an issue of inference and aims to answer the "what if" question, hence it requires a counterfactual scenario analysis. It evaluates the effect of international fragmentation-induced intermediate inputs tariff reduction on the value of exports within an infant industry protection framework. Other factors that could impact on the implementation of the policy need to be taken into consideration hence an apposite economic policy analysis framework entails an economy wide approach that encompasses inter-industry linkages. A CGE model is adopted in this thesis because of its economy wide approach and its feature of providing a rigorous and theoretically consistent quantitative analytical technique with control checks such as model sensitivity analysis and calibration.

This thesis focuses on economic policies that are designed to develop the electrical and electronic manufacturing industry in South Africa. Because the interconnectedness between the target industry and other sectors can be established, the results obtained can be assumed to represent reality. The general impact and the unintended consequences of such policies to the wider economy inform the policy maker on their feasibility and usefulness. Developing a single sector that has important linkages to other sectors of the economy may turn out to be less costly to the government than attempting to simultaneously develop several sectors. Capturing the transmission mechanism of policy effects from the electrical and electronic manufacturing industry to other sectors of South Africa's economy therefore requires an economy wide model that incorporates a suitable data source such as a supply chain database.

Different forms of CGE models have been developed over the years. This thesis adopts a CGE model that is built onto the Global Trade Analysis Project (GTAP) database based on its successful implementation in several policy-oriented research projects.

4.2 Research philosophy

This thesis adopted a positivist orientation that intends to yield facts that are free from researcher bias whereby explanation and prediction are part of contribution to knowledge. According to Park et al. (2020) and Sousa (2010), positivism is based on the verification of an *a priori* hypothesis by way of operationalising experimental variables, wherein subsequent findings from the experimentation are used to contribute to theory. To achieve this, the objective of positivist science is built on explanation and prediction (the symmetry thesis); by which explanation is aimed at past occurrences while prediction is concerned with future occurrences of phenomena, at the same time featuring a nomothetical approach.

4.3 Research approach

A quantitative and variable oriented deductive research approach was assumed in this thesis. Quantitative research is a methodical evaluation of phenomena that entails the processing and analysis of numerical data where relatively large volumes of quantitative data are used in the verification of hypotheses (Basias & Pollalis, 2018). Subsequently, the fact-based and observable numerical results obtained are considered to be objective (Basias & Pollalis, 2018; Djatsa, 2020).

This thesis adopts *ex-ante* analysis that requires estimation which can be done using CGE or Partial Equilibrium (PE) analysis. However, a CGE model is adopted because it accommodates linkages among sectors of an economy and therefore it is closest to real world economic processes while the PE model assumes the impact of policy change to be only on the sector under consideration. Such comparisons between CGE and PE are well documented by Cappariello et al. (2020).

A significant number of quantitative studies that have assessed the macroeconomic impact of economic policy factors have adopted the CGE approach. For instance, Krugman (1980) developed and advanced a competitive model to rationalise interindustry trade. The advances were adapted into a small economy CGE modelling study of Canada by Harris (1984) and later amplified by Smith and Venables (1988) who evaluated the effect of eliminating trade barriers in the European market. Current trade aligned CGE models began with the ORANI and the Michigan world models that classified imports and domestic goods as imperfect substitutes, that is, the Armington (1969) specification. This thesis adopts a static model hence it does not show the path followed in attaining the new equilibrium.

Features of the model include an option of making variations or alterations to the base model according to project specific demands, allowing for individual scenario specifications. These characteristics of a CGE model make it possible to apply an analysis on a specific industry, at the same time maintaining the integrity of the model. Accordingly, it is adopted in this thesis to capture the impact of the integration-protection framework on the electrical and electronic manufacturing industry as well South Africa’s broader economy. Subsequently, total welfare changes in the economy and the benefits of incorporating the policy framework in an African country perspective can be determined.

Domestically, output from South Africa's electrical and electronic manufacturing industry plays a central role in the automotive, health, food manufacturing, heavy and other manufacturing, agricultural, services, information technology and communication sector as well as the contemporary 4IR phenomenon. The survival, growth and development of the electrical and electronic manufacturing industry appears to hinge on the international fragmentation systems in global value chains. Thus, policy analysis results from a CGE model afford policy makers a broader view of policy impacts hence policy decisions intended to benefit the whole economy can be made. A CGE model integrates different sectors of an economy, links a regional economy to the rest of the world, captures changes (in production, consumption and prices of imports and domestic output) following policy change, by using its set of equations and optimisation of microeconomic processes in a defined representation of an economy. Therefore, it can be argued that the CGE model can present a compendious view of all the interlinkages among economic agents, the regions of the world and responses to an economic policy shock.

4.4 Population and sampling

Aggregated trade data at the industry level, the unit of analysis, was obtained from the GTAP 10 MRIO database. The GTAP database has become a very reliable source of data that is used in most global CGE models and underlies a significant number of those that investigate economic matters at the global level. Also, the electrical and electronic manufacturing industry is highly dynamic and it presents a channel through which to inject a growth stimulus into South Africa's economy.

4.5 Data

4.5.1 GTAP database construction

The GTAP 10 database contains 121 countries, 20 regions and 65 sectors that cover 98% of global GDP and contains tariff data from the International Trade Centre (ITC), macroeconomic data from the WDI as well as income and factor taxes from the IMF. An appreciation of the process of database construction and data verification is important to the GTAP modeller because it informs some decisions that may be related to the choices of policy scenarios.

The GTAP database contains a Social Accounting Matrix (SAM) for each region in the form of an I/O table as well as other data such as elasticity parameters. The GTAP database is therefore generated from I/O tables representing regions or countries of the world economy. According to Huff et al. (2000), the I/O tables are put forward to the GTAP centre by the network individual members or international organisations whereby the data must pass certain minimum threshold prerequisite checks at the initial screening stage. The United Nations Commodity Trade (UN-COMTRADE) statistics is identified as a major contributor that provides reconciled data on bilateral trade between countries and regions. To address matters of reliability, consistency and accuracy, acceptance criteria based on structure, sectoral classification, sign and balance (see Table 7) are adopted as the basic checkpoints of the submitted tables.

Further steps are then followed to ensure the conformance, validity, reliability and relevance of the I/O tables while maintaining uniformity of the data collected from various sources. For instance, Aguiar et al. (2016) highlight that some standard national accounting conventions add the output of non-market processes of production to government consumption and exclude their inputs (that are in turn added as intermediates into other industries) only in some of the I/O tables

Table 7: I/O tables acceptance properties as an entry level step for adoption into the GTAP database

Property	Description
Structure	Single region I/O table should contain the information needed and each region weighted in such a way that it is proportional to its GDP.
Sectoral classification	Sectoral concordance and transformation: data should not be an approximation and the appropriate level of disaggregation should be attained.
Sign	Positive and negative notation conditions should be met and any violations have to be minimal. For example, factor usage values should be non-negative except for exceptional circumstances that result in deviations.
Balance	Compliance with the sectoral balance stipulation that total sales are equal to total costs in each sector.

Source: Huff et al. (2000) and Corong & McDougall (2020).

The building of the GTAP database as presented in Figure 6 and according to Harslett (2013) involves the process of fitting the country I/O tables into international I/O tables that have already been upgraded and exposed to international balance conditions, rather than attempting to fit the international I/O tables into collective country I/O tables.

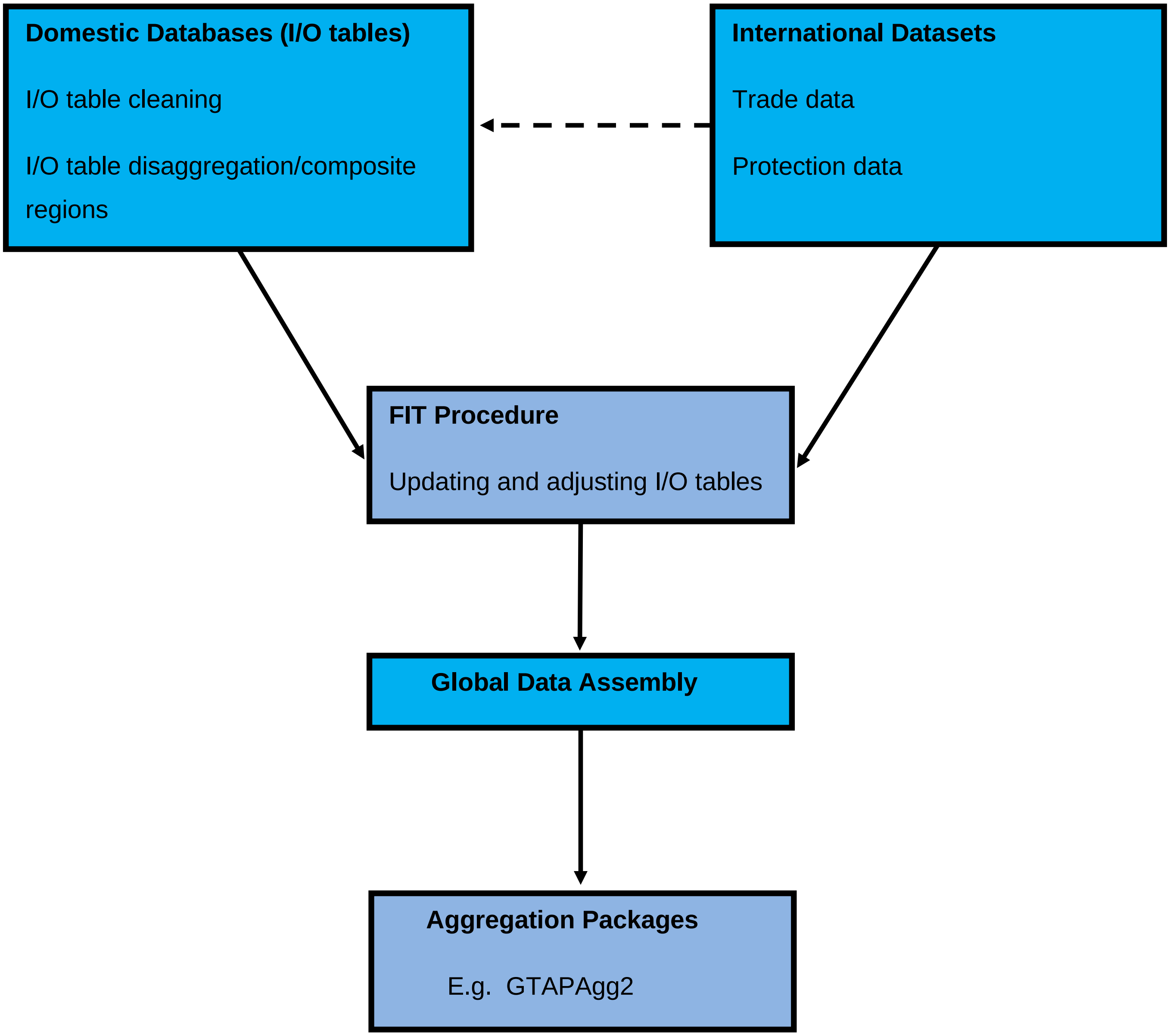

Figure 6: GTAP global database construction procedure

Source: Corong and McDougall (2020).

Sources of data on country and regional data on trade, protection, energy and macroeconomic aggregates are gathered from nationally published I/O tables, the UN-COMTRADE database, the UN trade website, European Statistics (EUROSTAT), World Development Indicators (WDI), International Trade Centre's MAcMap database and the IMF. Corong and McDougall (2020) detail the construction of main data set that involves the preparation of global sets and mapping files, international datasets and domestic databases that undergo preliminary assessment, matching regional databases to macroeconomic trade data for reference years, the FIT procedure (in relation to fitting I/O tables) and the final data assembly. Final data assembly encompasses the merging of international datasets with domestic I/O tables to create the principal global database. The next section briefly discusses a domestic I/O table in the form of a Social Accounting Matrix (SAM)

4.5.2 Social Accounting Matrix

The SAM is a transitions matrix in the form of rows that represent agents of an economy that receive income and columns representing agents of the economy that spend on purchases. It records all such transactions within a region or country hence it is considered a version of double entry bookkeeping that represents the national accounts of the concerned region. Because the SAM is built on a circular flow model of an economy, income must match expenditure. In this way, all economic activity in a region can be accounted for and displayed as a snapshot for any reference year of interest. The process of constructing a SAM plays a fundamental role as a point of reference for inspection of data consistency because it incorporates verification and comparison of data from various sources.

4.5.3 MRIO framework and data

The MRIO extension of the GTAP database is a supply chain framework that enhances certain aspects of model application such as commodity sourcing beyond the border and more precise application of policy analysis by agent. The rest of this section describes the MRIO 10 database structure, data on African countries (the context region) compared to other regions of the world, data specific to South Africa at sector level as well as a focus on the electrical and electronic manufacturing sector for the year 2014. Figure 7 is a simple depiction of how imports are allocated across end users.

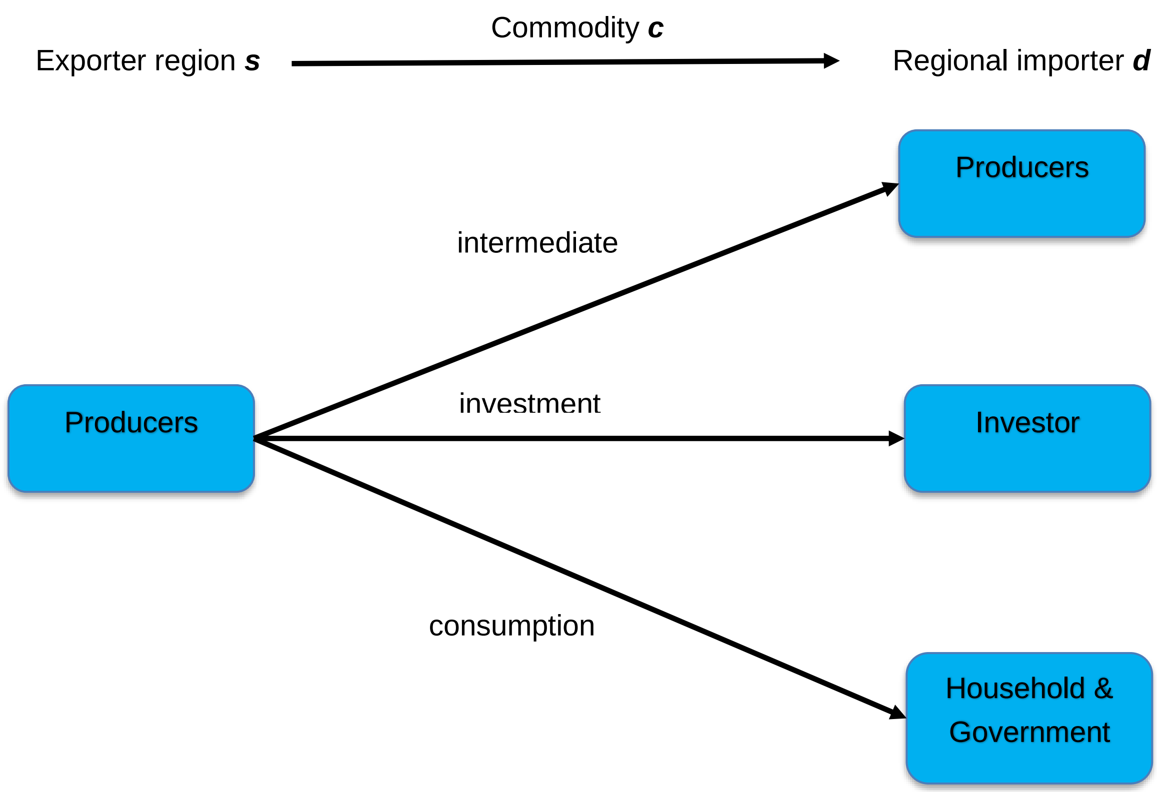

Figure 7: MRIO framework showing allocation of imports across end-users

Source: Carrico et al. (2020).

Accordingly, the framework splits imports by agent, source and destination and differentiates tariffs according to end users. The MRIO database for the base year 2014 shows that Sub Saharan (SSA) countries impose average tariffs as high as 11.6% on imports from the East Asian (EAS) countries, only second to 13.8% imposed by South Asian (SAS) countries on imports from the South East Asian (SEA) region (see Table 8). This is in comparison to a global average bilateral tariff rate of approximately 2%. In Table 8, the other regions are Australia, New Zealand and Oceania (OCE), North America (NAM), Latin America and Caribbean countries (LAC), European Union 28 (EU28), Middle East and North Africa (MENA) and the Rest of World (ROW) whereby exporters are presented in rows and importers are presented in columns.

Table 8: Bilateral tariff rates

Region	OCE	EAS	SEA	SAS	NAM	LAC	EU28	MENA	SSA	ROW	WORLD
OCE	1.54	1.76	1.65	5.4	0.67	2.63	3.2	4.17	4.34	1.19	2.10
EAS	3.94	3.05	2.2	7.99	2.12	8.29	2.52	7.69	11.56	6.01	3.69
SEA	0.56	0.72	0.71	13.75	2.81	6.28	1.77	3.85	8.84	1.78	2.24
SAS	2.99	2.38	4.15	7.71	3.19	5.36	1.39	5.07	9.00	2.36	3.64
NAM	1.03	4.46	2.11	6.02	0.03	4.23	1.04	2.95	4.99	2.13	1.73
LAC	1.01	3.79	6.5	3.24	0.71	1.14	2.47	4.98	6.82	4.33	2.53
EU28	3.19	4.12	2.47	6.55	0.84	5.00	0.00	2.97	5.43	2.66	1.28
MENA	0.58	1.02	1.13	3.0	0.34	2.1	0.38	2.86	5.55	3.72	1.46
SSA	2.56	0.83	1.16	2.41	0.16	1.35	0.13	1.81	3.19	0.91	1.2
ROW	1.02	2.48	1.04	7.76	0.56	3.01	0.39	3.18	5.15	0.55	1.31
WORLD	2.49	2.73	1.96	6.46	1.03	4.63	0.57	4.13	7.05	2.86	2.07

Source: MRIO database, Carrico et al. (2020)

Figure 8 shows a comparison between tariffs faced and tariffs imposed by the regions. Sub Saharan countries face the lowest tariffs on their exports at an average of 1.2% while imposing the highest tariffs on their imports at an average rate of 7%. EAS, SEA, NAM and EU28 regions impose lower tariff rates on imports than they face on their exports while the remaining regions impose higher tariff rates on imports compared to tariffs faced. With respect to intermediate inputs, Sub Saharan countries impose the highest tariff rates of 10.1% on such inputs while the European Union (EU28) imposes the lowest import tariff rates of 0.4%.

Data in Table 9 is specific to South Africa and it compares average tariff rates by agent based on the sector aggregation in this thesis where the agricultural, other manufacturing, services and the electrical and electronic manufacturing industries are represented by Agric, OtherMnfc, Services and ElecMnfc respectively. Table 9 that represents South Africa's sectors shows that the electrical and electronic manufacturing industry imposes higher tariff rates on its intermediate imports when compared to electrical and electronic goods imports by private households.

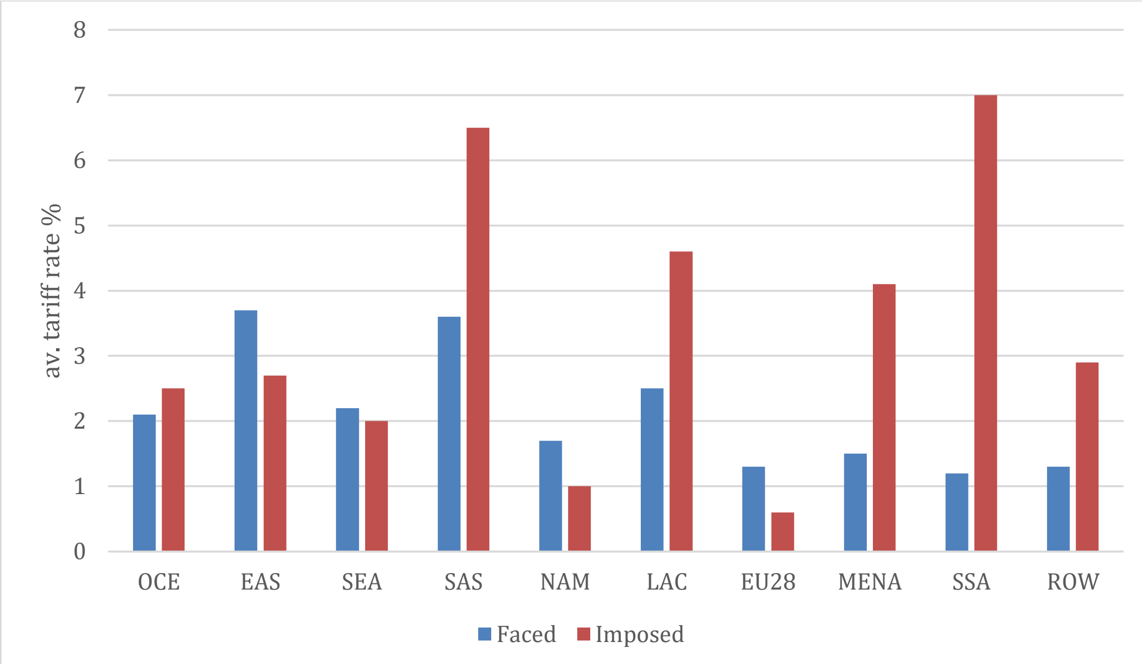

Figure 8: Tariff rates faced vs imposed

Source: MRIO database, Carrico et al. (2020)

Table 9: Tariff rates on South Africa's imports by agent

Agent / Imports	Agric	OtherMnfc	Services	ElecMnfc	Households	Government	Investment
Agric	8.27	8.27	9.43	8.86	9.45	7.92	10.01
OtherMnfc	7.01	5.00	7.75	5.61	18.78	8.07	8.43
Services	0.001	0.0004	0.0002	0.0002	0.004	0	0
ElecMnfc	3.92	3.95	3.08	3.00	2.58	3.93	3.96

Source: MRIO database

The relative sizes of the sectors by commodity shares in trade, industry share in factor employment as well as share of industry in GDP are presented in Table 10. The electrical and electronic manufacturing industry is smallest in terms of the share of exports in trade and second to OtherMnfc in terms of the share of imports in trade as further expressed in graphical exposition

Figure 9. The import to export ratio for the Agric, OtherMnfc, Services and ElecMnfc is 0.61, 0.93, 0.89 and 4.55 respectively. All the sectors except ElecMnfc indicate a trade surplus. This perhaps highlights the potential that exists for the electrical and electronic manufacturing industry to expand on exports as well as on domestic supply.

Table 10: Industry size by share of commodities and primary factors.

		Industry (GTAP aggregation)				
		Agric	OtherMnfc	Services	ElecMnfc	Total (%)
Share of industry in GDP (%)		8.18	34.61	55.01	2.2	100
Industry share in factor employment (%)	Land	100	0	0	0	100
	UnSkLab	5.95	24.20	68.67	1.18	100
	SkLab	3.26	13.69	82.30	0.75	100
	Capital	5.46	24.43	69.44	0.68	100
	NatRes	0	100	0	0	100
Commodity shares in trade (%)	Exports	9.32	76.31	11.64	2.72	100
	Imports	5.73	71.49	10.39	12.39	100

Source: Author's calculations based on MRIO data.

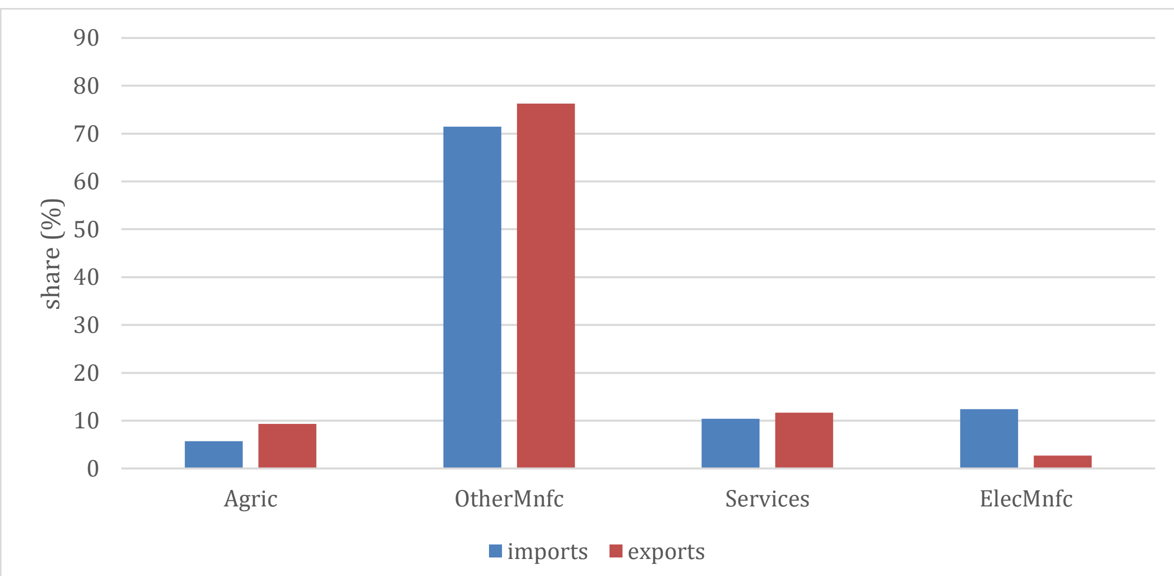

Figure 9: Graphical comparison of percentage sector sizes by commodity shares in trade

Source: MRIO database

In addition to imported intermediate inputs, the electrical and electronic manufacturing industry relies on inputs that are domestically available. Table 11 shows domestic purchases by firms whereas Table 12 shows import purchases by firms in each sector.

Table 11: Domestic purchases by firms in US$ million

Agent / Commodity	Agric	OtherMnfc	Services	ElecMnfc	Households	Government	Investment
Agric	15322.19	1020.68	2755.47	1.13	41550.84	8.77	12.39
OtherMnfc	6324.11	75783.09	59987.16	2451.89	38770.42	8.31	17566.63
Services	23233.85	79980.91	125919.73	6898.64	103909.82	69886.46	29478.15
ElecMnfc	75.68	2650.96	3767.02	1784.55	1522.59	0.22	4204.03
Total	44955.81	159435.63	192429.38	11136.20	185753.67	69903.77	51261.21

Source: MRIO database

Table 12: Import purchases by firms in US$ million

Agent / Imports	Agric	OtherMnfc	Services	ElecMnfc	Households	Government	Investment
Agric	2237.81	173.01	257.08	0.26	4138.91	0.07	0.59
OtherMnfc	1743.97	44199.40	15756.56	921.23	12664.77	6.55	11727.80
Services	595.74	3173.00	3607.56	135.99	4360.49	10.11	63.96
ElecMnfc	55.71	1220.87	3895.06	1300.76	1440.11	0.19	6646.09
Total	4633.23	48766.29	23516.26	2358.24	22604.28	16.93	18438.44

Source: MRIO database

Figure 10 compares domestic purchases to import purchases of electrical and electronic goods by agents in South Africa.

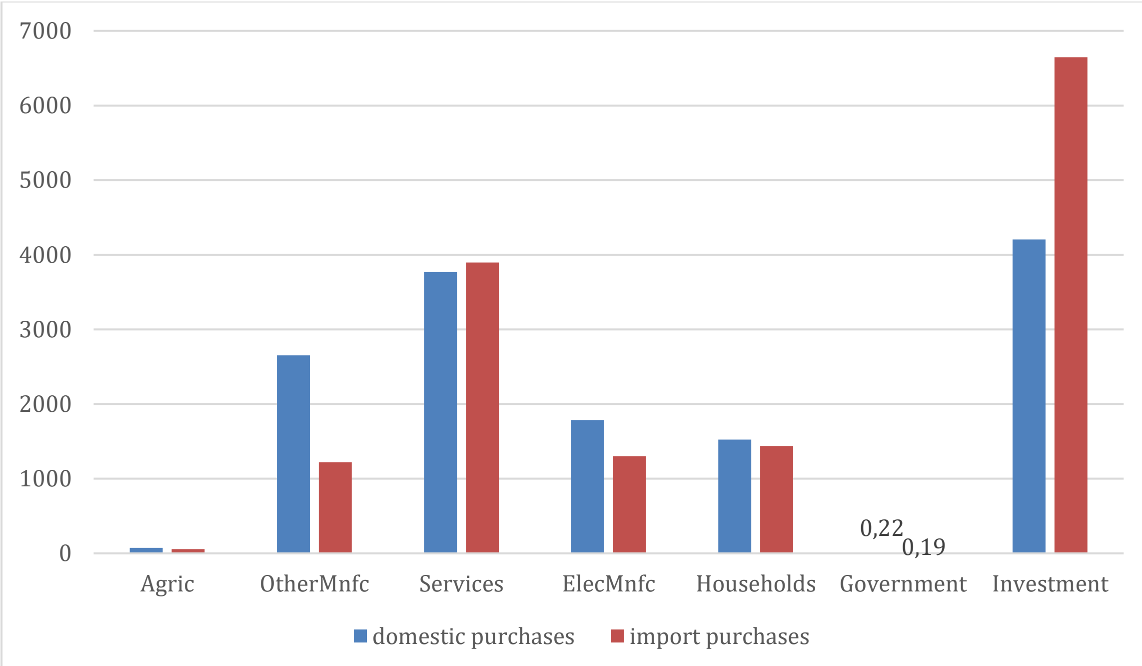

Figure 10: Domestic and imported purchases of electrical and electronic commodities

Source: Author's calculations based on MRIO data

The bulk of electrical and electronic imports are absorbed into investment, services and households. On the other hand, domestic purchases of electrical and electronic commodities are dominated by investment, services and other manufacturing. Summing up data from Tables 11 and 12 gives the cost structure for firms based on demanded commodities (see figure 11).

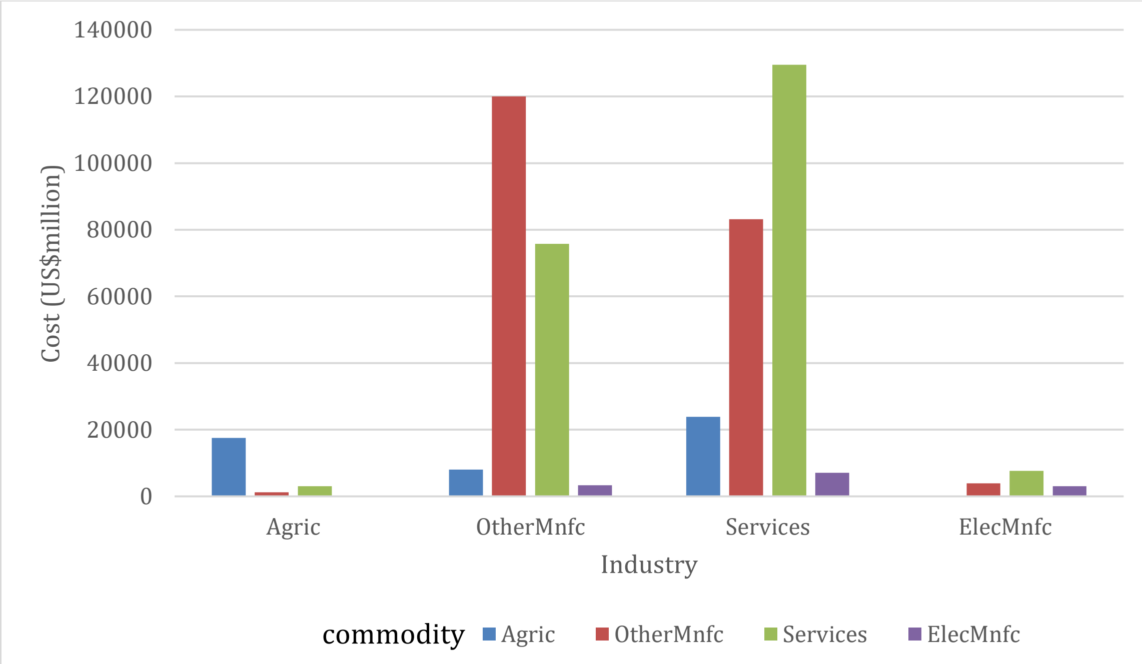

Figure 11: Cost structure of firms based on demanded commodities

Source: MRIO database

The disposition of output from each sector is shown in percentage form in Table 13. As is the case with other sectors, the bulk of the output from the electrical and electronic manufacturing industry is destined for the domestic market. Exports from the industry are only 19.76% of the output compared to 80.24% that goes to the domestic market.

Table 13: Disposition of output

Output disposition	Domestic	Transport	Export	Total
Agric	83.58	0	16.42	100
OtherMnfc	68.38	0	31.62	100
Services	96.92	0.03	3.05	100
ElecMnfc	80.24	0	19.76	100

Source: Author’s calculations based on MRIO data

Figure 12 that presents the disposition of domestic goods reflects that 14.88% of electrical and electronic goods go to consumption and approximately 85.12% is absorbed into production. This large share (85.12%) of electrical and electronic output presents an important interindustry linkage for domestic transmission of imported technology to other sectors of South Africa’s economy.

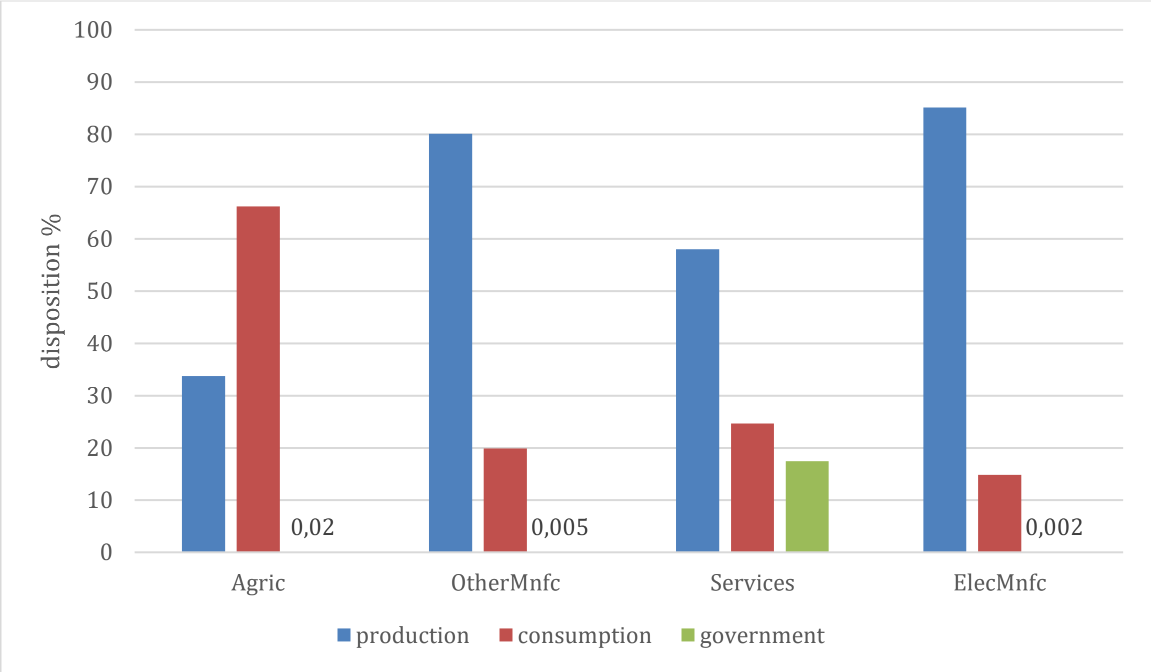

Figure 12: Disposition of domestic goods

Source: Author's calculations based on MRIO data

This contrasts with the agricultural sector for instance that has 66. 22% going into consumption and 33.76% into production.

Sources of factor income by sector are shown in Table 14, whereby natural resources and land are not used in the electrical and electronic manufacturing industry hence they show US$0 values. Table 14 represents expenditure on endowments by activity where Land, unskilled labour (UnSkLab), skilled labour (SkLab), Capital and natural resources (NatRes) represent endowments. Since the values indicate purchases by activities at purchaser's price, they represent the cost structure for demanded endowments by the activities.

Table 14: Sources of factor income by sector in South Africa

Sources of factor income (US$ million)	Agric	OtherMnfc	Services	ElecMnfc	Total
Land	895.73	0	0	0	895.73
UnSkLab	3970.93	16257.12	46129.94	790.72	67148.71
SkLab	2590.23	10943.32	65806.34	601.22	79941.11
Capital	8362.39	37619.43	106944.55	1045.77	153972.15
NatRes	0	5165.75	0	0	5165.75
Total	15819.28	69985.61	218880.84	2437.72	307123.45

Source: MRIO database

The electrical and electronic manufacturing industry in Table 14 reflects the smallest values of factor income for skilled and unskilled labour as well as capital since the industry is smallest relative to other sectors of the economy (see Table 10).

4.5.4 Treatment of elasticities

General equilibrium models incorporate exogenous parameters such as elasticities of substitution. The standard GTAP model incorporates certain parameter values that can be run without alteration or additional data. While some parameters may remain the same across regions, some require distinct specification because each region has some distinguished characteristics that require specific treatment. Such parameters include supply and demand elasticities.

To improve the validity and reliability of model parameters such as estimates that are dependent on trade flows and changes in trade costs over time, CGE models also borrow the elasticity estimates from other trade literature and as such this section indicates the estimates for the elasticity of substitution among imports in the Armington structure. The analysis in this thesis was done at industry level and South Africa is an African country hence the value of 7.77 (see Table 15) that relates to the electro technical sector in Sub Saharan countries is a closer match for application in data analysis. Results from this thesis are expected to be generalisable to other African economies.

Table 15: Trade elasticities of substitution that relate to electrical and electronic goods from different sources.

Region/Country	Industry as described in literature	Elasticity at the Aggregated level	Literature source
Sub-Saharan Developing Countries (Including South Africa)	Electro technical	7.77	Francois et al. (2005)
Latin American Developing Countries	Electronic	8.8	Hertel, Hummels, Ivanic & Keeney (2007)
Mixed Developing Countries	Electrical	10.60	Caliendo & Parro (2015)

Source: Author's compilation.

The elasticities presented in Table 15 are within the acceptable range of earlier substitution elasticities from Eaton and Kortum (2002) for a generalised manufacturing sector that range from 3.60 to 12.86 with a preferred estimate of 8.28. The rest of the elasticities that were adopted in this thesis are presented in the model description in the following section.

4.6 The model

The GTAP model was established in 1992 by the Global Trade Analysis Project team at Purdue University, USA and it refers to the CGE model that is built onto the GTAP database. This thesis adopted the extended supply chain version of the model that incorporates the MRIO framework. This is a comparative static model that captures interactions between South Africa and the Rest of the World. South Africa is regarded as a small open economy that is a price taker. Intermediate goods in an industry are used in the production of the final goods and production is at constant returns to scale in a perfectly competitive market. The market is perfectly competitive since the infant industry protection framework applied in this research does not assume application of the traditional high tariffs or quotas on imported competing final goods that tend to restrict trade from some countries and regions. This study rather places more emphasis on the integration of the infant industry protection framework into the international fragmentation system by eliminating import tariffs on international fragmentation-induced intermediate inputs.

The relationships among agents in a region and between regions are presented through equations that feature a general equilibrium condition and a market clearing stipulation at the region and global level. Producers maximise profits subject to resource constraints while consumers maximise utility subject to budget constraints. The model simulation outcome is dependent on endogenous variables' response to a shock, the initial equilibrium state and parameter specification. In this thesis, imported intermediate inputs and primary inputs provide a route through which a shock in the electrical and electronic manufacturing industry is implemented.

The model follows the circular flow format of an economy that accounts for the supply and demand of goods, services and primary factors. A graphical depiction of the circular flow of income and spending (Figure 13) reflects the accounting relationships that link the agents such as the Households, Producers, Government and the Rest of the World.

The *regional household* receives income from taxes and endowment factors. The income is spread towards savings as well as household and government expenditure. As presented in the circular flow model, *producers* provide investment goods to savings, exports to the *rest of the world* and consumption goods to *private households* as well as *government*, in return for payments. *Producers, private households* and *government* spend their income on commodities that are produced domestically and on imports from the *rest of the world*. *Producers* meet final demand by combining primary inputs with intermediate (domestic and imported) inputs. Under the circumstances, firms generate export and domestic sales. To complete the circular flow of income and spending, the model incorporates a constraint that equates total savings to total investments. The *global bank* ensures the macroeconomic closure by equating savings to investment, a market clearing condition.

This thesis exhibits a savings driven model in the sense that adjustments in savings impel changes in investment. The savings rate is exogenously modelled and remains constant such that the amount of savings adjusts to match changes in the amount of income. Subsequently, investment adjusts to match the amount of savings.

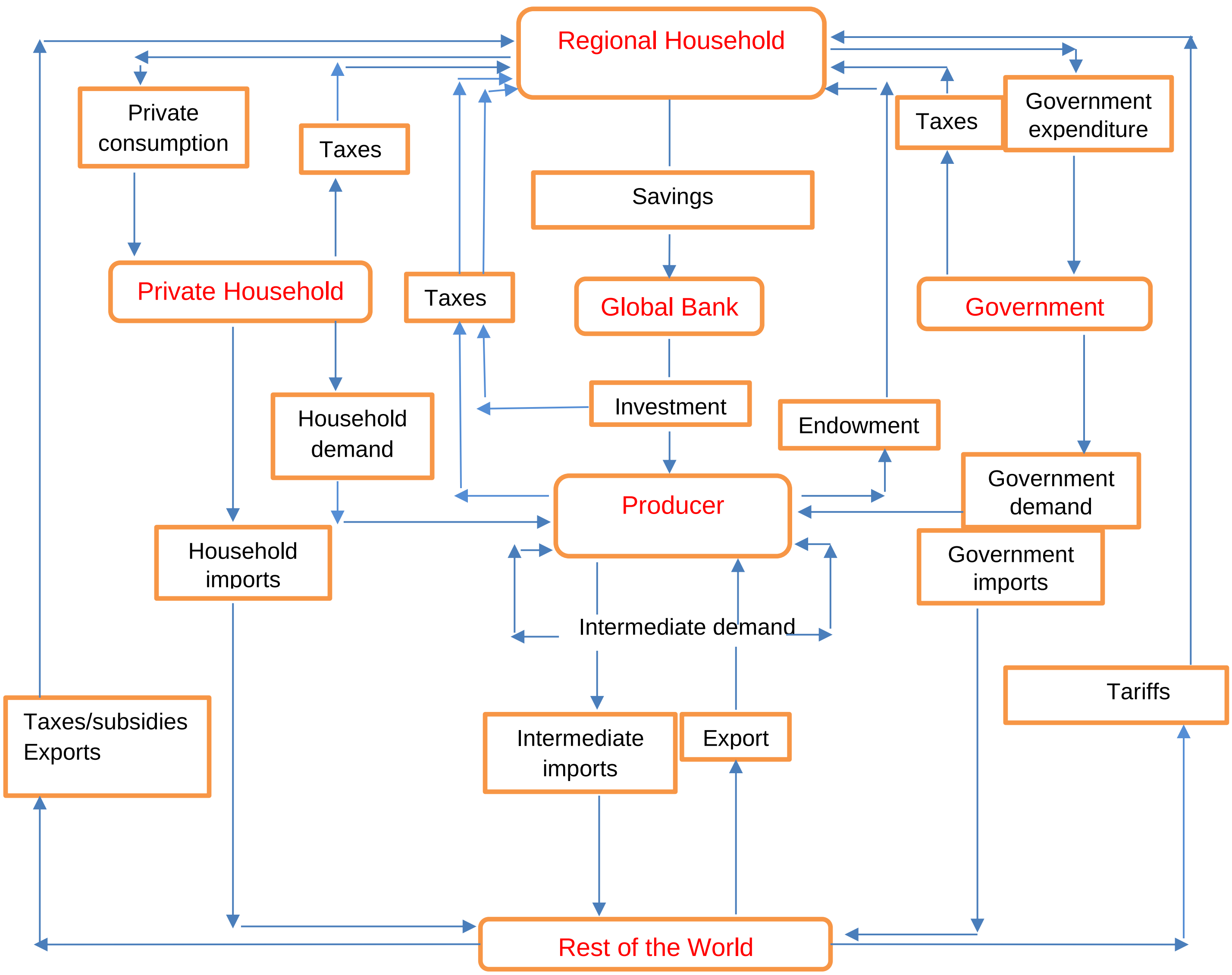

Figure 13: Circular flow of income and spending

Source: Adapted from Corong et al. 2017

Appendix B2 provides accounting variables relevant to the circular flow of income and spending as they are applied in the GTAP model. The following sections focus successively on the production structure, factors of production, supply of commodities, demand for commodities, tariff reduction, the unemployment closure, skilled labour and technology transfer.

4.6.1 Production structure

Production technology can be presented in the form of a nested production tree (Figure 14). In this structure, firms' production decisions are split into multiple smaller steps and nests that are described through behavioural equations. Elasticities of substitution are then incorporated to link the different nests within the production technology structure. Firms minimise the cost of production at the same time maximising the level of output. The sourcing of imports by the destination region is assigned at the region level in the standard GTAP model. However, the supply chain MRIO framework, adopted in this thesis, allows firms to make decisions on the source of imported intermediate inputs beyond the border, that is, at agent level by region of origin. In this way, different imported intermediate inputs are combined to form the composite input bundle qfm, at the base of Figure 14. Therefore, it becomes important that the elimination of import tariffs is maintained across all electrical and electronic intermediate inputs. This is expected to ensure that the relative accessibility of various imported intermediate inputs after tariff reductions remains constant.

Imports can be traced to importing agents, hence different prices of imports faced by the different agents in the importing region can be uniquely identified. As such, tariffs and technology transfers specific to imported electrical and electronic manufacturing intermediate inputs were distinctively identified for the requirements of this thesis.

The bottom nest in Figure 14 presents the combination of imported composite (qfm) and domestic intermediate inputs (qfd) to form an input bundle of components into the electrical and electronic manufacturing firms. The demand for imported and domestic intermediate inputs by firms is illustrated in percentage change terms through the linearised (GEMPACK) model equations (1) and (2) respectively, where *c* is the commodity demanded in activity *a* of region *r*.

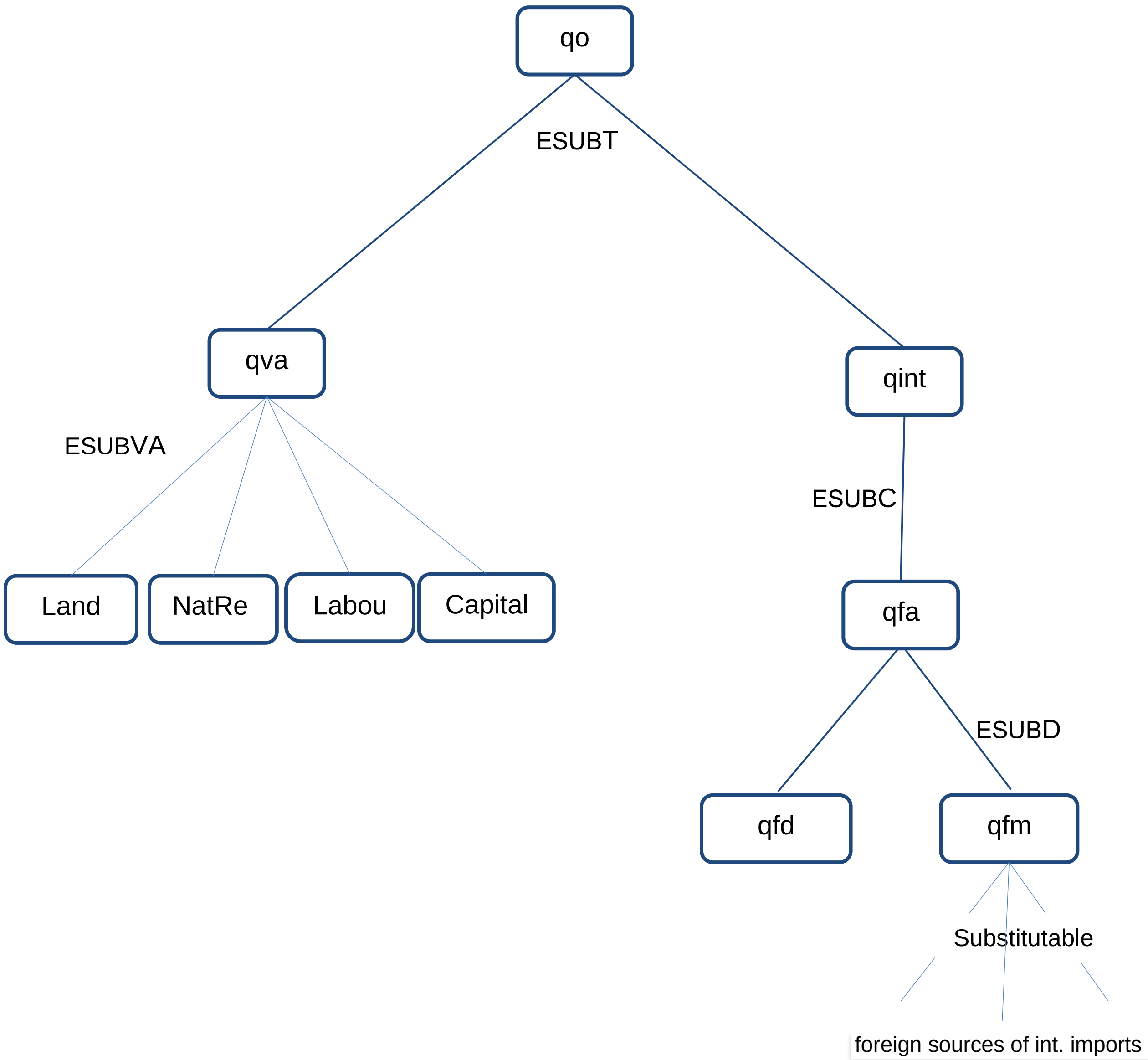

Figure 14: Nested production structure

Source: Hertel (1997)

Equation E_qfm

qfm(c,a,r) = qfa(c,a,r) - ESUBD(c,r) * [pfm(c,a,r) - pfa(c,a,r)] (1)

Equation E_qfd

qfd(c,a,r) = qfa(c,a,r) - ESUBD(c,r) * [pfd(c,a,r) - pfa(c,a,r)] (2)

In the equations, qfa(c,a,r) is the demand for the composite commodity bundle by *a* in *r*, ESUBD(c,r) is the commodity and region specific elasticity of substitution between domestic and imported commodities, pfm(c,a,r) is the price of imported inputs, pfd(c,a,r) is the price of domestic inputs and pfa(c,a,r) is the industry price for composite commodities by a in r. Equation (3) describes pfa.

Equation E_pfa

pfa(c,a,r) = [1 - FMSHR(c,a,r)] * pfd(c,a,r) + FMSHR(c,a,r) * pfm(c,a,r) (3)

where FMSHR(c,a,r) is a coefficient that represents the share of firms' imports in the domestic composite.

In this thesis, intermediate use in the electrical and electronic manufacturing industry is based on the Leontief function, a particular type of the Constant Elasticity of Substitution (CES) where individual intermediate inputs are consumed in fixed proportions to generate aggregate intermediate inputs (the composite bundle), qfa in Figure 13. In this scenario, the elasticity of substitution ESUBD is assigned the value zero, with fixed proportions between imported intermediate inputs and domestic inputs.

South Africa's electrical and electronic manufacturing firms import components such as resistors that are not domestically available, however, the firms also use domestically available inputs such as rubber and plastics. For this reason, the anticipated increase in the availability of imported intermediate inputs, due to tariff reductions, can possibly lead to an increase in quantity levels at the aggregate intermediate bundle (qint) and subsequent output from the firms subject to the availability of domestic inputs. This can be illustrated using the L shaped curve of the Leontief production function (see Figure 15). The further away the isoquant curve (QINP) lies from the origin, the higher the number of bundles formed, nonetheless, an increase in imported intermediate inputs while domestic inputs quantities are held constant will not result in an increase in the number of bundles of the aggregate intermediate inputs.

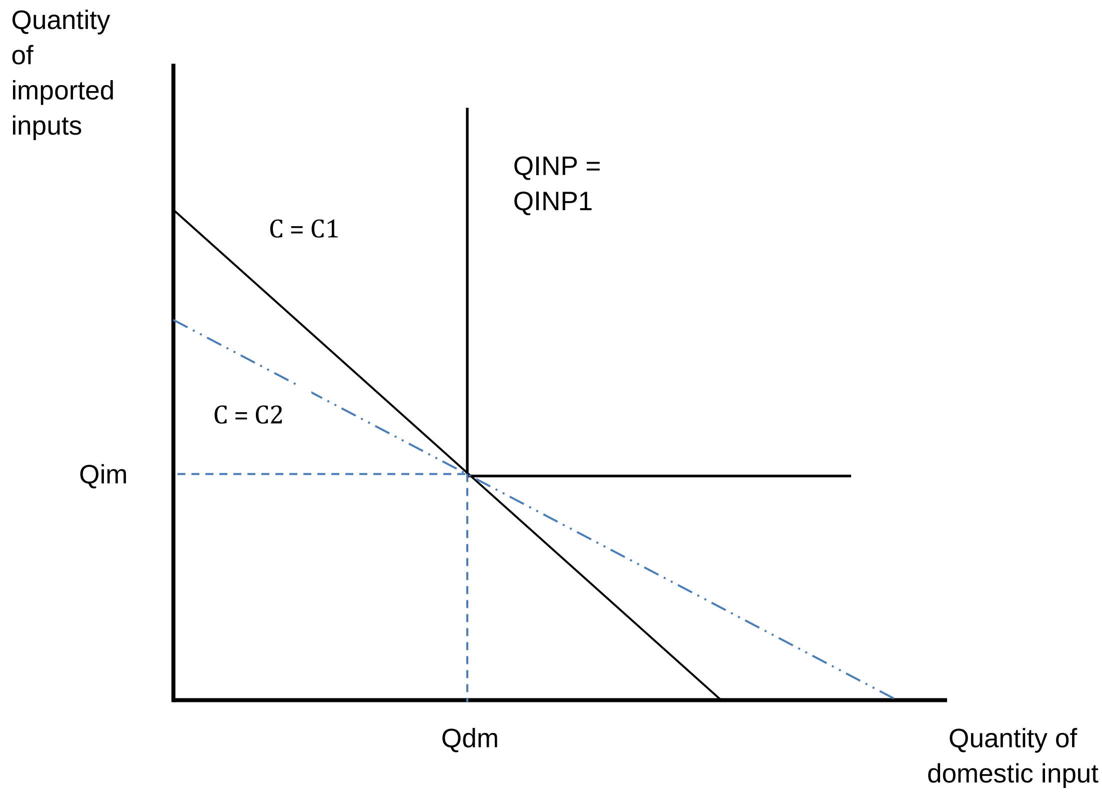

Figure 15: Intermediate input demand

Source: Author's presentation of Leontief function

The assumption in this thesis is restricted availability of imported intermediate inputs due to the prevailing import tariffs that render the imports more costly for the firms to purchase and a subsequent suboptimal utilisation of the complementary domestic inputs. The isocost line *C* in Figure 15 represents the various combinations of domestic inputs and imported inputs whose total cost is the same. This total cost drops lower as the isocost line gets closer to the origin hence firms minimize the cost of making the aggregate intermediate bundle by functioning at the point of tangency between the isoquant *QINP* and the isocost line *C1* where *Qim* and *Qdm* represent the quantity of imported and domestic intermediate inputs respectively. The slope of the line *C* is the ratio of domestic input prices to imported input prices.

The second nest in Figure 14, depicts the value-added bundle, qva, that is disaggregated into the demand for each primary factor, qfe (e,a,r) as described in equation (4).

Equation E_qfe

qfe(e,a,r) = - afe(e,a,r) + qva(a,r) - ESUBVA(a,r) * [pfe(e,a,r) - afe(e,a,r) - pva(a,r)] (4)

where ESUBVA is the elasticity of substitution among primary factors in value added of activity *a* and pva (a,r) is the effective price of the primary factor composite as illustrated in equation (5). Land and natural resources are not required in the electrical and electronics manufacturing industry hence labour (skilled and unskilled) and capital remain the factors at play. The electrical and electronic manufacturing industry allows to a significant extent, substitutability between unskilled labour and capital such that more workers can be hired in place of capital as well as complementarity between capital and skilled labour. Complementarity is exhibited particularly in cases where capital equipment cannot be replaced by workers. This model allows for a degree of substitutability between the two factors of production by adopting the GTAP value of ESUBVA of 1.26 for electrical and electronic manufacturing, 0.657 for the agricultural sector, 0.978 for other manufacturing and 1.37 for services. These values are supported by De Wet (2005) with a range of between 0.63 and 2.02 and Balistreli et al. (2003) ranging between 0.307 and 3.736. A value of zero means that labour and capital are complements and a higher value approaching infinity presents the two factors as perfect substitutes.

Equation E_pva

pva(a,r) = sum{e,ENDW, VASHR(e,a,r) * [pfe(e,a,r) - afe(e,a,r)]}; (5)

VASHR (e,a,r) in the above equation represents the share of factor e in total value added in activity *a* of region *r*. Also in the second nest is the intermediate composite bundle qint (a,r) that comprises combinations of qfa (c,a,r) and an elasticity of substitution ESUBC(a,r) with an elasticity value of zero in this thesis. Equation (6) describes sector demands for intermediate inputs *c* by activity *a* in region *r*.

Equation E_qfa

qfa(c,a,r) = - afa(c,a,r) + qint(a,r) - ESUBC(a,r) * [pfa(c,a,r) - afa(c,a,r) - pint(a,r)]; (6)

and the average price of the intermediate input composite is described in equation (7).

Equation E_pint

pint(a,r) = sum{c,COMM, INTSHR(c,a,r) * [pfa(c,a,r) - afa(c,a,r)]} (7) where INTSHR(c,a,r) is the share of intermediate *c* in total composite inputs of activity *a* in region *r*.

At the top of the production technology tree, firms merge the value-added bundle with the intermediate composite bundle in fixed proportions to assemble the final product, qo as shown in Figure 14. At this level, the elasticity of substitution ESUBT between qva(a,r) and qint(a,r) is assigned the value 0. As a result, an increase in the quantity of the intermediate composite bundle while the value-added bundle is held constant, will not increase the total output qo. The sector demands for composite intermediate commodity inputs, demands for primary factor composite and industry output at zero pure profits condition are described in equations (8), (9) and (10) respectively.

Equation E_qint

qint(a,r) = - aint(a,r) + qo(a,r) - ao(a,r) - ESUBT(a,r) * [pint(a,r) - aint(a,r) - po(a,r) - ao(a,r)]; (8)

Equation E_qva

qva(a,r) = -ava(a,r) + qo(a,r) - ao(a,r) - ESUBT(a,r) * [pva(a,r) - ava(a,r) - po(a,r) - ao(a,r)]; (9)

Equation E_qo

po(a,r) + ao(a,r) = sum{e,ENDW, STC(e,a,r) * [pfe(e,a,r) - afe(e,a,r) - ava(a,r)]}

+ sum{c,COMM, STC(c,a,r) * [pfa(c,a,r) - afa(c,a,r) - aint(a,r)]} + profitslack(a,r); (10)

where aint(a,r), ao(a,r) and ava(a,r) are the composite intermediate augmenting technical change, output augmenting technical change and value-added augmenting technical change, respectively, by activity *a* in region *r*. The variable po(a,r) is the unit cost of activity *a* in region *r*. An elaboration on sets, shares and slack variables is given in Appendices B1, B4 and B10. This thesis focuses on the electrical and electronic manufacturing industry in South Africa where skills shortages (Sunderland, 2020) negatively impact on production. Therefore, there is an industry constraint with respect to this primary factor. The modelled protection framework that alleviates skills shortages combined with increased accessibility to imported inputs is expected to provide manufacturing firms with sufficient options to increase total output qo. Increases in output qo affect demand for for primary factors of production and the composite value-added bundle qva in the industry through equations (8) and (9).

4.6.2 Factors of production

The model does not allow for mobility of the factors of production between regions, however labour and capital are treated as mobile within a region while land and natural resources are considered sluggish. This thesis incorporates an increase in skilled labour supply in South Africa through a skills development programme such that there is a shift in skills endowment. Such a programme can result in an increase in skilled labour productivity, that is, an increase in the level of output per unit of factor. South Africa is considered to be a more capital intensive and a less labour intensive economy, a feature that is very concerning considering its high unemployment rate. Given the possibility of labour-capital substitutability particularly in the electrical and electronic manufacturing industry, this thesis contends that a shift towards labour biased production could be beneficial to South Africa through comparative advantage effects.

Under the standard model closure, an increase in the availability of labour will cause the wage to adjust by dropping until the supply of each factor matches the demand, the so called equilibrium condition. However, under the unemployment closure, adopted in this thesis, an increase in the availability of both skilled and unskilled labour does not influence the real wage rate (that remains fixed) while the supply of capital for instance, changes to restore equilibrium between demand and supply of the factors of production at the fixed wage, at which point the productive capacity changes. That being the case, a change in skilled labour endowment affects the demand for capital in different ways, based on substitutability between the primary factors. An increase in the demand for labour could result in an increase in the demand for capital that complements labour or a decrease in the demand for capital that substitutes labour. In this thesis, this combination of factors allows for substitution as explained earlier. An increase in skilled and unskilled endowment in the electrical and electronic manufacturing industry for instance, is expected to result in a decline in demand for capital. The market clearing equilibrium condition where demand for mobile factors (skilled labour, unskilled labour and capital) equates supply of the factors is described in equation (11) whereas equation (12) ensures market clearing for all endowments in region *r*.

Equation E_pe1 (11)

qe(e,r) = sum{a,ACTS, ENDWMSHR(e,a,r) * qfe(e,a,r)} + endwslack(e,r);

Equation E_peb

qfe(e,a,r) = qes(e,a,r); (12)

In the equations, ENDWMSHR(e,a,r) represents the share of mobile endowment *e* by activity *a* and region *r* whereas qes(e,a,r) is the supply of endowment *e* for use by activity *a* in region *r*. The basic price of mobile endowments in activity *a* in region *r* is described in equation (13) and equation (14) links basic and firm demand prices for mobile endowments.

Equation E_qes1

pes(e,a,r) = pe(e,r); (13)

Equation E_pfe

pfe(e,a,r) = peb(e,a,r) + tfe(e,a,r); (14)

where tfe(e,a,r) is the tax on primary factor *e* used by activity *a* in region *r* and peb(e,a,r) is the basic price of endowment *e* in activity *a* in region *r*.

4.6.3 Supply of commodities

One of the expected impacts of an expanding electrical and electronic manufacturing industry in South Africa is technology advancement in most other sectors in the economy because of the sectoral interlinkages discussed earlier. An increase in activity in the electrical and electronic manufacturing industry following the designed policy framework is expected to translate to higher output hence facilitating transmission of technology to other sectors of the economy. In the model, equation (15) describes the supply of commodity c from activity *a* in region *r* contingent on the activity level denoted by qo(a,r). Equation (16) describes the average unit cost (tax exclusive) of output of activity a while equation (17) presents the basic (tax inclusive) price of output of activity *a* in region *r*.

Equation E_qca

qca(c,a,r) = IF[MAKES(c,a,r) gt 0, qo(a,r) - ETRAQ(a,r) * [ps(c,a,r) - po(a,r)]]; (15)

Equation E_po

po(a,r) = sum{c,COMM, MAKESACTSHR(c,a,r) * ps(c,a,r)}; (16)

Equation E_pb

pb(a,r) = sum{c,COMM, MAKEBACTSHR(c,a,r) * pca(c,a,r)}; (17)

This thesis assumes a diagonal make matrix hence the elasticity of transformation is redundant. The share of *c* and *a* in output of activity *a* at supplier (pre tax) prices and at basic (post tax) prices is represented by MAKESACTSHR and MAKEBACTSHR respectively. Equation (18) links the basic and supply price of commodity *c* from activity *a* in region *r.* Equation (19) is a CES allocation of commodity output by activity, where the value ESUBQ is equal to zero.

Equation E_ps

pca(c,a,r) = ps(c,a,r) + to(c,a,r); (18)

In the above equation, to(c,a,r) is the commodity and activity specific power of tax where

to(c,a,r) > 1 for a tax and

to(c,a,r) < for a subsidy.

Equation E_pca

pca(c,a,r) = IF[MAKEB(c,a,r) gt 0, pds(c,r) - ESUBQ(c,r) * [qca(c,a,r) - qc(c,r)]]; (19)

Given that ESUBQ is equal to 0, it follows that

pca(c,a,r) = pds(c,r) (20)

In equation (19), ESUBQ that represents elasticity for allocation of commodity supply is 1/CES therefore the commodities are perfect substitutes, hence the equation (20), meaning that the law of one price holds. This is not expected to be an issue in this model since the sectors are aggregated in such a way that there are no two sectors producing the same commodity. Equation (21) describes the market clearing condition for total commodity supply.

Equation E_qc

qc(c,r) = sum{a,ACTS, MAKEBCOMSHR(c,a,r) * qca(c,a,r)}; (21)

where MAKEBCOMSHR(c,a,r) is the share of commodity *c* by activity *a* in commodity supply at basic prices.

4.6.4 Import and export demand

While the electrical and electronic manufacturing industry exports its output to the foreign markets, a portion is consumed domestically depending on demand for imported varieties. Following Corong et al. (2018), an aggregated agent-based demand for the imported composite good is shown in equation (22).

$$QMS = \sum_a QFM(c,a,r) + QPM(c,r) + QGM(c,r) + QIM(c,r) \quad (22)$$

The Aggregate import price is expressed in equation (23).

$$PMS(c,d)QMS(c,d) = \sum_s PMDS(c,s,d)QXS(c,s,d) \quad (23)$$

The linearized model equation (24) describes aggregate imports of commodity *c* by region *r*

Equation E_qms

qms(c,r) = sum{a,ACTS, FMCSHR(c,a,r) * qfm(c,a,r)} + PMCSHR(c,r) * qpm(c,r)

+ GMCSHR(c,r) * qgm(c,r) + IMCSHR(c,r) * qim(c,r); (24)

where FMCSHR(c,a,r) represents the share of import *c* used by activity *a* in region *r*, PMCSHR(c,r) is the share of import *c* used by private households in total imports in region *r*, GMCSHR(c,r) is the share of import *c* used by government in total imports in *r* and IMCSHR(c,r) is the share of import *c* used by investment agents in total imports in region *r*. The private household demand, government demand and investment demand for commodity *c* in region *r* are represented by qpm(c,r), qgm(c,r) and qim(c,r) respectively. The equation assures market clearing for imported commodities.

Equation (25) describes the regional demand for disaggregated imported commodities by source.

Equation E_qxs

qxs(c,s,d) = sum{aa,AGENTS, QXSSHR(c,aa,s,d) * qamds(c,aa,s,d)}; (25)

where QXSSHR(c,aa,s,d) is the agent specific share in total imports, CIF weights. Ultimately, the variable qxs(c,s,d), is representative of exports from South Africa by commodity *c* and *d* is the Rest of the world.

The total output from domestic production must meet total demand to satisfy the goods market equilibrium. This total demand is a combination of domestic demand and total exports. In a scenario where consumers (firms, private households and government) prefer less of the domestically produced variety, more of this output is shifted towards exports, and vice versa. Equation (26) assures market clearing for domestic sales whereas equation (27) assures market clearing for commodities.

Equation E_qds

qds(c,r) = sum{a,ACTS, FDCSHR(c,a,r) * qfd(c,a,r)} + PDCSHR(c,r) * qpd(c,r)

+ GDCSHR(c,r) * qgd(c,r) + IDCSHR(c,r) * qid(c,r); (26)

where the private household, government, and investment demands for domestic commodity *c* in region *r* are represented by qpd(c,r), qgd(c,r) and qid(c,r) respectively. In the equation, FDCSHR is the share of domestic product *c* used by activity *a* in region *r*. The shares of domestic product *c* used by private households, government and investment in region *r* are represented by PDCSHR(c,r), GDCSHR(c,r) and IDCSHR(c,r) respectively.

Equation E_pds

qc(c,r) = DSSHR(c,r) * qds(c,r) + sum(d,REG, XSSHR(c,r,d) * qxs(c,r,d))

+ IF[c in MARG, STSHR(c,r) * qst(c,r)] + tradslack(c,r); (27)

In equation (27), DSSHR is the share of domestic sales of *c* in region *r*, XSSHR is the share of export sales of *c* to *s* in r, STSHR is the share of sales of *c* to global transport services in *r* and qst(c,r) represents sales of *c* from *r* to global transport.

4.6.5 Income

The regional household in the model accumulates income, for instance, gross factor payments and taxes from across all activities in a region. This is summarised in equation (28) that describes factor income at basic prices net of depreciation and equation (29) that describes regional income as the sum of primary factor income and indirect tax receipts.

Equation E_fincome

FY(r) * fincome(r)

= sum{e,ENDW, sum{a,ACTS, EVFB(e,a,r)*[peb(e,a,r) + qes(e,a,r)]}}

- VDEP(r) * [pinv(r) + kb(r)]; (28)

where EVFB(e,a,r) is expenditure on endowment *e* by activity *a* in region *r*, VDEP(r) is the value of capital depreciation in *r*, pinv is the price index of investment goods in *r* and kb(r) is the beginning of period capital stock in *r*.

Equation E_y

INCOME(r) * y(r) = FY(r) * fincome(r) + 100.0 * INCOME(r) * del_indtaxr(r)

+ INDTAX(r) * y(r) + INCOME(r) * incomeslack(r); (29)

where del_indtaxr(r) is the change in ratio of indirect taxes to INCOME in *r* and INDTAX(r) represents indirect tax receipts in *r*.

Income is spent over government and private households expenditure as well as savings. These transmissions are presented in equation (30) that describes private consumption expenditure, equation (31) that describes government consumption expenditure and equation (32) that describes savings.

Equation E_yp

yp(r) - y(r) = -[uepriv(r) - uelas(r)] + dppriv(r); (30)

Equation E_yg

yg(r) - y(r) = uelas(r) + dpgov(r); (31)

Equation E_qsave

psave(r) + qsave(r) - y(r) = uelas(r) + dpsave(r); (32)

The utility variables uelas(r), uepriv(r), and the distribution parameters dppriv(r); dpgov(r); dpsave(r); are presented in Appendix B12 and Appendix B9 respectively.

4.6.6 Tariff rates and tariff reduction

South Africa's tariff system on imported commodities is centralised by the South African Revenue Authority System (SARS). With respect to tax revenue, import tariffs represent a significant source of revenue in African countries. A relevant aspect to this thesis is tariff reduction on imported intermediate inputs that has the effect of reducing tax revenue generated by South Africa. Equation (33) expresses the revenue generated through import tax where TMS*csd* -1 represents the ad valorem tax imposed on import *c* from the exporting region *s* by importing region *d*, PCIF*c,s,d*) is the base price of the imports and QXS *c,s,d* is the quantity of imports.

$$TAXRIMP(d) = \sum_s \sum_c (TMS_{c,s,d} - 1)\, PCIF(c,s,d)\, QXS(c,s,d) \qquad (33)$$

In this thesis, that adopts the MRIO model version, the linearized standard model equation (34) is revised to the agent specific equation (35), that describes the change in ratio of import tax payments to regional income.

Equation E_del_taxrimp

100.0 * INCOME(d) * del_taxrimp(d) + TAXRIMP(d) * y(d)

= sum{c,COMM, sum{s,REG, VMSB(c,s,d) * [tm(c,d) + tms(c,s,d)] + MTAX(c,s,d) * [pcif(c,s,d) +

qxs(c,s,d)]}}; (34)

Equation E_del_taxrimp

100.0 * INCOME(d) * del_taxrimp(d) + TAXRIMP(d) * y(d)

= sum{c,COMM, sum{s,REG, sum{aa,AGENTS, VMAB(c,aa,s,d) * [tm(c,d) + tms(c,s,d) +

tmsa(c,aa,s,d)] + MATAX(c,aa,s,d) * [pcif(c,s,d) + qamds(c,aa,s,d)]}}}; (35)

Where VMAB(c,aa,s,d) represents import flows by source and agent, at basic prices, MATAX(c,aa,s,d) is the agent specific import tariff revenue on imports of *c* from source *s* to destination *d,* tmsa is the agent specific power of import tariff on *c* from *s* to *d*, pcif represents the cif price of imported commodity *c*, qamds(c,aa,s,d) is the quantity of import *c* from *s* for use by agent *aa* in *d* and the common variable *y(d)* is the regional income in the destination region. The implementation of this thesis's policy structure can only be justifiable if the resultant economic gains to South Africa's broader economy offset the loss of tax revenue through import tariff elimination.

Import tariff reduction is adopted in this study as a mechanism for providing cost advantages to the vulnerable manufacturing industry. Tariff reduction is incorporated into the GTAP model such that specific linearised equations are targeted. For instance, the value of purchases of imported intermediate inputs (*VMFB*) is affected since it is inclusive of import tariffs, as shown in equation (36).

$$VMFB(c,a,r) = pms(c,r) * qfm(c,a,r) \qquad (36)$$

Where *qfm* represents the imported intermediate inputs by the electrical and electronic manufacturing industry and pms is the price associated with the inputs.

The exogenous variable *tmsa* is targeted and shocked in this thesis. This shock, in this model that incorporates the MRIO version of the database, specifies the importation of intermediate inputs by region as well as by agent and the price of the imported commodity is inclusive of the tariff rate as shown in equation (37) below.

$$pamds(c,aa,s,d) = pcif(c,s,d) + tm(c,d) + tms(c,s,d) + tmsa(c,aa,s,d); \qquad (37)$$

This represents a tariff inclusive price of import *c* from region *s* for use by agent *aa* in *d* where *c* is the imported commodity (international fragmentation induced intermediate inputs), *aa* is the importer agent in South Africa, *s* is the source region represented by Rest of the World and *d* is the destination region, South Africa. In equation (37), *tm* is the source-generic change in tax on imports of *c* into *d* and *tms* is the source-specific change in tax on imports of *c* from *s* to *d*. The next section outlines the incorporation of labour in this thesis.

4.6.7 Unemployment closure and skilled labour

A change in the unemployment rate in a country can have an impact on the productivity of industries. This applies to the electrical and electronic manufacturing industry in South Africa because of its demand for both skilled and unskilled labour, required for technical know-how as well as non-technical jobs. According to Burfisher (2016), a majority of CGE models adopt a full employment closure, however, this becomes a problem when modelling economies that are genuinely affected by unemployment. Developing countries have less skilled workers and tend to be inclined towards a dependency on agriculture, that lags in taking advantage of new technological information (UNCTAD, 2021). South Africa is typical of a developing country that is heavily affected by unemployment, with an unemployment rate of approximately 35% (DTI, 2022). This, combined with a lack of adequate skilled labour in the electrical and electronic manufacturing industry, becomes reasonable ground to model an infant industry protection framework that emphasises government expenditure towards skills training. Under this assumption, the anticipated labour demands, as a result of a tariff shock on the imported intermediate inputs do not present a constraint to productivity from for instance, the electrical and electronic manufacturing industry. This contrasts with full employment that would otherwise present labour constraints to the growth and development of the vulnerable industry.

In the MRIO model, the labour supply variable (*qe*) is endogenous whereas the real wage variable [1]*pebfactreal* (MRIO notation) is exogenous, thereby defining a full employment closure. However, a swap command as shown in equation (38) is adopted to define an alternate closure of unemployment. Table 11 summarises the study specific simulation adjustments.

swap qe(ENDWL, SouthAfrica) = pebfactreal(ENDWL, SouthAfrica); (38)

Where *pebfactreal* is a tax inclusive ratio of return to mobile factor (*ENDWL)* in *South Africa,*

and

set ENDWL (SkLab, UnSkLab)

is a subset of set ENDWM.

In this model, skilled labour is distinct from unskilled labour.

Scholars such as Gilles et al. (2023) highlight potential transmission mechanisms of knowledge that is embedded in high technology goods. The next section discusses the incorporation of technology transfer in this research.

[1] *pebfactreal in the GTAPv7 MRIO-model represents tax-inclusive real factor prices whereas pefactreal represents tax-exclusive real factor prices for mobile and sluggish endowments.*

4.6.8 Technology transfer

The transfer of technology through intermediate inputs is presented in the model as technical advancement shock in the advanced innovating country. In essence, technological advancement is experienced in South Africa through imported electrical and electronic inputs. This approach follows the principle of technology transfer as in studies by Das (2019) and Van Meijl and Van Tongeren (1999).

A 2% shock on *afall* representing technical change via imported electrical and electronic inputs from the Rest of the World region into South Africa was performed where *afall(c,a,r)* represents input *c* augmenting technical change by activity *a* in region *r*. The 2% shock is a minimal value based on the approximate global electronic components market growth rate, representing a technical change in the Rest of the World region. A report by The Global General Electronic Components Market (2022) indicates that the global general electronic components market grew at a Compound Annual Growth Rate (CAGR) of 2.4% from the year 2016 to the year 2021 and is predicted to further grow at an annual growth rate of 4.8% for the period from the year 2022 to the year 2026.

Other studies, such as Das (2009), apply a shock value of 4% based on their reference source region's (United States) approximate annual rate of technical change, while Van Meijl and Van Tongeren (1999) adopt a value of 2% to represent technological progress in North America. This approach distinguishes the intermediate inputs that transmit the technology from the manufactured products that utilise the intermediate inputs (Van Meijl and Van Tongeren, 1999) such that the impact of the acquired technology is estimated by quantifying changes in productivity.

This study assumes that improvements in productivity lead to export value gains. Importation of technology embedded intermediate inputs, the potential for technology spillovers and the assumed propensity of the domestic electrical and electronic manufacturing industry to absorb knowledge all point to the feasibility of a policy framework that necessitates the survival and growth of a vulnerable industry.

4.6.9 Decomposition of welfare

The equivalent variation (EV) is measured in US$ million for each region in the model and McDougall (2003) documents the mechanism of decomposing EV. The Equation E_EV_ALT that describes the decomposition of equivalent variation EV_ALT(r) by region is provided in Appendix C. It then follows that equation (39) describes the equivalent variation for the world.

Equation E_WEV_ALT

WEV_ALT = sum{r,REG, EV_ALT(r)}; (39)

In the Equation E_EV_ALT, (see Appendix C) the left hand side of the expression that describes equivalent variation by region is presented as EV_ALT(r) and the right hand side is presented through terms that capture preference shifts, a scaling factor, changes in allocative efficiency, changes in endowments, depreciation, changes in technology, changes in terms of trade and changes in population. In this thesis, technology and labour endowment vary endogenously through the unemployment and technology transfer shocks. Preference shifts capture the contribution to EV of change in distribution parameters. The expression incorporates a region specific EV scale factor EVSCALFACT(r), equation (40).

EVSCALFACT(r) = [UTILELASEV(r) / UTILELAS(r)] * [INCOMEEV(r) / INCOME(r)]; (40)

where UTILELASEV(r) is elasticity of cost of utility with respect to utility for EV calculation.
and
UTILELASEV(r) = UTILELAS(r); (41)

INCOMEEV(r) is the regional income for EV calculation where

INCOMEEV(r) = INCOME(r) (42)

Changes in allocative efficiency are a result of market distortions (such as tariff eliminations) that are linked to reallocation of resources in a region. Changes in endowments capture the effect of factor variations on the regional welfare, for instance, an increase in labour through the unemployment factor is anticipated to improve overall welfare whereas capital improvements have the effect of raising both capital stock and depreciation. Changes in technology tend to improve efficiency hence they have a positive impact on regional welfare, subject to constant regional terms of trade. Changes in terms of trade capture variations relating to imports and exports for instance a rise in export prices improves regional welfare whereas an increase in import prices leads to a deterioration of regional welfare.

4.7 Conclusion

This chapter discussed the suitability of computable general equilibrium modelling in answering the study questions and its merits over other methodological approaches. The general principle behind the model, the process of gathering data and the construction process of the GTAP database were presented. The model in this thesis was discussed. This included discussion of the main equations in simulations as well as the various parameter choices that were adopted in this thesis. The next chapter focuses on the execution of the research methodology including assumptions made as part of the model setting.

Chapter 5: Application and execution of the research methodology

5.1. Overview

This chapter provides an outline of the operations that are associated with the application of the model in this research. This includes a section on data preparation through sector and region aggregation, the model closure, a brief discussion on data analysis approach and a summary of model simulations.

5.2 Sector and region aggregation

Data preparation is required before any project specific simulations can be done. Such preparation involves study specific aggregation of data with respect to regions and sectors. Similarly, this section presents separate aggregations for this study's sectors and regions. The region aggregation summary that creates two regions namely South Africa and the Rest of the World is presented in Table 16.

Table 16: Aggregation of the GTAP database regions

Region identity in the modified GTAP database	Region composition (countries and regions) based on GTAP 10 database
South Africa	South Africa
Rest of the World	Australia, New Zealand, Rest of Oceania, China, Hong Kong, Japan, Korea, Mongolia, Taiwan, Rest of East Asia, Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Viet Nam, Rest of Southeast Asia, Bangladesh, India, Nepal, Pakistan, Sri Lanka, Rest of South Asia, Canada, United States of America, Mexico, Rest of North America, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Rest of Caribbean, Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia,

Region identity in the modified GTAP database	Region composition (countries and regions) based on GTAP 10 database
Rest of the World (continued)	Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Switzerland, Norway, Rest of European FTA, Albania, Bulgaria, Belarus, Croatia, Romania, Russian Federation, Ukraine, Rest of Eastern Europe, Rest of Europe, Kazakhstan, Kyrgyzstan, Tajikistan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia, Bahrain, Iran, Islamic Republic of Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates, Rest of Western Asia, Egypt, Morocco, Rest of North Africa, Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe, Sudan, Tunisia, Rest of Eastern Africa, Botswana, Namibia, Rest of South African, Customs, Rest of the World, Rest of Western Africa, Rest of Central Africa, South Central Africa

Source: Author's aggregation based on the GTAP version 10 MRIO database.

To be able to identify the electrical and electronic manufacturing industry as an isolated industry, Table 17 summarises sectoral aggregation for this study where four sectors namely, electrical and electronic manufacturing, other manufacturing, agricultural activities and services were formulated. Appendix A shows the detailed sectoral list as provided in the GTAP 10 database.

Table 17: Sectoral aggregation based on the GTAP 10 database

Sectors as modelled in the study	GTAP 10 sectors
Electrical and Electronic manufacturing	Manufacture of computer, electronic and optical products Manufacture of electrical equipment
Other Manufacturing	Fishing, Coal, Oil, Gas, Other extraction (formerly 103n Minerals n.e.c.), Textiles, Wearing apparel, Leather products, Wood products, Paper products, printing, Petroleum, coal products, Chemical products, Basic pharmaceutical products, Rubber and plastic products, Mineral products n.e.c. Ferrous metals, Metals n.e.c. Metal products, Machinery and equipment n.e.c. Motor vehicles and parts, Transport equipment n.e.c. Manufactures n.e.c.
Agricultural activities	Paddy rice, Wheat, Cereal grains not elsewhere classified (n.e.c.), Vegetables, fruit, nuts, Oilseeds and oleaginous fruits, Sugar crops (cane, beet), Plant-based fibers, Crops n.e.c, Bovine animals, horses and other equines, Other animals and animal products n.e.c, Raw milk, Wool, silk-worm cocoons, Forestry and logging products, Bovine meat products Meat products nec, Vegetable oils and fats, Dairy products and egg products, Processed rice, Sugar and molasses, Food products nec, Beverages and tobacco products
Services	Electricity; steam and air conditioning supply, Gas manufacture, distribution, Water supply; sewerage, waste management and remediation activities, Construction, Wholesale and retail trade; repair of motor vehicles and motorcycles, Accommodation and food service activities, Land transport and transport via pipelines, Water transport, Air transport, Warehousing and support activities, Information and communication, Financial services nec ,Insurance (formerly isr),Real estate activities, Other business services, Recreational and other services, Public administration and defence; compulsory social security; and activities of extraterritorial organizations and bodies, Education, Human health and social work activities, Dwellings

Source: Author's aggregation based on the GTAP version 10 MRIO database.

South Africa's imports of electrical and electronic intermediate inputs are mainly from Asian countries (China, Taiwan, Japan and South Korea) while its exports of electrical and electronic products are generally spread over the Rest of the World (with significant exports to African economies) as reflected in the WITS (2020) import and export data. Nonetheless, to capture all its electrical and electronic bilateral trade flows for both intermediate inputs and final goods export, all other regions in the GTAP database are included in the Rest of the World aggregation.

5.3 Model simulations and closure

This section outlines the simulation experiments, the corresponding model closure and model shocks. Table 18 is a summary of simulations carried out in this study.

Table 18: Simulation experiments

Policy scenario (experiment)	Model shock/closure	Exogenous variables
Standard model 50% import tariff reduction	A 50% tariff reduction shock on imported electrical and electronic inputs from the ROW region to South Africa was applied.	Exogenous (Standard GTAP closure): psave varies by region, pfactwld is numeraire, Pop psaveslack pfactwld profitslack incomeslack endwslack cgdslack tradslack ams atm atf ats atd aosec aoreg avasec avareg aintsec aintreg aintall afcom afsec afreg afecom afesec afereg aoall afall afeall au dppriv dpgov dpsave to tinc tpreg tm tms tx txs qe qesf Additional closure variables amsall ams tmsa Rest endogenous;
Standard model 100% import tariff reduction	A 100% tariff reduction shock on imported electrical and electronic inputs from the ROW region to South Africa was applied.	Exogenous (Standard GTAP closure): psave varies by region, pfactwld is numeraire, Pop psaveslack pfactwld profitslack incomeslack endwslack cgdslack tradslack ams atm atf ats atd aosec aoreg avasec avareg aintsec aintreg aintall afcom afsec afreg afecom afesec afereg aoall afall afeall au dppriv dpgov dpsave to tinc tpreg tm tms tx txs qe qesf Additional closure variables amsall ams tmsa Rest endogenous;
Scenario 1(a) 50% import tariff reduction	A 50% tariff reduction shock on imported electrical and electronic inputs from the ROW region to South Africa was applied.	Exogenous (Standard GTAP closure): psave varies by region, pfactwld is numeraire, Pop psaveslack pfactwld profitslack incomeslack endwslack cgdslack tradslack ams atm atf ats atd aosec aoreg avasec avareg aintsec aintreg aintall afcom afsec afreg afecom afesec afereg aoall afall afeall au

Policy scenario (experiment)	Model shock/closure	Exogenous variables
Factor unemployment	A variable swap statement was introduced to endogenise skilled and unskilled labour while the real wage rate was fixed: xSet ENDWL (SkLab, UnSkLab); xSubset ENDWL is subset of ENDWM; swap qe(ENDWL,"SouthAfrica") = pebfactreal(ENDWL,"SouthAfrica");	dppriv dpgov dpsave to tinc tpreg tm tms tx txs qe qesf Additional closure variables amsall tmsa Rest endogenous;
Scenario 1(b) 100% import tariff reduction Factor unemployment	A 100% tariff reduction shock on imported electrical and electronic inputs from the ROW region to South Africa was applied. A variable swap statement was introduced to endogenise skilled and unskilled labour while the real wage rate was fixed. xSet ENDWL (SkLab, UnSkLab); xSubset ENDWL is subset of ENDWM; swap qe(ENDWL,"SouthAfrica") = pebfactreal(ENDWL,"SouthAfrica");	Exogenous (Standard GTAP closure): psave varies by region, pfactwld is numeraire, Pop psaveslack pfactwld profitslack incomeslack endwslack cgdslack tradslack ams atm atf ats atd aosec aoreg avasec avareg aintsec aintreg aintall afcom afsec afreg afecom afesec afereg aoall afall afeall au dppriv dpgov dpsave to tinc tpreg tm tms tx txs qe qesf Additional closure variables amsall tmsa Rest endogenous;
Scenario 2(a) 50% import tariff reduction Factor unemployment	A 50% tariff reduction shock on imported electrical and electronic inputs from the ROW region to South Africa was applied. A variable swap statement was introduced to endogenise skilled and unskilled labour while the real wage rate was fixed as applied in policy **scenario 1**.	Exogenous (Standard GTAP closure): psave varies by region, pfactwld is numeraire, Pop psaveslack pfactwld profitslack incomeslack endwslack cgdslack tradslack ams atm atf ats atd aosec aoreg avasec avareg aintsec aintreg aintall afcom afsec afreg afecom afesec afereg aoall afall afeall au dppriv dpgov dpsave to tinc tpreg tm tms tx txs qe qesf Additional closure variables amsall tmsa Rest endogenous;

Policy scenario (experiment)	Model shock/closure	Exogenous variables
2% technology advancement transmitted via imported electrical and electronic inputs	A 2% shock was applied on variable *afall* to represent technology transmission from the ROW region to South Africa via imported electrical and electronic inputs.	
Scenario 2(b) 100% import tariff reduction Factor unemployment 2% technology advancement transmitted via imported electrical and electronic inputs inputs	A 100% tariff reduction shock on imported electrical and electronic inputs from the ROW region to South Africa was applied. A variable swap statement was introduced to endogenise skilled and unskilled labour while the real wage rate was fixed as applied in policy **scenario 1.** A 2% shock was applied on variable *afall* to represent technology transmission from the ROW region to South Africa via imported electrical and electronic inputs.	Exogenous (Standard GTAP closure): psave varies by region, pfactwld is numeraire, Pop psaveslack pfactwld profitslack incomeslack endwslack cgdslack tradslack ams atm atf ats atd aosec aoreg avasec avareg aintsec aintreg aintall afcom afsec afreg afecom afesec afereg aoall afall afeall au dppriv dpgov dpsave to tinc tpreg tm tms tx txs qe qesf Additional closure variables amsall tmsa Rest endogenous;

Source: Author's compilation based on the GTAP model.

The model response to each simulation experiment was observed hence it was possible to determine the impact of each isolated policy scenario on the value of exports from the electrical and electronic manufacturing industry.

5.4 Data analysis

The GTAP model is solved computationally using GEMPACK software. The analysis is primarily model simulations (based on a framework of equations) that calculate the deviation of the endogenous (dependent) variable, in percentage change and response to any drift in the exogenous variable from its original value. To determine the reliability of the simulation results with respect to model parameter such as elasticities, a systematic sensitivity analysis was conducted.

5.4.1 Model simulations

This section describes the experimental design of data analysis using the model and the derivation of the simulations from questions. In addition to the two tariff removal simulations on the standard model, two sets of experiments with a total of four simulations were conducted to answer the policy questions in this study, based on the two hypotheses: **H1** and **H2** (see Sections 2.5 and 2.6). The tariff reductions were applied in conjunction with the proposed infant industry protection policy framework as described below. Specific model closures are summarised in Table 18.

Set 1 (H1): To determine the effect of imported international fragmentation-induced intermediate inputs tariff reduction on the value of exports from the electrical and electronic manufacturing industry, within an infant industry protection framework that entails skilled labour training, represented by the unemployment closure. Model simulations were executed where the intermediate input tariff rate was varied at 50% and zero percent in successive simulations. Two simulations 1(a) and 1(b) were conducted in this set.

Simulation (1a): Intermediate inputs import tariffs were reduced by 50% plus model incorporating the unemployment closure.

Simulation (1b): Intermediate inputs import tariffs were reduced by 100% plus model incorporating the unemployment closure.

Set 2 (H2): To determine the effect of technology transfer on the relationship between imported international fragmentation-induced intermediate inputs tariff reduction and the value of exports from the electrical and electronic manufacturing industry, within an infant industry protection framework that entails skilled labour training, represented by the unemployment closure accompanied with technology transfer. This model setting adopts technological change due to imports and therefore assumes utilisation of such technical information in addition to Set 1 model specifications. Two simulations 2(a) and 2(b) were carried out in Set 2.

Simulation 2(a): Intermediate inputs import tariffs were reduced by 50% plus model incorporating the unemployment closure in the presence of technology transfer and spillover effects.

Simulation 2(b): Intermediate inputs import tariffs were reduced by 100% plus model incorporating the unemployment closure in the presence of technology transfer and spillover effects.

Results from the standard model simulations were compared to results from sets 1 and 2. Model simulation results from Set 2 were then compared to simulation results from Set 1. Two separate simulations at 50% and 100% of tariff rate cut were preferred at each stage of policy analysis over a single complete tariff elimination step so as to observe the response consistency of export value to different magnitudes of tariff cuts. Likewise, the effect of gradual tariff elimination can be determined and compared to a single complete tariff elimination step. Tariff revenue is arguably an important source of income for the government hence this study adopts a gradual tariff rate reduction to assist policymakers in comparing the gains to the economy against the loss in revenue to the government after policy implementation.

5.5 Conclusion

This chapter presented the study specific aggregation from the main database, the general closure for the model and the specifications relevant to the infant industry protection framework within international fragmentation. The model adopted features that incorporated the abundance of skilled labour, availability of imported intermediate inputs and the associated technology spillovers. These features were adopted alongside tariff cuts on imported international fragmentation-induced intermediate inputs. The specific simulations for this study were presented in the form of a simulation closure table. The next chapter reports and examines the thesis results.

Chapter 6: Simulation results

6.1 Overview

The previous chapter focussed on the framework of the policy scenarios as well as data preparation and analysis. A summary of study specific aggregated regions and sectors and the basic structure of the closures for the simulation procedure were laid out. This chapter presents results and explanations from the simulation experiments carried out. Interpretation of results from CGE analysis is not without its challenges hence Adams (2005) outlines an approach that facilitates an easier comprehension of the implications of simulation results.

The dependent variable was the value of exports from South Africa's electrical and electronic manufacturing industry. Simulations to establish results based only on the tariff reductions were done. These simulations were important in determining the difference in export value response between merely reducing tariffs and implementing further policy scenarios. To illustrate the impact of different individual policy decisions on the value of exports, the results are presented in three segments, namely, results from the standard model with tariff reductions, tariff reduction and the unemployment closure, and tariff reduction combined with the unemployment closure and technology spillovers. This chapter closes with a presentation of sensitivity analysis results.

In this thesis, an efficient transfer of technological knowledge was anticipated only under conditions of adequate skilled labour. For this reason, technology spillovers are evaluated under tariff reductions and unemployment closure conditions. The infant industry protection framework was primarily based on the elimination of import tariffs on imported international fragmentation-induced intermediate inputs, the unemployment closure (combined with availability of skilled labour) and the technology transfer model assumption. The latter two components of the framework are described as follows:

(i) The standard GTAP model assumes full employment. This study adopted an unemployment closure in anticipation of possible increased production due to the expected increase in the accessibility to international fragmentation-induced intermediate inputs. The unemployment closure eliminated any labour shortage constraints because of the mobility of workers between sectors. StatsSA (2022) reports an unemployment rate of about 35% hence it is befitting to adopt an unemployment closure with respect to South Africa. This was accompanied by an assumption of a government (in conjunction with industry) initiative to increase skills training in both industry and institutions of higher learning as part of an intervention policy to protect the vulnerable electrical and electronic manufacturing industry.

(ii) Efficient technology transfer was an infant industry protection assumption that was a result of the anticipated increase in accessibility to imported international fragmentation-induced intermediate inputs. The increased availability of the imported inputs was in turn expected to translate to improved availability of embedded technology and an onset of knowledge spillovers to the electrical and electronic manufacturing industry. A model shock representing technology advancement in the source region of imported international fragmentation-induced intermediate inputs was incorporated to induce technology transfer to the destination region.

The policy scenario simulations were applied sequentially, to identify the isolated effect of each policy scenario. This was followed by a comparison of the magnitude of change in export values.

6.2 Tariff reduction, factor prices and export value

This section is a summary of the simulation results after tariff reduction only. Table 19 presents the results from the initial simulation. It shows a 15.49% increase in the value of exports at 50% tariff reduction with respect to the electrical and electronic manufacturing industry (row 5, Table 19). At 100% tariff reduction, the increase in the value of exports is at 16.74%, a further 1.25% increase compared to reducing tariffs by half. The change in export value is inversely proportional to the change in the pfactor variable. The variable pfactor*(r)* represents the percentage change in an index of a region's factor prices compared to the average world price. Results indicate a 0.147% and 0.142% decrease in pfactor for South Africa at 50% and 100% tariff reductions, respectively. A decrease in factor prices is known to contribute to lower costs of production hence translating to lower prices of the domestically produced goods (see Table 19).

The model in this thesis does not describe financial markets hence it lacks a distinct real exchange rate variable. The mechanism of transmission in the model primarily captures the effect of tariff reductions on relative prices of commodities and primary factors of production. One way to explain the increase in the value of exports is via the pfactor variable. A decline in South Africa's pfactor variable is considered to be equivalent to a real exchange rate depreciation. Effectively, a real exchange rate depreciation in the model results in an increase in exports as the domestically manufactured goods become more attractive to purchasers in foreign markets.

In contrast, an appreciation in the real exchange rate would correspond to a decline in exports. Table 19 further indicates lesser increases in exports from the services and other manufacturing sector, at 1.88% and 7.60%, respectively, while the agricultural sector shows the largest increase of 17.67% in export value.

A study by Amiti and Konings (2007) investigates productivity gains rather than export value from enhanced intermediate input access and shows that a 10% fall in tariffs leads to a 12% gain in productivity while Rutherford and Tarr (2002) demonstrate that a 10% tariff cut on intermediate input varieties results in a 10.6% gain in productivity. Considering that productivity gains may lead to gains in export value, it is therefore not surprising that South Africa's electrical and electronic manufacturing industry experienced enhanced export flows following only tariff reduction on imported intermediate inputs. Tariff reduction can therefore be positively impactful in necessitating the integration of the electrical and electronic manufacturing industry into international fragmentation. However, it remains unlikely that tariff reductions alone can be sufficient in enhancing the survival of a vulnerable industry in the long run, in an African economy, against competition from foreign more technologically advanced industries.

Table 19: Change in exports, prices and pfactor value after tariff reductions only

Industry	Policy scenario			
	50% tariff reduction		100% tariff reduction	
	Change in value of exports (%)	Change in price of domestically produced commodity (%)	Change in value of exports	Change in price of domestically produced commodity (%)
Agric	17.67	-0.76693	17.72	-0.77832
OtherMnfc	7.60	-1.27363	7.71	-1.28864
Services	1.88	-0.7357	1.95	-0.75574
ElecMnfc	15.49	-1.2119	16.74	-1.35736
South Africa pfactor change (%)	-0.147		-0.142	

Source: Author's calculations based on model simulations.

The next section summarises the main study results. It presents the impact of tariff reductions under further policy scenarios that represent integration to international fragmentation through imported inputs.

6.2.1 Main results based on study hypotheses

The following simulation experiments were designed based on the study hypotheses. Simulation scenario (1) and simulation scenario (2) were designed to test study hypotheses H1 and H2 respectively.

The study hypotheses are presented as:

H1: Elimination of import tariffs on international fragmentation-induced intermediate inputs positively impacts the value of the electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

H2: Technology transfer through intermediate inputs enhances the positive effect of imported international fragmentation-induced intermediate inputs tariff reduction, on the value of the electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

The simulation experiments were structured as follows:

Scenario 1(a) 50% tariff cut on imported international fragmentation-induced intermediate inputs into the electrical and electronics manufacturing industry in South Africa combined with unemployment and skills availability.

Scenario 1(b) 100% tariff cut on imported international fragmentation-induced intermediate inputs into the electrical and electronics manufacturing industry in South Africa combined with unemployment and skills availability.

Scenario 2(a) 50% tariff cut on imported international fragmentation-induced intermediate inputs into the electrical and electronics manufacturing industry in South Africa combined with unemployment and skills availability plus a technology spillover shock from the rest of the world.

Scenario 2(b) 100% tariff cut on imported international fragmentation-induced intermediate inputs into the electrical and electronics manufacturing industry in South Africa combined with unemployment and skills availability plus a technology spillover shock from the rest of the world.

Table 20 shows a summary of two sets of simulation results. The first set (1a & 1b) summarises the impact of tariff reductions under the unemployment closure and an abundance of skilled labour. The second set (2a & 2b) presents the impact of tariff reductions under the unemployment closure, an abundance of skilled labour and the technology spillover effect.

Table 20: Simulation results showing change in export value by industry

Policy scenario	**Exporting Region**	**Change in value of exports by industry**							
		Agric		**OtherMnfc**		**Services**		**ElecMnfc**	
		%	**US$million**	**%**	**US$million**	**%**	**US$million**	**%**	**US$million**
(1a)	South Africa	17.84	1921.24	7.63	6737.91	2.44	329.25	16.67	525.80
(1b)	South Africa	17.89	1927.03	7.75	6836.19	2.53	340.92	17.94	565.72
(2a)	South Africa	17.64	1900.27	7.39	6524.65	2.27	306.42	20.09	633.66
(2b)	South Africa	17.70	1906.06	7.50	6622.93	2.36	318.10	21.36	673.58

Source: Author's calculations based on GTAP simulations.

The results show a significant increase in export value from the electrical and electronic manufacturing industry after the implementation of tariff cuts on imported intermediate inputs. Policy scenario (1a) and (1b) correspond to 16.67% and 17.94% increases in export value respectively. This confirms the hypothesis (H1) of this thesis. When technology transfer is also modelled in the second set, the gain in export value rose to 20.09% and 21.36% in policy scenarios (2a) and (2b) respectively, thereby confirming the hypothesis (H2). Comparing Table 19 and Table 20, we find that the infant industry protection framework yielded more in export value than the standard model (see also summary Table 26). The further gain in export value could be an indication of additional cost benefits because of a reduction in primary input costs, combined with increased productivity as a result of more efficient production processes. More efficient production processes can be assumed to be a result of the increased skilled labour availability within the workforce and more effective utilisation of technology-embedded imported intermediate inputs. There is substitutability between labour and capital hence the industry becomes more labour intensive as some capital is replaced by labour. The percentage increase in export value under the designed policy framework also reveals the level of potential for export growth at the prevailing baseline scenario of industry production conditions.

Notable from Table 20 is the drop in the rate of export value gain with increasing tariff reduction. While policy scenario (1a) yields a 16.67% gain in export value, policy scenario (1b) represents only a further 1.27%. This trend is observed through all simulations, indicating that the initial 50% tariff reduction yields much more in export value compared to complete tariff elimination. This plays a role in informing decisions on preference between gradual tariff elimination and a single complete tariff elimination step. Export gains are experienced in the three other sectors; however, the services sector experiences the least gains of all sectors at 2.53% after policy scenario (1b). The agricultural sector gains the most with a 17.89% change in export value after policy scenario (1b).

Simulation scenarios 2(a) and 2(b) were designed to determine the impact of the technology transfer effect on the prescribed protection policy framework. A closer examination and comparison between simulation scenario 1 and simulation scenario 2 in Table 20 reveals that the impact of technology spillovers on the value of exports at 50% and 100% tariff reductions is positive and equal. The impact is represented by the difference between scenarios 1(a) and 2(a) as well as the difference between scenarios 1(b) and 2(b), that both give a value of approximately 3.4% (Tables 20 and 26). A study that investigates the impact of technology transmission from one region to another (Das, 2010) finds 10% gains in productivity (rather than exports) in the importing region following a 10% technology improvement in a foreign source region.

The technology spillovers can therefore be considered to have a positive impact on South Africa’s electrical and electronic manufacturing firms’ production processes by facilitating cost effective manufacturing processes. This argument is based on the assumption that the importation of technology via imported inputs eliminates, to an extent, the highly costly setup of domestic research and development facilities. Evidence from some studies (Das, 2019; Papaconstantinou et al., 1996) has shown that smaller countries import the bulk of their applied knowledge through imported intermediate inputs and equipment, with high technology manufacturing industries at the forefront of the knowledge importers. In answering the research question, each hypothesis was tested, and a summary of the results is shown in Table 21.

Table 21: Research questions, hypotheses and results from the study

Main research question	Research sub question	Hypothesis	Simulation scenario	Results (positive/negative/no change)	Finding and comments based on results
What is the impact of an infant industry protection policy framework in the backdrop of international fragmentation-induced intermediate inputs, on the export flows of electrical and electronic manufacturers in South Africa?	Sub question 1: What is the effect of imported intermediate inputs tariff reduction on the value of electrical and electronic firms' export flows, within an infant industry framework?	H1: Elimination of import tariffs on international fragmentation-induced intermediate inputs positively impacts the value of the electrical and electronic manufacturing firms' export flows within an infant industry protection framework.	50% tariff cut on imported intermediate inputs with adequate skilled labour and unemployment closure and adequate skilled labour	positive	Confirmed
			100% tariff cut on imported intermediate inputs with adequate skilled labour and unemployment	positive	Confirmed
	Sub question 2: What is the effect of technology transfer on the relationship between imported intermediate inputs tariff reduction and the value of	H2: Technology transfer through intermediate inputs enhances the positive effect of imported international fragmentation-induced intermediate inputs tariff	50% tariff cut on imported intermediate inputs with adequate skilled labour and unemployment combined with technology spillover assumption	positive	Confirmed
			100% tariff cut on imported intermediate inputs with adequate skilled labour and unemployment combined	positive	Confirmed

Main research question	Research sub question	Hypothesis	Simulation scenario	Results (positive/negative/no change)	Finding and comments based on results
	electrical and electronic firms' export flows, within an infant industry framework?	reduction, on the value of the electrical and electronic manufacturing firms' export flows within an infant industry protection framework.	with technology spillover assumption		

Source: Author's compilation.

The adoption of foreign technological knowledge may reduce firms' commitment to certain facets of domestic research and development. Therefore, the positive impact of technology spillovers on the value of exports contributes to the aspect of a less costly infant industry protection approach in contrast to the traditional high-cost approach that is characterised by high capital outlays on research and development facilities, high import tariffs and subsequent high prices for domestic consumers.

The increased access to imported intermediate inputs further enhances the adoption of imported technologies hence the positive impact of integrating an infant industry protection framework into the international fragmentation system. In addition to gains in the value of exports, changes in other variables also indicate a positive impact of this study's policy framework. The next section centres on output, prices, factor demand, trade balance and GDP.

6.3 Factor demand, output and real GDP

Following model simulations, an analysis of the electrical and electronic manufacturing industry's broader response to the different policy scenarios was carried out. Subsequently, the impact of the policies on South Africa's economy was evaluated. After the implementation of 100% tariff reductions under the standard model output from the electrical and electronic manufacturing industry as well as the other manufacturing sector decline by 3.18% and 0.69% respectively as shown in Table 22. On the other hand, the services and agricultural sectors experience output gains of 0.05% and 2.8% respectively. Similarly, the demand for capital, skilled and unskilled labour from the electrical and electronic manufacturing industry falls by 3.17%, 3.19% and 3.17% respectively while the demand for the three factors by the other manufacturing industry also declines by 0.75%, 0.76% and 0.75% respectively. There is a rise in demand for capital, skilled and unskilled labour in the agricultural sector by 3.06%, 3.05% and 3.06% respectively. The services sector shows an increase in demand for skilled and unskilled labour by 0.04% and 0.05% while the demand for capital falls by 0.05%.

Tariff reductions contribute towards an increase in productivity and output through reduced costs of production. The agricultural and services sectors are large sectors with a combined share in GDP of 63.19% hence their gains in output outweigh the decline in output from the other manufacturing and the electrical and electronic manufacturing industry. The result is a real GDP gain of 0.08% in South Africa (see Table 23). Different studies that incorporate import tariff reductions generally show varying gains in GDP depending on the region's level of economic development and the commodities involved. Elsheikh et al. (2015) in a study on the Sudanese economy obtain a value less than 0.1% gain in real GDP.

Table 22: Changes in output, prices and factor demand at 100% tariff reduction

		Standard model				1b. Unemployment				2b. Unemployment and technology transfer			
		Agric	Other Mnfc	Services	Elec Mnfc	Agric	Other Mnfc	Services	Elec Mnfc	Agric	Other Mnfc	Services	Elec Mnfc
Industry output (% change)		2.88	-0.69	0.05	-3.18	3.93	0.55	2.06	0.01	3.91	0.47	2.12	0.57
Price of commodities (% change)		- 0.77	-1.28	-0.75	-1.35	-0.81	-1.29	-0.90	-1.49	- 0.77	-1.25	-0.86	-1.89
Demand for factors (% change)	UnSkLab	3.06	-0.75	0.05	-3.17	5.26	2.27	4.05	0.81	5.26	2.22	4.14	2.20
	SkLab	3.05	-0.76	0.04	-3.19	5.26	2.27	4.05	0.81	5.26	2.22	4.14	2.20
	Capital	3.06	-0.75	-0.05	-3.17	3.31	-0.62	-0.01	-2.92	3.28	-0.72	0.01	-1.59
Price of factors (% change)	UnSkLab	- 0.15	-0.15	-0.15	-0.15	-1.79	-1.79	-1.79	-1.79	- 1.76	-1.76	-1.76	-1.76
	SkLab	- 0.13	-0.13	-0.13	-0.13	-1.79	-1.79	-1.79	-1.79	- 1.76	-1.76	-1.76	-1.76
	Capital	- 0.15	-0.15	-0.15	-0.15	1.16	1.16	1.16	1.16	1.25	1.25	1.25	1.25

Source: Author's calculations based on model simulations

Policy scenario 1 introduces unemployment into the model. Under policy scenario (1b), there is an increase in demand (from the baseline) for skilled and unskilled labour across all industries ranging from 0.81% in the electrical and electronic manufacturing industry to as high as 5.26% in the agricultural sector. On the other hand, the demand for capital falls in the electrical and electronic manufacturing industry, services and the other manufacturing industry by 2.92%, 0.01% and 0.61% respectively (Table 22). An exception is the agricultural sector that experiences a 3.31% increase in demand for capital. As the cost of labour declines relative to the cost of capital (Table 22), firms will tend to replace capital by substituting towards labour. This has positive productivity effects particularly in electrical and electronic manufacturing where initially the factor costs of capital outweigh the cost of labour. This has an impact on prices of output. The drop in domestic output prices (explained in section 6.2) could explain the decrease in the GDP price index (Table 23). The change in the GDP price index for South Africa declines starting from approximately -1.807% under the standard model at 100% tariff reduction whereby the negative value represents a drop in the price index from the baseline. Even though the GDP price index does not consider price changes for imported goods, it still incorporates price changes on domestic goods purchases by households, firms, government and foreigners (Church, 2016), hence it can be used to indicate the direction of inflation in South Africa after policy implementation.

As the industry becomes more labour intensive and costs of production decline, upward changes in output are experienced as shown in Table 22, hence contributing to the upward change in real GDP. As observed after policy scenario (1b) the gain in real GDP is high at 1.89% (Table 23). This value is not very surprising considering that simulations that incorporate unemployment tend to result in high increases in GDP as changes in productive capabilities ensue because of increases in labour supply, lower wages and lower costs of production. The unemployment closure implemented in this thesis, where the real wage rate is fixed while the quantities of skilled and unskilled labour are allowed to adjust, is a realistic representation of labour markets in South Africa and other African countries. This condition specifically reflects the abundance of unskilled labour that can be employed at the prevailing wage rate in response to changing industry demands for the factor. In a related study, Rojid and Ancharaz (2010) obtain real GDP gains as high as 7.26% for Mauritius in an assessment of East and Southern African countries' trade with the EU.

Policy scenario 2 incorporates technology transfer via electrical and electronic imports into South Africa. Technology transfers are known to induce positive changes through improvements in factor productivity in the destination region and sectors. New technologies improve efficiency and output per worker, a lower cost of production and output gains. At the same time, more technologically advanced goods are produced, for instance, advanced equipment from the electrical and electronic manufacturing industry. Such equipment, if purchased and utilised domestically also becomes a channel through which technology based improvements are transmitted to other sectors. Table 22 shows that demand for skilled and unskilled labour increases significantly across all sectors ranging from 2.2% to 5.26% under policy scenario (2b). This is partly because the electrical and electronic manufacturing industry serves all sectors of the economy including vital areas such as some manufacturing services, medical, automotive, banking, defence, agriculture, communications and aerospace services. With the continuing advancement in global technology, such as the 4IR, it can be argued that the electrical and electronic manufacturing industry's critical role in South Africa's economy has become perpetual. Authors such as Zhong et al. (2017) echo this sentiment by suggesting that electrical and electronic technology advancement within a country can have a positive impact on productivity in different sectors across its economy.

Meanwhile demand for capital falls in the electrical and electronic manufacturing as well as the other manufacturing industry. There is nonetheless an increase in demand for capital in services and agricultural sectors. This corresponds to a decline in the cost of labour relative to the cost of capital. Ultimately, there is an increase in output from the agricultural, other manufacturing, services and electrical and electronic manufacturing industry by 3.91%, 0.47%, 2.12% and 0.57% respectively. Not surprisingly, the value of real GDP increases but only slightly more than in scenario (1b) to 1.96% (see Table 23). This indicates that the total contribution of technology effects towards the GDP gain is 0.07%. Various studies have been conducted to determine the impact of technology transmission through traded commodities. In a related study, Das and Powell (2015) use a GTAP model with high sectoral aggregation and find that a 2% technology advancement in the United States of America results in a 0.06% gain in GDP in the Rest of the World region. Human capital, particularly skilled labour is an enabler to effective technology absorption, and this becomes an important factor in adopting foreign technologies in developing countries whose comparative advantage is human resources while their access to capital is highly limited. At this point, complementarity between labour and technology positively contributes towards increases in output. Other hand, unskilled labour plays an important role as a substitute for capital.

Table 23 also presents the impact of different policy scenarios on South Africa's trade balance as a percentage of world income. Being a small country relative to the Rest of the World, the values of South Africa's trade as a percentage of world trade are very small. The changes in trade balance range from -0.0027% under the standard at 50% tariff elimination to -0.0063% under policy scenario 2b, where a negative value indicates that increases in imports exceed increases in exports.

Table 23: Changes in GDP and trade balance

		Model closure/Policy scenario					
		Standard model		1. Unemployment & skills availability		2. Unemployment, skills availability and technology transfer	
		50% Tariff reduction	100% Tariff reduction	50% Tariff reduction	100% Tariff reduction	50% Tariff reduction	100% Tariff reduction
GDP price index (% change)	South Africa	-1.749	-1.807	-1.8518	-1.91135	-1.81498	-1.87451
	Rest of the World	-0.65998	-0.6600	-0.65953	-0.65956	-0.65981	-0.65983
Real GDP (% change)	South Africa	0.08445	0.0809	1.8669	1.894085	1.928547	1.96
	Rest of the World	0.1048315	0.104852	0.10476	0.104759	0.104748	0.104748
Trade balance (% change in world income)	South Africa	-0.00276	-0.00317	-0.005604	-0.006065	-0.005785	-0.00625
	Rest of the World	0.00276	0.00317	0.005604	0.006065	0.005785	0.00625

Source: Author's calculations based on model simulations.

Table 24 displays changes in skilled and unskilled labour as well as capital supply for agricultural activities (Agric), other manufacturing services (OtherMnfc), services and electrical and electronic manufacturing (ElecMnfc).

Table 24: Changes in factor supply

	Model closure/Policy scenario							
	Standard model (100% tariff reduction)				2b. Unemployment, skills availability and technology transfer			
Industry	Agric	OtherMnfc	Services	ElecMnfc	Agric	OtherMnfc	Services	ElecMnfc
UnSkLab (%change)	3.0617	-0.75354	0.054585	-3.17623	5.26	2.22	4.14	2.20
SkLab (% change)	3.052	-0.76685	0.035924	-3.19337	5.26	2.22	4.14	2.20
Capital (%) change	3.062	-0.75305	0.055284	-3.17559	3.28	-0.72	0.01	-1.59

Source: Author's calculations based on model simulations.

Results from this study suggest that the application of the protection policy framework to the electrical and electronic manufacturing industry may increase employment in other sectors of the economy while at the same time improving the country's GDP. The electrical and electronic manufacturing industry is relatively small in size when compared to sectors such as agriculture, services and other manufacturing, nonetheless, results show that its growth and development can have a significant impact on these other linked sectors and South Africa's economy as a whole. The next section summarises the impact of the various policy scenarios on South Africa's economy from a broader perspective of welfare changes.

6.4 Welfare decomposition

Welfare changes in South Africa's economy resulting from various study simulations are measured within the model using the *equivalent variation* (EV) metric. EV values in US$ terms indicate gains or losses in welfare after the implementation of the industry protection policy to South Africa's electrical and electronic manufacturing industry. Welfare decomposition captures how well off an economy becomes after a policy implementation. Hanslow (2000) expresses this as in part dependent on the impact of the policy change on national income, changes in prices and the purchasing power of the income. This section evaluates the allocative efficiency, technical efficiency, investment savings and endowment contributions towards South Africa's welfare changes. The results are indicated in Table 25.

Under the standard model at both 50% and 100% tariff reductions, welfare contributions from endowment effects and technology effects are non-existent for South Africa. Therefore, under this policy scenario, it comes down to allocative efficiency effects (the excess burden of taxes) and terms of trade effects as the sources of total welfare changes. The first column in Table 25 presents allocative efficiency effects. Allocative efficiency effects are known to result from perturbations to equilibrium for instance through import tariff removals. Allocative efficiency gains under this policy scenario are due to the removal of distorting taxes. The gains to an economy through tariff reductions and real exchange rate changes was explained earlier in this chapter. There are very small allocative efficiency gains of just under US$0.3 billion for South Africa under the standard model at both 50% and 100%. Investment-savings effects that result from changes in prices of domestically produced goods relative to the price of savings (in the global bank) are very small and positive at approximately US$0.03million and remain fairly constant at this value for the rest of the policy scenarios.

Table 25: Welfare decomposition under different policy scenarios

Policy scenario		Region	Allocative efficiency effects (US$ million)	Technology effects (US$ million)	Terms of Trade effects (US$ million)	Investment saving effects (US$ million)	Endowment effects (US$ million)	Total welfare effect (US$ million)
Standard model	50% tariff reduction	South Africa	295.46325	0	-725.1303	26.688917	0.00003	-402.978167
		Rest of the World	81625.8515	0	725.12707	-26.699677	-0.000272	82324.27869
		Total	81921.3148	0	-0.003296	-0.010759	-0.000241	81921.30052
	100% tariff reduction	South Africa	283.117401	0	-747.28894	29.700331	-0.000034	-434.471243
		Rest of the World	81626.11719	0	747.285583	-29.718317	-0.000213	82343.68424
		Total	81909.23459	0	-0.003357	-0.017986	-0.000247	81909.213
1. Unemployment & skills availability	50% tariff reduction	South Africa	2375.942627	0	-757.63104	28.047087	4155.942871	5802.301542
		Rest of the World	81582.82813	0	757.627747	-28.06757	0.000008	82312.38831
		Total	83958.77075	0	-0.003296	-0.020483	4155.942879	88114.68985
	100% tariff reduction	South Africa	2399.39379	0	-780.3505	31.082029	4227.45361	5877.579
		Rest of the World	81582.36719	0	780.34729	-31.103531	-0.000141	82331.61
		Total	83981.7609	0	-0.003296	-0.021502	4227.453472	88209.19
2. Unemployment, skills availability and technology	50% tariff reduction	South Africa	2441.5031	61.70622	-731.0896	27.997128	4244.2089	6044.3258
		Rest of the World	81573.9765	11668.24	731.086365	-28.019917	0.000152	93965,2831
		Total	84015.4797	11729.946	-0.003296	-0.022789	4244.2091	100009.609
	100% tariff reduction	South Africa	2464.954	61.70622	-753.80902	31.03206	4315.719	6119.602
		Rest of the World	81573.51	11668.24	753.805725	-31.0559	-0.00017	93964.4997
		Total	84038.46	11729.946	-0.003296	-0.02381	4315.719	100084.102

Source: Author's compilation based on model simulations.

However, terms of trade losses that are related to a drop in export prices (Table 22) impact negatively on total welfare under this policy scenario. This thesis models two regions. Therefore, one region's terms of trade (measuring export prices relative to import prices) losses equal its partner's terms of trade gains. Hence, a terms of trade total of zero for each policy scenario. There are adverse terms of trade effects for South Africa in all policy scenarios, however, these are offset by the large allocative efficiency gains and favourable endowment effects under the designed policy framework such that the country eventually experiences total welfare gains.

Policy scenario 1 shows much more significant gains in allocative efficiency with US$2.4 billion under policy scenario (1b). This policy scenario incorporates the unemployment closure under which allocative efficiency and endowment effects are the contributors to South Africa's welfare gains. Endowment effects result from the increase in supply (and demand) of skilled and unskilled labour with the direct effect of increasing productivity and output. Endowment effects account for improvements of US$4.2 billion towards total welfare gains. Because of the increase in supply of labour, there is reallocation of the factor to more productive sectors of the economy, leading to further gains in allocative efficiency. This accounts for approximately US$2.1 billion, that is, the difference between the value at policy scenario (1b) and the value under the standard model. In this case allocative efficiency gains are not only driven by tariff reductions but also by the increase in labour endowment.

Policy scenario 2 adds technology transfer to tariff reductions and the unemployment closure. Accordingly, technology effects are of major interest under this policy scenario. Technology effects are a result of changes in the productivity of workers. New imported technologies via inputs can result in an improvement in labour productivity hence increased output per worker. Additionally, efficiencies arise from the complementarity between imported technology and skilled labour. Under policy this scenario, technology effects are very small, represented by US$0.06 billion. Importation of foreign new technologies is modelled only through electrical and electronic inputs that constitute a small fraction of total trade hence the lower transmission rate of technology. However, it can still be argued that the sector linkages between the electrical and electronic manufacturing industry to other sectors of the economy should provide important domestic transmission routes of the imported technology. This can be used as motivation for South Africa to adopt more of the imported intermediate input embedded technology for research, development and production processes within the electrical and electronic manufacturing industry. Changes in allocative efficiency gains under policy scenario (2b) when compared to policy scenario (1b) are small. The difference is a US$0.065billion improvement under policy scenario (2b). The same applies to endowment effects with an incremental value of US$0.071billion while saving-investment effects remain almost unchanged. The last column in Table 25, representing total welfare effects, shows an improvement for South Africa from total welfare losses of approximately US$0.4 billion under the standard model to total welfare gains of approximately US$6.1 billion under policy scenario (2b). Allocative efficiency gains and favourable endowment effects are the two biggest contributors to South Africa's total welfare gains. Therefore, the results suggest that the proposed industry protection policy could positively contribute to South Africa's economic growth.

6.5 Establishing the effect of each model closure on export value

Table 26 identifies the impact of each isolated policy scenario on the value of exports from the electrical and electronic manufacturing industry.

Table 26: Comparing percentage change in export value under different policy scenarios

	Model closure/Policy scenario					
	Standard GTAP model closure		**1. Unemployment & skills availability**		**2. Unemployment, skills availability and technology transfer**	
	a. 50% tariff elimination	**b.** 100% tariff elimination	**a.** 50 % tariff elimination	**b.** 100% tariff elimination	**a.** 50 % tariff elimination	**b.** 100% tariff elimination
Percentage change in export value from the baseline scenario	15.49	16.74	16.68	17.94	20.09	21.36
Percentage change in export value from Standard GTAP model closure	_	_	1.19	1.121	4.60	4.62
Percentage change in export value from **1.** (Unemployment & skills availability)	_	_	_	_	3.41	3.42

Source: Author's calculations based on GTAP simulations.

It can be observed that the unemployment and technology transfer closure yields the largest change in export value from the baseline value. This summary of results reveals that the gain in export value is 21.36% under policy scenario (2b) and 16.74% under the standard model at 100% tariff elimination. The unemployment closure does not present any labour constraints, hence higher gains in export value could also be an indication of the level of significance of skilled labour in the electrical and electronic manufacturing industry, which is characterised by technological knowledge importation and medium to high technology products manufacturing. The next section examines the model's sensitivity to elasticity parameters and shock values.

6.6 Systematic Sensitivity Analysis

Associated with model simulations are parameters that may have a significant effect on the results obtained. According to Hertel (2012), simulation results are dependent on elasticities that are sometimes determined by the modeller. Sensitivity analysis is therefore adopted by a majority of CGE modellers to check for consistency of simulation results. In the same manner, this study conducted a systematic sensitivity analysis on elasticity values based on the Gaussian Quadrature.

In this study's sensitivity analysis, a variation of 50% was found to be adequate considering that the range of elasticity of substitution values borrowed from literature and discussed in this document, falls within 50% of the adopted value of 7.77. Table 27 shows the mean and standard deviation of each result as determined through systematic sensitivity analysis with respect to Armington's elasticity of substitution between imports and exports. These values were then subjected to Chebyshev's theorem. Chebyshev's theorem does not require any assumptions on the shape of the probability distribution of results corresponding to the variables (Burfisher, 2016).

Table 27: Confidence intervals at 50% variation of elasticity of substitution value 7.77

Confidence interval	Standard deviation multiplier	Standard deviation	Mean	Upper limit	Lower limit
75%	2	0.411988	17.638594	18.46257	16.814618
88.9%	3	0.411988	17.638594	18.874558	16.40263
95%	4.47	0.411988	17.638594	19.480180	15.7970076
99%	10	0.411988	17.638594	21.758474	13.518714

Source: Author's calculations based on model simulations.

According to the author, the equation for Chebyshev's theorem is given as:

$$\textit{Chebyshev's theorem result} = 1 - 1 / K^2 \quad (43)$$

for K>1

Where K is the standard deviation multiplier,

Where the upper and lower limits are computed as:

$$\textit{Upper limit} = X + sdK \quad (44)$$

$$\textit{Lower limit} = X - sdK \quad (45)$$

For *X* the mean, and *sd* the standard deviation.

Applying Chebyshev's theorem, we can be 75% confident that the results of the simulations under the range of elasticity parameters lie between 16.81 and 18.46. Similarly, we have 99% confidence that the results lie between 13.52 and 21.76. The results can therefore be said to be robust over the given range of elasticities, that is, from 3.885 (7.77 – 3.885) to 11.655 (7.77 + 3.885). Furthermore, the results suggest that it can be reported with 99% confidence that the tariff policy increases the value of exports from the electrical and electronic manufacturing industry. The sensitivity analysis is primarily to compare the variations in simulation results obtained at different elasticity parameter values.

In addition, repeated simulations at 7.77, 8.8 and 10.60 elasticity of substitution parameter values were computed. The results of the 50% tariff elimination experiment are indicated in Table 28. The deviations from a value of 16.098% at the adopted elasticity value of 7.77, were observed as 0.179% and 0.305% at elasticity values of 8.8 and 10.60 respectively. The observed deviations are quite low, thereby confirming the model's robustness over the adopted range of elasticity of substitution parameters.

Table 28: Simulation results at 50% tariff reduction under varying elasticity values

	Percentage change at 7.77 prm	Percentage change at 8.8 prm	Percentage change at 10.60 prm
Result at 50% tariff reduction only	16.098	16.277	16.582
Deviation of result from that obtained at adopted elasticity of substitution value of 7.77	0.00	0.179	0.305

Source: Author's calculations based on GTAP simulations.

Furthermore, systematic sensitivity analysis was carried out with respect to the tariff shock values. A systematic sensitivity analysis at 100% variation of the shock value was implemented and the results are given in Table 29.

Table 29: Sensitivity with respect to shocks at 100% variation of shock value

Confidence interval	Standard deviation multiplier	Standard deviation	Mean	Upper Limit	Lower Limit
75%	2	1.257521	17.638597	20.153639	15.123555
88.9%	3	1.257521	17.638597	21.41116	13.866034
95%	4.47	1.257521	17.638597	23.2597159	12.0174781
99%	10	1.257521	17.638597	30.213807	5.063387

Source: Author's calculations based on GTAP simulations.

Similarly, by applying Chebyshev's theorem to determine model sensitivity at 100% variation of the shock value, we can be 88.9% confident that the results obtained from the sensitivity analysis lie between 13.87 and 21.41%, over the given range of shock values.

6.7 Conclusion

This chapter presented the results from the model simulations for each policy scenario described under the thesis hypotheses. A comparison of the various policy scenarios was presented in tabular form. The comparative analysis approach provided a structured way of determining the impact of each isolated policy scenario on the value of exports. The impact of tariff reductions was presented, followed by the impact of each additional infant industry protection policy such that in-depth, overarching conclusions could be derived from the simulation results. Changes in other variables such as output, GDP, factor demand and prices were also explored. Policy changes have an impact on economic welfare and as such, welfare changes for South Africa were laid out. While some of the parameters such as the elasticity of substitution were determined by the modeller, an analysis of the sensitivity of the model to the elasticity parameters and shocks was carried out.

The integration of an infant industry protection framework into the international fragmentation system through imported international fragmentation-induced intermediate inputs led to an increase in export value from South Africa's electrical and electronic manufacturing industry. A generalised indication from the thesis results is that industry specific policies that are aimed at enhancing the survival and growth of vulnerable industries, in the context of African countries, can possibly yield positive results. A further examination of the results including their implications is presented in the next chapter.

Chapter 7: Discussion

7.1 Overview

This chapter focuses on the interpretation of results and the implication on the proposed policy framework, the electrical and electronic manufacturing industry and South Africa's economy. This study has revealed that tariff reductions on imported international fragmentation-induced intermediate inputs affect the value of exports from the electrical and electronic manufacturing industry in South Africa, under the assumptions of an infant industry protection framework. Results indicate that the initial partial removal of tariffs is more effective, with a 20.09% change from the baseline value whereas a complete elimination of tariffs results in only a further 1.27% change. Studies such as Mustafa (2020) and Panagariya (2011) reveal that the conventional applications of infant industry protection either fail or are highly costly and are therefore not suitable for application, particularly in developing countries. This perhaps highlights the mismatch between the conventional infant industry frameworks and contemporary global economic systems. This thesis attempted to bridge this gap by formulating an industry protection framework that allows for instant integration of a vulnerable industry into the prevailing international fragmentation system within high technology manufacturing industries. The rest of this chapter discusses results concerning the relationship between tariff reduction and export value, the industry specific policy framework, intermediate inputs as a source of knowledge, unemployment and skilled labour, the vulnerable industry and South Africa as a host country.

7.2 The relationship between tariff reduction and export value

The effect of tariff reductions on the value of exports from the electrical and electronic manufacturing industry was observed at three levels in the data analysis process. Firstly, the effect of tariff reduction without any further additional policy, secondly, the effect of tariff reduction in a scenario of high unemployment combined with the availability of skilled labour and lastly, the effect of tariff reduction in a scenario of high unemployment combined with the availability of skilled labour in the presence of technological information transfer. It is also generally anticipated that a tariff reduction on imported intermediate inputs should result in an increase in the volume of imported inputs because of the resulting lower purchase price of the inputs.

Results from the thesis revealed a 15.49% and 16.74% increase in the value of exports after the implementation of 50% and 100% tariff reductions, respectively, with no further policy application.

In comparison, a study by Feng et al. (2016) that observes tariff reductions only, on Chinese manufacturing firms across all sectors finds that only a 1% increase in the value of imported inputs boosted the value of exports by 1.6% over a period of approximately six years.

The implementation of tariff reductions under the unemployment and skilled labour policy scenario resulted in 16.68% and 17.94% increases in the value of exports, in response to 50% and 100% tariff cuts respectively. A combination of all policy scenarios including the transfer of technology through spillovers, resulted in an even higher increase in the value of exports. In this policy scenario, 50% and 100% tariff reductions resulted in a 20.09% and 21.36% increase in export value, respectively. The deliberation is that the infant industry protection framework significantly improves the value of exports when compared to just a tariff reduction. The value of exports increases by a further 4.60% to 4.62% indicating that the policies designed to assist the vulnerable industry might have played a very significant role. Such an increase could be attributed to increased productivity due to an abundance of skilled labour (matching the higher demand for labour from the industry) and the complementarity to some extent between skilled labour and the technologies that are embedded in the intermediate inputs. This is in consideration of studies such as Sunderland (2020) that highlight severely high skills shortages across South Africa's sectors. Kogan et al. (2021) confirm skills-technology complementarity in their study that demonstrates a positive association between technological improvements and labour productivity.

The increase in the value of exports could also be a result of improved productivity or firms adopting more varieties of intermediate inputs, thereby boosting their capability to produce and export more expensive differentiated products for specific foreign markets. Studies by Bas and Strauss-Kahn (2015) and Manova and Yu (2017) confirm this aspect of higher priced products because of more diversified inputs. Fan et al. (2018) indicate that more differentiated products due to access to more varieties of intermediates can result in firms manufacturing high valued products for exotic markets.

It is also valuable to note that because of the relatively small size of the electrical and electronic manufacturing industry in South Africa, a 21.36% change in export value at 100% tariff reduction represents US$0.673 billion change in export value. In comparison, the total value of exports from the electrical and electronic manufacturing industry represented approximately 3% of South Africa's total exports, that stood at approximately US$167.4 billion for the baseline year.

7.3 The industry specific policy framework

When a manufacturing industry is integrated into international fragmentation, it implies that its focus is on developing a cost-effective way of acquiring ready-made inputs, rather than producing such inputs on its own. This aspect is a lot more significant in industries that manufacture high technology products (Chen & Xing, 2022), such as the electrical and electronic manufacturing industry, because of the added role played by inputs as carriers of knowledge. According to Njike (2020), international fragmentation entails the segmentation of production processes, and it results in intensified global intermediate inputs trade. A cost-effective way of acquiring such inputs through the implementation of tariff reductions on international fragmentation-induced imported intermediate inputs was evaluated in this thesis.

Results from this thesis reflect a gain in export value corresponding to tariff reductions and an industry protection policy framework. Furthermore, results indicate an increase in output and a higher demand for labour and capital. Alongside a rise in demand for factors of production, results also indicate a drop in prices of goods from the electrical and electrical manufacturing industry. Lower prices of manufactured goods could help firms penetrate new foreign markets or improve sales volumes domestically. Integration into international fragmentation is therefore appealing to vulnerable industries in developing countries where the high cost and limited accessibility to inputs normally result in reduced productivity.

7.4 Intermediate inputs as a source of knowledge

The role of imported intermediate inputs as a source of technological information has already been discussed in Sections 2.5 and 2.6 of this thesis. High technology international fragmentation-induced intermediate inputs as a source of knowledge across regions and sectors have received attention from scholars in recent trade literature (Audretsch & Belitski, 2020; Bas & Strauss-Kahn, 2014; Feng et al., 2016; Fusacchia et al., 2021; Xu & Mao, 2018) and the consensus from these studies is that such inputs increase both total productivity and export performance from firms.

The difference between this thesis and the above-mentioned studies is that it applies the concept of knowledge transfer and spillover gains via imported international fragmentation-induced intermediate inputs in the context of a vulnerable industry in an African economy context. This thesis further incorporates the infant industry protection framework. The gain in export value, that is associated with technology transfer, was determined by calculating the difference in export value change between policy scenario 1b and policy scenario 2b. This incremental gain in the value of exports is approximately 3.4% (see Table 25) for the electrical and electronic manufacturing industry. More technologically advanced goods are expected to be produced by the electrical and electronic manufacturing industry because of technology spillovers. However, it can be argued that limiting factors such as capacity constraints could be hampering larger gains in export value from the industry. Nonetheless, other sectors of South Africa's economy that utilise products from the electrical and electronic manufacturing industry are likely to experience large gains due to improved technologies in such products.

Welfare decomposition (see Table 24) reveals positive technology effects under policy scenario 2 alone. The results indicate technology gains of approximately US$0.061 billion to South Africa. This is a further indication of the significance of intermediate inputs as a source of knowledge. Improved access to international fragmentation-induced intermediate inputs within the electrical and electronic manufacturing industry comes with the added advantage of access to input embedded technological information. The technology spillover effect should therefore be an extra incentive to implement policies that increase access to imported intermediate inputs while adopting policies that protect and promote the survival of a vulnerable industry within a developing country context. Firms within the vulnerable industry are then able to build information databases from such knowledge, thereby reducing commitment to the otherwise more expensive research and development facilities.

Associated with the importation of technological information is the need to have adequately skilled workers to facilitate the process of knowledge transfer and the building of databanks. Acemoglu (1998) highlights the relationship between technology and skills by stating that new technologies are inherently complementary to skills. It can be argued that skills and technology enhance the technological abilities of industries. Pandey et al. (2022) posit that enhancing the technological abilities of an economy goes beyond just access to technology: it involves enabling factors such as human capital. Most developing countries lack these factors, and the result is restricted absorption of modern technologies into such countries (Pandey et al., 2022; Pigato et al, 2020).

This thesis addressed this shortfall by prescribing a policy framework that improves the availability of adequately skilled labour for South Africa's electrical and electronic manufacturing industry. It therefore formulates an infant industry protection framework that requires industry in collaboration with the government, to facilitate skills training at institutions of higher learning. The next section discusses skilled labour in the context of knowledge transfer.

7.5 Unemployment and skilled labour

The availability of adequately skilled labour remains a huge challenge to high technology manufacturing industries such as the electrical and electronic manufacturing industry in developing countries. According to Sutherland (2020), South Africa has a shortage of skills in areas such as technology due to an underperforming education system. The implication of a lack of skilled labour is the possibility of failed protection policies that are targeted at high technology manufacturing industries. South Africa's electrical and electronic manufacturing industry will have to meet the increased demand for skilled labour if it is to expand and develop to global competitiveness. One of the conditions of infant industry protection in this study is government assistance to the manufacturing firms by providing adequate skilled labour through government sponsored training in industry and at institutions of higher learning. Under this assumption, model simulations 1a and 1b show approximately 1.19% and 1.12% more gains in export value when compared to the standard model simulation at 50% and 100% tariff reduction respectively. This disparity in export value reflects the significance of the availability of adequate labour and the required skillset in the production processes of the electrical and electronic manufacturing industry.

A look at welfare decomposition (Table 24) reveals that favourable endowment effects are experienced under both policy scenarios 1 and 2. Endowment gains of approximately US$4.2 billion are experienced under policy scenario 1b. This indicates the magnitude of the positive impact of adequate labour and skills on South Africa's economy. The study results confirm that an infant industry protection framework that is integrated into international fragmentation increases the value of exports and could possibly result in the growth, development, and survival of vulnerable firms in the electrical and electronic manufacturing industry in South Africa. The results also indicate that the policy framework positively impacts South Africa's economy. The following section further focuses on the significance of the thesis results to the vulnerable industry.

7.6 Implications of results to the vulnerable industry

The primary objective of this thesis was to formulate a set of policy strategies that can be applied to enhance the survival, growth and development of the electrical and electronic manufacturing industry in South Africa. While the results of this research widely reflect a positive impact of the policy strategies on the industry, its continued survival and growth is dependent on the government's continued implementation of this strategy until it reaches growth levels that sustain long term survival of its firms.

The model adopted in this study is a static analytical tool hence it does not project the continuous performance of the industry over an extended period, for instance, 10 years. Instead, it presents a snapshot of the simulation projection at a point in time. Continued investment in production processes through continued adaptation of newer technologies therefore remains of paramount importance to continued export growth and development of firms, particularly in the highly dynamic high technology industries in developing countries.

The adoption of international fragmentation-induced imported intermediate inputs has implications for the creation of research and development facilities domestically. The imported intermediate inputs are infused with advanced technologies (Gilles et al., 2023) hence South Africa's electrical and electronic manufacturing firms can reduce or eliminate the need to develop their own research and development facilities pertaining to such technologies, contingent on the availability of skilled labour. Because the protection framework designed in this thesis entails coordination between government and industry in skills training programmes, it arguably becomes less costly for firms to acquire the necessary skilled labour. As a result, firms that benefit from technology spillovers and learning effects are expected to keep up with advanced technologies as well as catch up to global production standards within the same industry. Such developments within firms are in turn expected to impact positively on the economic welfare of the country. The next section, therefore, reviews thesis results concerning the host country.

7.7 Implications of results to the host country

Successful implementation of policies aimed at enhancing the survival and growth of vulnerable industries is expected to boost national economic growth and development. Studies on infant industry protection (Alexender & Keay, 2018; Harris et al., 2015) define the rationale behind the policy as a national drive by the implementing countries to improve economic welfare. Governments tend to implement various economic growth policies depending on the availability of resources, such as primary factor endowments, and in addition, the political will to adopt such policies. Results from this study suggest decent gains in export value under the assumed set of policy scenarios. However, it remains critical that the proposed policies are feasible for the government to execute, based on both its political and economic environment. For instance, South Africa has a high unemployment rate of 34.5% (StatsSA, 2022) while the availability of skilled labour for high technology industries such as the electrical and electronic manufacturing industry remains low (Sutherland, 2020). To take advantage of the abundance of human resources, South Africa would benefit from industry specific skills training programs that not only reduce unemployment but also increase the skills base within the labour force. This would then create a match between the labour force skills capabilities and the industry skills requirements.

Results from this thesis further display changes in real GDP and trade balance after implementation of the designed policy framework (see Table 22). The percentage change in real GDP for South Africa ranges from 0.08 % under the standard model to 1.96% under policy scenario (2b). Change in trade balance, calculated as a percentage change in world income, is -0.0063% under policy scenario (2b), signalling South Africa's relatively small size in the global economy. To further probe the economy wide impact of the industry protection framework, welfare changes were analysed in terms of the equivalent variation metric (see Table 15.4). Results indicate total welfare gains after implementation of the protection policy framework. A closer examination of welfare decomposition reveals that terms of trade losses are very small when compared to the favourable allocative efficiency, technology and endowment effects. The overall result is a shift from total welfare losses of approximately US$0.402 billion under the standard model conditions to total welfare gains of approximately US$0.061 billion for South Africa after the implementation of the industry protection framework.

This thesis therefore motivates a policy scenario where industry specific skills training is implemented to transform the already abundant human capital into the adequately skilled labour force required for the electrical and electronic manufacturing industry in South Africa. At a national level, this has the effect of reducing unemployment. This is reflected through an increase in demand for labour by the electrical and electronic manufacturing industry (see Table 21). In the long run, the growth and development of the vulnerable industry is expected to enhance national economic growth, for instance, by positively contributing to total national output and improving modern technology application in other interlinked sectors of the economy.

7.8 Robustness and reliability

To test for the robustness of the model and reliability of results against elasticity parameters, simulations were repeated at two different parameter values (8.8 and 10.60) in addition to the adopted parameter value of 7.7. Furthermore, a systematic sensitivity analysis study on the elasticity of substitution parameters and shock values was performed, with results indicating that the model was robust under the study specifications.

7.9 Conclusion

This thesis focused on formulating an infant industry protection framework that is integrated into the international fragmentation system and evaluating its impact on the value of exports from South Africa's electrical and electronic manufacturing industry. To operationalise this, the effect of imported international fragmentation-induced intermediate inputs tariff reduction on the value of exports from the electrical and electronic manufacturing industry was determined, under an infant industry protection policy framework. As such, this chapter discussed the results obtained and their implication on various aspects of the protection framework. A major focus was placed on the relationship between tariff reduction and export value, the industry specific policy framework, intermediate inputs as a source of knowledge, unemployment and skilled labour, the vulnerable industry, the host country and methods of verifying the robustness of study results. The tariff reductions and unemployment closure combined with technology spillover effects were found to more than triple the impact of tariff reductions alone, on the value of exports from the electrical and electronic manufacturing industry. Both hypotheses (H1) and (H2) were supported, indicating that the formulated integration-protection framework significantly increased the value of exports while the technology transfer and the resulting spillover effects further enhanced the increase in export value. Two fundamental aspects in this thesis, that is, the designed novel integration-protection framework and the effectiveness of the framework are explained in the two following paragraphs, successively.

While the conventional mechanisms of infant industry protection application have at times been discredited as costly, anti-trade (Panagariya, 2011) and hence described as unfit for implementation, the need for support and protection structures on nascent vulnerable firms, particularly in African economies has remained a permanent feature. The integration-protection framework designed in this thesis bridges the gap between these two themes. The underlying principle in the protection framework in this thesis is industry adaptation to the contemporary global wave of production, trade and technological processes (represented by international fragmentation) with assistance from the state. The uniqueness of this integration-protection framework is that the integration of the target industry into the international fragmentation system is instantaneous, a huge contrast to the conventional theme of industry protection. To facilitate the global integration of firms, the main attributes of international fragmentation systems such as advanced technologies, new research and development products from advanced economies, and uninterrupted access to global markets form a part of the integration-protection framework. With imported international fragmentation-induced intermediate inputs playing the central role in the integration process, the gradual elimination of tariffs on these inputs resulted in an increase in the value of exports, albeit at a decreasing rate. The initial 50% tariff elimination resulted in a higher increase in the value of exports when compared to the second 50% regime, suggesting further studies in the evaluation of the designed protection framework. However, the initial conclusion from these results was that capacity constraints could be responsible for the subdued increase after the second 50% tariff reduction was applied.

The effectiveness of the designed integration-protection framework was determined by, in addition to the assumed stable political and economic environment, the value of exports from the electrical and electronic manufacturing industry and other variables, such as GDP and output prices that relate to South Africa's economy. The improved export value under the combined effects of increased labour availability and technology spillovers was an indication of the positive effect of the protection framework on the targeted industry. In addition, the increase in output, demand for labour and a decline in prices were evidence of increased activity within the electrical and electronic manufacturing industry. However, a positive effect on the target industry alone may not be sufficient to justify the implementation of a policy, hence, an evaluation of the impact of the policy on the wider economy was carried out. The gain in GDP, an improvement in trade balance and cross-sector increases in demand for labour indicated a rise in activity hence highlighting the positive effect of the integration-protection framework on South Africa's economy. This confirms the theme throughout this thesis, that is, a policy that positively impacts the electrical and electronic manufacturing industry should have positive ripple effects across other sectors of South Africa's economy. The next chapter concludes the thesis.

Chapter 8: Conclusion

8.1 Overview

Infant industry protection has been a subject of discussion for a significantly long period in trade literature. The theoretical basis and mechanism of application of infant industry protection have traditionally been biased towards the imposition of high tariffs or even complete bans on imported goods, at the same time attempting to build large facilities, such as research and development centres for the targeted vulnerable domestic industry (Alleyne et al., 2022). However, such combinations of protection policies that create barriers to trade eventually result in the isolation of the vulnerable industry from global trade networks.

Other policies that traditionally constitute the infant industry protection framework include government intervention programmes such as subsidies (Clarke & Rosales, 2022) over long periods: that at times never end. The protection policy has been characterised by excessively high costs to governments, domestic firms and consumers (Panagariya, 2011). The high costs have generally rendered the infant industry protection policy framework too expensive to implement in developing countries with limited resources and low economic growth. On the other hand, global trade has evolved over the years with the advent of international fragmentation and much more complex global networks, rendering the application of the traditional infant industry protection framework even more complicated to implement, particularly in highly dynamic medium to high technology industries in African countries.

The purpose of this study was to formulate a policy framework that enhances the survival and growth of vulnerable industries in African countries, at the same time utilising the benefits of international fragmentation. The study, therefore, proposed an infant industry protection framework that is integrated into international fragmentation using imported international fragmentation-induced intermediate inputs as the nexus of the protection strategy. The industry of focus was the electrical and electronic manufacturing industry in South Africa. Section 2.3.2 of this thesis discussed the categorisation of this industry as an infant industry, based on its performance and competitiveness that are below global standards and behind its peers in the so-called emerging markets.

Different policy instruments, representing the industry protection framework were implemented and the impact of each policy instrument on the value of exports from the electrical and electronic manufacturing industry was evaluated. While the results confirmed the study hypotheses, the success of the policy prescription and survival of the vulnerable industry balances on the consistency of policy execution by the government. There are previous studies (see Chapter Two) in the literature that relate to infant industry protection, however, this study is unique in a few ways. Firstly, it proposed the integration of an infant industry protection framework into the international fragmentation system. Secondly, it adopted international fragmentation-induced intermediate inputs as the focal point of the integration process and designed a unique set of complementary protection policies that befit the electrical and electronic manufacturing industry in South Africa. Thirdly, the study emphasised the mere survival of a vulnerable industry, rather than a dominance motive, within an African economy. Subsequently, this study placed emphasis on a relatively less costly infant industry protection framework, particularly when compared to the conventional approach of infant industry protection. Finally, the study characterised South Africa's electrical and electronic manufacturing industry as deserving assistance to enhance its survival, growth and contribution to the country's economic growth. The following sections highlight some key aspects and findings of the thesis.

8.2 Research design and methodology

This study involves policy formulation and policy analysis; hence it was desirable to adopt computable general equilibrium that incorporates economy wide interactions in policy analysis. The GTAP model using the MRIO version of the GTAP 10 database was adopted. The GTAP model is not a black box, hence data preparation and modifications were carried out. The GTAP 10 MRIO database was adopted because of its extra capability to identify tariffs and intermediate imports by agent (Carrico, 2017; Carrico et al., 2020). Operationalisation of the infant industry protection policy framework on the GTAP model was based on industry specific properties such as the requirement for skilled labour, that were drawn up by the modeller, hence the uniqueness of the research study. As with any other modelling experiments, the reliability of results was ascertained through sensitivity analysis.

8.3 The research questions and hypotheses

To implement the proposed framework for the protection of the vulnerable industry, a set of questions and study hypotheses were formulated. The main study question explored the impact of an infant industry protection policy framework in the backdrop of international fragmentation-induced intermediate inputs, on the value of exports from electrical and electronic manufacturers in South Africa. Sub question (1) focused on the effect of imported intermediate inputs tariff reduction on the value of electrical and electronic firms' export flows, within an infant industry framework. Sub question (2) was concerned with the effect of imported intermediate input embedded technology transfer on the relationship between imported intermediate inputs tariff reduction and the value of electrical and electronic firms' export flows, within an infant industry framework.

Following on the two research sub questions, hypotheses were presented. Hypothesis (H1): Elimination of import tariffs on international fragmentation-induced intermediate inputs positively impacts the value of the electrical and electronic manufacturing firms' export flows within an infant industry protection framework. Hypothesis (H2): Technology transfer through intermediate inputs enhances the positive effect of imported international fragmentation-induced intermediate inputs tariff reduction, on the value of the electrical and electronic manufacturing firms' export flows within an infant industry protection framework.

8.4 Research findings

In carrying out the model simulations, tariff reduction was gradual, that is, a 50% tariff reduction was followed by a 100% tariff reduction. The study results indicated an increase in export value following 50% and 100% tariff reductions. A maximum of 17.94% gain in export value was obtained under policy scenario 1, hence confirming study hypothesis (H1). A similar regime of tariff reductions on a model that incorporates technology transfer yielded a slightly higher increase in the value of exports compared to results obtained under policy scenario 1. A maximum of 21.36% gain in export value was obtained under policy scenario 2. This result confirmed study hypothesis (H2). The set of results further confirmed that tariff reductions alone may not be adequate to sustain the survival, growth and development of the vulnerable firms within the industry. However, tariff reductions under the infant industry protection policy framework significantly raise gains in the value of exports, to levels that would arguably boost the survival, growth and development prospects of the vulnerable firms within the electrical and electronic manufacturing industry in South Africa. This suggests feasibility and sustainability of the designed protection policy framework.

In addition to its positive effect on the value of exports from the electrical and electronic manufacturing industry, the protection framework presented a variety of economic impacts on South Africa. Findings on the overall economic impact on South Africa indicate GDP and total welfare gains of up to 1.96% and US$0.061 billion under policy scenario 2b. Total welfare decomposition further reveals that favourable allocative efficiency, endowment and technology effects contribute the most to welfare gains. This arguably highlights the propitiousness of the policy framework in the sense that any costs that are associated with policy implementation can easily be offset by gains from policy implementation. In summary, adoption of the proposed policy framework increases the value of exports from the electrical and electronic manufacturing industry at the same time improving national welfare.

8.5 Study contributions based on results obtained

Theoretical, practical and methodological contributions are drawn based on the findings from this study. The infant industry protection theory has been fairly discussed over the past decades. Nonetheless, the modern evolution of global trade and production networks, particularly in medium to high technology industries, necessitates a re-evaluation of both the theory and mechanism of application of infant industry protection. This study was motivated by the apparent need to align infant industry protection with international fragmentation using a cost-effective mechanism of application that is feasible under resource constrained African countries. Study contributions are discussed in the following sections.

8.5.1 Theoretical contribution

The infant industry protection framework in its most common forms has been known to negatively impact the industries that it is supposed to protect. Scholars such as Lane (2020), Lin and Chang (2009) and Wu (2019) have claimed that the mechanism of infant industry application can only be antagonistic to global integration, thereby stifling the targeted industries. The claims are aligned with Hamilton (1791), in his campaign for the use of taxes and quantity restrictions on imports. Nonetheless, Hamilton (1791) also motivated for promotion of capitalisation and development as well as the transfer of labour resources from other industries to the specific disadvantaged vulnerable firms. The infant industry protection framework has also been characterised by an initial isolation of the target industry from global trade for a period that is normally determined by the government, based on the rate of the industry’s catch-up progress (Cheng et al., 2019).

This study fills a gap in that the modelled protection framework does not require an initial phase of isolation from global trade. In this regard, the study contributions based on the infant industry protection framework that is integrated into international fragmentation, as well as the mere survival aspect that is in tandem with a low-cost framework are discussed in the following sections.

An infant industry protection framework premised on international fragmentation-induced inputs: This study contributes to theory by exploring a dimension under which higher exports can be obtained under infant industry conditions that allow for integration into international fragmentation, combined with policy conditions that allow for enhanced government support through technical skills training. The policies that constitute an infant industry protection framework are ordinarily initiated and implemented by the government, contingent on resources available to implement the policies. Theoretically, infant industry protection has been characterised as too costly for African countries.

In extending theory, this study characterises integration into international fragmentation as a primary feature of infant industry protection, combined with government policies that enhance the survival of a vulnerable industry. This approach to infant industry protection deviates from the traditional infant industry protection policies that impose high tariffs or quotas as the major underlying principle. Integration of the vulnerable industry into international fragmentation facilitates instantaneous exchange processes that result in the development and improvement of industries and manpower in the concerned country. This again varies from the conventional infant industry application approach which according to Hamilton (1791) and List (1841) would result in the initial isolation of the vulnerable industry from global trade for a period.

With the insurgence of much more complex global networks with various important interlinkages in both production and trade in different regions over the past decades, it has become important to formulate industry protection strategies that align with global trends. This aspect is particularly significant in high technology areas of an economy, such as the electrical and electronic manufacturing industry where continuous technological improvements render the industry highly competitive and dynamic. This study contributes by emphasising integration into international fragmentation as the focal point of activities that are aimed at infant industry protection. The integration strategy outlined in this thesis can be considered less costly from a developing country’s perspective. This is mainly due to the improved importation of foreign technologies that in turn lead to a reduction or elimination of investment costs in research and development facilities and certain areas of specialised skilled labour. The less costly the infant industry protection framework, the higher the likelihood of success of the applied protection framework. Such low-cost infant industry protection strategies can then be applied more frequently in resource constrained African countries, leading to accelerated growth and development of the concerned economies.

Mere survival of the firms: As reiterated in this document, most infant industry protection policies are considered not viable (particularly in poor countries) due to the high cost associated with such protection policies. Such costs include high capital costs associated with expensive research and development facilities or high import tariffs (or complete bans) on imports. These result in higher production costs to manufacturing firms while domestic consumers are negatively affected. The highly costly protection strategies are however possible in adequately resourced advanced nations where the gains from infant industry protection are expected to be sufficiently large, to offset the high costs of industry protection. The motive behind infant industry protection in these developed countries often translates to keeping the industries abreast competitively and attaining the global market leader status.

On the contrary, infant industry protection in developing countries such as South Africa can be viewed in a rather different way. Firstly, the governments in developing countries are less likely to afford the conventional costly infant industry protection policies. This means that they would rather adopt less costly protection policies such as the industry protection strategy already described in this thesis, that is, the integration of a protection framework into international fragmentation. This integration-protection approach maximises learning opportunities and survival prospects of the vulnerable industry at a low cost of protection. If the infant industry protection policy can be applied without disruption of global supply chains and without isolating the target industry from global trade, then it becomes an important alternative for development and industrialisation in developing countries. Secondly, the primary motive of infant industry protection in developing countries is the mere survival of such industries, as opposed to instantly creating industry leaders requiring to stay abreast of competition. It can be argued that low gains or low returns from the protection policy can still be sufficient to sustain the mere survival of vulnerable industries in developing countries. Yu et al. (2022) also confirm that the survival and technological progress of some industries in countries such as China has hugely relied on keeping up with global technological advancements through imitation, however, such progress does not guarantee global dominance.

8.5.2 Practical contribution

Findings from the study indicate that the formulated novel set of policy prescriptions can potentially enhance the survival of nascent vulnerable high technology manufacturing firms in African economies. This study does not formulate an all-encompassing protection framework, rather, it specifically provides a tailor-made intervention strategy for the electrical and electronic manufacturing industry in South Africa. However, it is vital to note that because of structural similarities of the economies of most African countries, such a strategy may easily be adopted in similar countries within the region.

Results from the study reveal that the use of imported international fragmentation-induced intermediate inputs as the nexus of the configuration between infant industry protection and international fragmentation yields positive results with respect to export flows. This, therefore, serves as a point of reference in relation to the application of such or related policies within the developing country context. One of the important characteristics of an infant industry is that it must possess the potential to grow and develop into an even bigger industry in the future by adopting resources or capabilities that are inappropriately applied (Andreoni & Chang, 2019). While an infant industry in its initial stages of growth typically contributes less to a country's GDP, an adequately protected infant industry later develops to contribute significantly more to economic growth. Resultantly, the maturity of infant industries is a potential stimulus for increased employment creation and improved overall economic performance. In the long run, the protection framework proposed in this thesis goes beyond just nurturing a vulnerable industry: it facilitates national economic development. This aspect is confirmed by results from this study, which indicate an increase in the value of exports and demand for labour from the electrical and electronic manufacturing industry as well as an improvement in total welfare for South Africa.

This study further contends that South Africa's electrical and electronic industry is an infant industry that has the potential to grow and develop under the proposed protection framework. While the vulnerability of the industry has been argued in this thesis, study results such as favourable technology effects and a rise in demand for capital and skilled labour are some of the fundamental ingredients required to spur industry growth. This suggests that growth and development of the electrical and electronic manufacturing industry could be realised in the long run if the proposed protection strategy is consistently applied.

8.5.3 Methodological contribution

In response to Kehoe et al. (2017) who argue that the use of computable general equilibrium models in academic research is generally subdued, this research contributes through the use of the GTAP (MRIO version) model in integrating an infant industry protection framework concept into international fragmentation within an African country context. This is achieved by adopting international fragmentation-induced intermediate inputs.

The focus is on South Africa's electrical and electronic manufacturing industry. The industry is highly dynamic because of the general continuous advancement in global technological knowledge, exemplified by the 4th industrial revolution (Tampubolon & Nababan, 2022) combined with complex international fragmentation systems that characterise modern global trade patterns (Mondal, 2023). It can be argued that analysis of more complex global trade systems requires more accurate analysis tools. Accordingly, Carrico et al. (2020) suggest that the continuing intensification of global economic integrations necessitates the adoption of more advanced databases to adequately cater for the complex cross region trade interlinkages. While some previous studies in international trade have adopted the standard GTAP database (Antimiani et al., 2018; Fusacchia, 2020; Ofa & Karingi, 2014), this study adopts the GTAP MRIO version of the database. When compared to the standard GTAP 10 database, the GTAP 10 MRIO database more accurately allocates intermediate imports by source and destination while further untangling the globally interlinked production systems (Itakura, 2019).

8.6 Policy implications and recommendations

Drawing from the results and conclusions of this study, this section makes recommendations to policymakers, industry, and relevant trade negotiating bodies concerning the application of the industry protection policy framework that is integrated into international fragmentation.

One of the major aspects from the thesis is the role played by human capital in increasing productivity, output and economic development in a country. South Africa has significant human resources as reflected in its high unemployment rate. However, the economy is more capital intensive and less labour intensive, such that the increased use of capital in place of labour in production sectors might be contributing to the high unemployment rate. Results from this study show that it is possible to attain higher productivity in certain sectors by replacing capital with labour, for instance in the electrical and electronic manufacturing industry. Since the abundance of human capital is a comparative advantage for the country, higher economic growth and lower unemployment rates could be attained by shifting towards a more labour intensive approach. While global technological advancement mostly comes with substitution of labour with capital, such capital always comes at higher cost than adopting labour. This concept can be generalised to most African countries that have in recent years focused on policies that are biased towards capital intensive production systems at the expense of the abundant human capital. Rather, focus should be directed towards improving the skills base within the labour force through industry specific training.

The general argument throughout this thesis is that an integration of infant industry protection into international fragmentation through the adoption of international fragmentation-induced intermediate inputs is fundamental to the growth of South Africa's electrical and electronic manufacturing industry. The results obtained widely support this theme. An initial 50% tariff reduction resulted in a 20.09% rise in the value of exports from the electrical and electronic manufacturing industry whereas a further 50% tariff cut contributed an additional 1.27% gain in the value of exports. This means that the initial 50% tariff reduction is more effective in improving the value of exports when compared to complete tariff elimination. However, the above results further suggest that the production capacity of the industry could possibly be a major constraint as tariff reductions render imported intermediate inputs more accessible. Accordingly, the recommendation in this respect, is the adoption of a firm expansion or capitalisation strategy that expands operations and allows for higher production capacities to complement the increased accessibility to imported intermediate inputs.

In terms of the tariff elimination strategy, the recommendation to policymakers is, therefore, a gradual tariff elimination policy, where the initial phase is a 50% tariff reduction before a complete elimination of the tariffs can be implemented. This approach maintains the government's equally important source of revenue in the form of tariffs, for an extended time. While the tariff reduction process has generally been taking place in South Africa dating back to the 1990s, this process has apparently not been swift enough, prompting the World Bank (2018) to highlight the country's weak integration into global value chains and its failure to catch up with peer economies. This can be said to be true concerning the electrical and electronic manufacturing industry's tariffs on imported intermediate inputs.

This study formulates a policy framework that is contingent on the availability of technological knowledge and human capital to facilitate the transfer of knowledge. The policy framework is based on the adoption of technologies, prioritising human capital and integration of firms into international fragmentation systems. Fundamental aspects that can be drawn from this framework are:

(a) Improving access to international fragmentation-induced imported intermediate inputs, thereby reducing the vulnerable industry's cost of production and cost of protection.
(b) Improved access to the imported inputs is expected to generate beneficial linkages within the global supply chain.

(c) Technology spillovers from the knowledge that is embedded in intermediate imports can be experienced if accessibility to such imports is improved.
(d) Knowledge acquired through imported products, and of course other channels such as journals, means a reduction (or complete elimination) of costs that are associated with expensive high technology research and development facilities.
(e) The need for labour (skilled and unskilled) to support the growth and development of the vulnerable industry.
(f) The specific requirement for skilled labour to process, adopt, accumulate and disseminate domestically, the technological information that is embedded in the imported inputs.

With regards to skilled labour and foreign technology absorption, an industry led, government sponsored skills training programme is recommended. Several scholars emphasise the importance of technology in economic development. For instance, Sultanuzzaman et al. (2019) evaluate technology spillovers in emerging Asian economies and conclude that economic growth in these countries can be augmented by applying policies that intensify the improvement of technology and trade. A programme in which the electrical and electronic manufacturing industry assumes prime mandate in the design, control and implementation of industry-based skills training is anticipated to smoothly promote the diffusion of imported technology into the domestic industry. An on-the-job training programme where the electrical and electronic industry guides the government on the structure of the scheme has the advantage of creating a perfect fit between the labour force's skills capabilities and the industry's skills demands. This contrasts with current government led training programmes such as the Sector Education and Training Authority (SETA). According to Franz et al. (2022), SETA has so far failed to alleviate skills shortages in the manufacturing industry.

Although the government of South Africa introduced the Skills Development Act (1988) which includes programmes such as SETA, to address skills shortages in the country, the shortage of skills remains very high (De Lannoy et al., 2018). The authors bemoan a lack of an effective way to predict skills that are required by firms as the cause of persistent skills shortages. Some studies have revealed shortcomings of programmes such as SETA. For instance, Franz et al. (2022) claim that too few companies participate in workplace training programmes. Only 15% of registered companies contribute levies and are members of SETA while only approximately 7% of these adopt the grant process of taking learners and accepting financial support for the training program (Franz et al., 2022; National Skills Authority, 2019). The above studies reveal the inadequacy of the current skills enhancing programmes and this could be negatively impacting the survival and growth of electrical and electronic manufacturing firms in South Africa.

Furthermore, the above studies show that it is mostly big companies that tend to engage in the SETA skills program. A majority of the prominent electrical and electronic manufacturing firms are relatively small (less than 500 employees, see Table 3), and this raises questions about their involvement in the existing skills training programs. Therefore, it can be argued that the existing structure of skills training falls short in assisting firms in the electrical and electronic manufacturing industry.

The recommendation to the industry is that in addition to firms undertaking the lead in skills training, such firms should be able to apply techniques and protocols that allow them to learn from the technology that is embedded in the imported intermediate inputs. This means that the skills training must be relevant to contemporary industry skillset requirements. Learning allows for the transfer of knowledge from the exporting countries to South Africa's electrical and electronic manufacturing industry. This learning effect is a fundamental aspect in making infant industry protection less costly to the implementing country. Studies such as Melitz (2003) have also shown that learning effects are fundamental to the transfer of information. As a result of the efficient transfer of knowledge from imports and the successful set up of knowledge banks, the number of skilled employees, the skill level and the cost of creating such a labour force (from both the industry and the government perspective) may be significantly reduced.

8.7 Study Limitations

This study was carried out at industry level aggregation therefore the mechanics of individual firms were discounted, for instance, the exact characterisation of imported intermediate inputs profile by specific exporting firms were not considered. A firm level study that provides a broader picture of the dynamics within firms that are actively engaged in exporting uncovers more policy related information. As an illustration, identification of specific quantities and types of intermediate inputs that are utilised by specific categories of firms (e.g., large and small firms or manufacturers of critical equipment and manufacturers of general electronic products) is necessary in establishing priority and critical intermediate inputs within the industry. It then becomes easier to identify source regions that could be prioritised in any bilateral agreements concerning such intermediate imports.

8.8 Further studies

A further study that incorporates and analyses South Africa's electrical and electronic manufacturing industry's intermediate inputs by source country could be done to ascertain the profile of intermediate inputs by source region. Different regions tend to provide different qualities and varieties of intermediate inputs. Bilateral trade policies may then be formulated based on more detailed trade profiles per source region of imports. Furthermore, a dynamic computable general equilibrium model could be adopted to approximate the effectiveness of the protection framework over various selected timeframes.

8.9 Conclusion

This research investigated the theoretical basis of the infant industry theory, its mechanism of application over the past years, the context of its application as well as its relevance in both developed and developing countries. The research formulated a policy strategy that attempts to enhance survival prospects besides inducing higher productivity within the electrical and electronic manufacturing industry, hence improving its contribution to South Africa's economic growth. Also highlighted in the thesis is the continuous evolution of global trade with respect to the advent of international fragmentation processes. This thesis then discussed the proposed integration of the infant industry protection framework into the dynamic, high technology based international fragmentation system. The integration is illustrated through the electrical and electronic manufacturing industry in South Africa.

As previously acknowledged in this thesis, infant industry protection mechanisms have traditionally been applied in an approach that initially isolates the vulnerable industry from global networks. This study designed a strategy that assists in the growth and development of vulnerable industries, at the same time improving their engagement with global trade and production systems from the onset of the protection strategy. The rationale behind this strategy is that global trade has become more complex in recent years, because of production systems that can be spread across borders. While the adoption of the protection strategy may be generalised across African countries, it is imperative to state that each infant industry protection framework should be adopted with caution, mainly because different industries in different economies require tailor made intervention strategies that may not necessarily apply in other countries. For instance, skilled labour and advanced research and development facilities have been known to be key in high technology manufacturing industries, however, different countries may have significant capital endowment and trade and labour policy differences. The study results reveal that the survival of a vulnerable industry can be achieved through a policy framework that does not antagonise the contemporary, dominant, modern international fragmentation system.

The results also indicate that with industry specific policies, an infant industry protection framework that is integrated into international fragmentation may provide a low-cost avenue for the growth and development of vulnerable industries in African economies. The gains from such a framework may not immediately lead to global dominance, nonetheless, the vulnerable industries can be guaranteed survival in the long run. Vulnerable industries in developing countries would require a phase where survival and stability can be sustained and maintained before any endeavours into global dominance can be instituted. At the same time, a focus on labour intensive production reduces unemployment.

The study demonstrated that a vulnerable industry such as the electrical and electronic manufacturing industry in South Africa, does not necessarily require highly costly infrastructure for research and development, but can instead acquire the imported intermediate input-embedded technological information to enhance its survival, within an infant industry protection framework. Nevertheless, minimal structural requirements must be met to be able to absorb and utilise the imported technological information. Such minimum requirements would mostly refer to the general features that firms require to enter the industry in the first place. The adoption of imported technological information to facilitate industry growth and survival can be generalised with respect to high technology manufacturing industries within African economies, where constraints in critical resources such as skilled labour and capital persist. The adoption of foreign technologies is expected to increase productivity and growth while stimulating further investments in innovation within domestic firms. Ultimately, the applied industry protection framework can induce total welfare gains for the host country.

References

Abboushi, S. (2010). Trade protectionism: Reasons and outcomes. *Competitiveness Review: An International Business Journal incorporating Journal of Global Competitiveness, 20*, 384-394. https://doi.org/10.1108/10595421011080760

Abou Hamia, M. A. (2022). What level of international technology should developing countries transfer to sustain their economic growth? *Quality & Quantity*, 1-23. https://doi.org/10.1007/s11135-021-01259-8

Acemoglu, D. (1998). Why do new technologies complement skills? Directed technical change and wage inequality. *The Quarterly Journal of Economics, 11*3(4), 1055-1089. http://www.jstor.org/stable/2586974

Adams, P.D. (2005). Interpretation of results from CGE models such as GTAP. *Journal of Policy Modeling*, *27*(8), 941-959. https://doi.10.1016/j.jpolmod.2005.06.002

African Development Bank Group. (2019). Unlocking the potential of the fourth industrial revolution in Africa. African Development Bank. Korea-Africa Economic Cooperation. www.afdb.org

Aguiar, A. (2013). *GDP consistency in GTAP 8.* Center for Global Trade Analysis, Purdue University, Purdue University. http://www.gtap.agecon.purdue.edu/resources/res display.asp?RecordID=4290

Aguiar, A. (2020). *Updating GMig2 to GTAP 10*. Center for Global Trade Analysis Project, Purdue University. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6006

Aguiar, A., Chepeliev, M., Corong, E., McDougall, R., & Van der Mensbrugghe, D. (2019). The GTAP Data Base: Version 10. *Journal of Global Economic Analysis, 4*(1), 1-27. doi:10.21642/JGEA.040101AF.

Aguiar, A., Narayanan, B., & McDougall, R. (2016). An overview of the GTAP 9 database. *Journal of Global Economic Analysis, 1*(1), 181-208. doi:10.21642/JGEA.010103AF.

Ahmad, F., Draz, M.U., & Yang, S-C. (2018). Causality nexus of exports, FDI and economic growth of the ASEAN5 economies: evidence from panel data analysis. *The Journal of International Trade & Economic Development*, *27*(6), 685-700.doi: 10.1080/09638199.2018.1426035

Aiginger, K., & Rodrik, D. (2020). Rebirth of industrial policy and an agenda for the twenty-first century. *Journal of Industry and Competition Trade, 20*(2), 189-207. https://doi.org/10.1007/s10842-019-00322-3

Alenda-Demoutiez, J., & Mugge, D. (2020). The lure of ill-fitting unemployment statistics: How South Africa's discouraged work seekers disappeared from the unemployment rate. *New Political Economy, 25*(4), 590-606. doi: 10.1080/13563467.2019.1613355

Alleyne, A., Lorde, T., & Moore, W. (2022). *The practicality of regional import substitution as a strategy for sustainable development in the Caribbean.* MPRA_paper_113129. https://mpra.ub.uni-muenchen.de/id/eprint/113129

Altamimi, A. (2018). The WTO practice of legality is ensuring transparency for self-enforcing trade. *Journal of International Trade Law and Policy, 17*(3), 132-155. doi.org/10.1108/JITLP-02-2018-0013

Amiti, M., 2000. Trade liberalisation of intermediate inputs*. The Australian Economic Review 33*, 299–302. doi: 10.1111/1467-8462.00160

Amiti, M., & Konings, J. (2007). Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. *The American Economic Review, 97*(5), 1611-1638. doi:10.1257/aer.97.5.1611

Amiti, M., Redding, S., & Weinstein, D. (2019). *The Impact of the 2018 Trade War on U.S. Prices and Welfare* (CEPR Discussion Paper 13564). www.cepr.org

Anand, R., Perrelli, R., & Zhang, B. (2016). *South Africa's exports performance: Any role for structural factors* (IMF Working Paper WP/16/24). www.imf.org

Anderson, S.P., & Schmitt, N. (2003). Nontariff barriers and trade liberalization. *Economic Inquiry, 41*(1), 80-97. doi.org/10.1093/ei/41.1.80

Andreoni, A. (2011). Productive Capabilities Indicators for Industrial Policy Design. *United Nations Industrial Development Organisation, Working Paper 17.* https://eprints.soas.ac.uk/19235/1/2011%20Productive%20Capabilities%20Indicators%20UNIDO.pdf

Andreoni, A., (2014). Structural Learning: embedding discoveries and the dynamics of production. *Structural Change and Economics Dynamics, 29.* doi.org/10.1016/j.strueco.2013.09.003

Andreoni, A., & Chang, H.-J. (2016). Industrial policy and the future of manufacturing. *Economia e Politica Industriale, 43*(4), 491–502. doi:10.1007/s40812-016-0057-2

Andreoni, A. (2016). Varieties of industrial policy: Models, packaging and transformation cycles. In A. Norman, & J. Stiglitz (Eds.). *Efficiency, finance and varieties of industrial policy*, New York. Columbia University. www.gtac. org.za

Andreoni, A. (2018). The architecture and dynamics of industrial ecosystems: diversification and innovative industrial renewal in Emilia Romagna. *Cambridge Journal of Economics, 42*(6), 1613-1642. https://doi-org.uplib.idm.oclc.org/10.1093/cje/bey037

Andreoni, A., & Chang, H.J. (2019). The political economy of industrial policy: Structural interdependencies, policy alignment and conflict management. *Structural Change and Economic Dynamics, 48*, 136-150. doi: 10.1016/j.strueco.2018.10.007

Andreoni, A & Tregenna, F. (2020). Escaping the middle-income technology trap: A comparative analysis of industrial policies in China, Brazil and South Africa. *Structural Change and Economic Dynamics, 54*, 324-340. doi.org/10.1016/j.strueco.2020.05.008

Antimiani, A., Fusacchia, I., & Salvatici, L. (2018). GTAP-VA: An integrated tool for Global Value Chain Analysis. *Journal of Global Economic Analysis, 3*(2), 69-105. https://doi.org/10.21642/JGEA.030202AF

Araujo, S., & Flaig, D. (2016). *Quantifying the effects of trade liberalisation in Brazil: A CGE model simulation* (OECD Working Paper 1295). www.oecd.or/eco/workingpapers

Association of Representatives for the Electronics Industry. (2019). *Why are we falling short*? *AREI*. Retrieved from www.arei.co.za

Armington, P. S. (1969). A theory of demand for products distinguished by place of production. *International Monetary Fund, 16*(1), 159-178. doi: 10.2307/3866403

Asongu, S.A., & Minkoua, J.R. (2018). Dynamic openness and finance in Africa. *The Journal of International Trade & Economic Development, 27*(4), 409-430. doi:10.1080/09638199.2017.1387167

Audretsch, D.B., & Belitsk, M. (2020). The role of R&D and knowledge spillovers in innovation and productivity. *European Economic Review*, 123. doi.org/10.1016/j.euroecorev.2020.103391

Awokuse, T. O., & Christopoulos, D.K. (2009). Nonlinear dynamics and the exports–output growth nexus. *Economic Modelling, 26*(1), 184-190. doi:10.1016/j.econmod.2008.06.009

Bagwell, K., Staiger, R.W. (1990). A theory of managed trade. *American Economic Review, 80*(4), 779-795.https://search-proquest-com.uplib.idm.oclc.org/

Baldwin, R.E. (2017, August). The Great Convergence: Information Technology and the New Globalization. *Research Institute of Economy, Trade and Industry International Symposium*. https://www.rieti.go.jp/en/index.html

Baldwin, J., & Yan, B. (2014). *Global value chains and the productivity of Canadian manufacturing firms.* Economic Analysis Research Paper series, Statistics Canada. https://www.statcan.gc.ca.

Balistreri, E.J., Hillberry, R.H., & Rutherford, T.F. (2011). Structural estimation and solution of international trade models with heterogeneous firms. *Journal of International Economics, 83*(2), 95-108. doi: 10.1016/j.jinteco.2011.01.001

Banga, K., & Balchin, N. (2019). Linking Southern Africa into South Africa's global value chains. Working Paper, No. 2019/62. The United Nations University World Institute for Development Economics Research. doi.org/10.35188/UNU-WIDER/2019/696-8

Bardhan, P. (1971). On the optimum subsidy to a learning industry: an aspect of the theory of infant-industry protection. *International Economic Review, 12*(1), 54-70. doi: 10.2307/2525496

Bas, M., & Strauss-Kahn, V. (2014). Does importing more inputs raise exports? Firm-level evidence from France. *Review of World Economics, 150*(2), 241-275. doi: 10.1007/s10290-013-0175-0

Bas, M., & Strauss-Kahn, V. (2015). Input-trade liberalisation, export prices, and quality upgrading. *Journal of International Economics, 95*(2), 250-262. doi:10.1016/j.jinteco.2014.12.005

Basias, N., & Pollalis, Y. (2018). Quantitative and qualitative research business & technology: Justifying a suitable research methodology. Review of Integrative Business & Economics Research 7(1), 91-105. http://buscompress.com/journal-home.html

Barrot, L-D., Calderon, C., & Seven, L. (2018). Openness, specialization and the external vulnerability of developing countries. *Journal of Development Economics, 134,* 310-328. https://doi.org/10.1016/j.jdeveco.2018.05.015

Bastable, C.F. (1921). *The Commerce of Nations* (10th ed.). London: Macmillan and Co. (Original work published 1891). https://www.jstor.org/stable/2139097

Bastos, P., Silva, J & Verhoogen, E. (2018). Export destinations and input prices. *American Economic Review, 108*(2), 353-392. doi.org/10.1257/aer.20140647

Belkania, D. (2020). Export structure and economic performance in transition economies. *European Research Studies Journal, 23*(1), 476-490. https://ssrn.com/abstract=3580924

Belloc, M., & Di Maio, M. (2011). *Survey of the Literature on Successful Strategies and Practices for Export Promotion by Developing Countries.* International Growth Centre Working Paper No. 11/0248 54. https://dx.doi.org/10.2139/ssrn.2001000

Benita, F. (2019). Trade openness, economic growth and the global financial crisis of 2007-2009 in Latin America*. Journal of International Development, 31*(5), 411-431. doi: 10.1002/jid.3411

Bernard, A. B., & Jensen, J.B. (2004). Why some firms export. *Review of Economics and Statistics, 86*(2), 561-569. doi: 10.1162/003465304323031111

Besedes, T., & Prusa, T. (2006). Ins, outs, and the duration of trade. *Canadian Journal of Economics, 39*(1), 266-295. doi: 10.1111/j.0008-4085.2006.00347.x

Blonigen, B.A. (2016). Industrial policy and downstream export performance. *The Economic Journal, 126*, 1635–1659. doi: 10.1111/ecoj.12223

Bobulescu, R. (2003). Protectionism in Retrospect: Mihail Manoilescu (1891-1950?). *Brazilian Journal of Political Economy, 23*(4), 622-632. doi:org/10.1590/0101-31572003-0644

Boler E. A., Moxines, A., & Ulltveit-Moe, K. H. (2012). Technological Change, Trade in Intermediates and the Joint Impact on Productivity. Centre for Economic Policy Research. www.cepr.org/pubs/dps/DP8884.asp

Bond, E.W. (2001). Commercial Policy in a fragmented world. *American Economic Review, 91*(2), 358-362. http://www.jstor.org/stable/2677788

Bos, M.J.D., & Vannoorenberghe, G. (2019). Imported input varieties and product innovation: Evidence from five developing countries. *Review of International Economics, 27*, 520-548. doi: 10.1111/roie.12387

Bournakis, I., Christopoulos, D., & Mallick, S. (2017). Knowledge spillovers and output per worker: an industry level analysis for OECD countries. doi.org/10.1111/ecin.12458

Brenton, P., Saborowski, C., & Uexkull, E. (2010). What explains the low survival rate of developing country export flows? *The World Bank Economic Review, 24*(3), 474-499. https://www.jstor.org/stable/23029702

Buckley, P. J., Strange, R., Timmer, M. P., & de Vries, G.J. (2020). Catching up in the global factory: Analysis and policy implications. *Journal of International Business Policy, 3*, 79-106. doi: 10.1057/s42214-020-00047-9

Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the Impact of MERCOSUR on Argentinean firms. *American Economic Review, 101*(1), 304-340. http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.1.304

Byun, S. K., Oh, J-M., & Xia, H. (2020). Incremental versus Breakthrough Innovation: The Role of Technology Spillovers. *Management Science, 66, 1-54*. doi: 10.1287/mnsc.2019.3507

Caliendo, L., & Parro, F. (2015). Estimates of the trade and welfare effects of NAFTA. *The Review of Economic Studies, 82*(1), 1-44. doi:10.1093/restud/rdu035

Camino-Mogro, S., Pinzon, K., & Carrillo-Maldonado, P. (2020). *Do imports of intermediate inputs generate higher productivity? Evidence from Ecuadorian manufacturing firms* (Inter-American Development Bank Working Paper Series 1129). http://www.iadb.org

Cappariello, R., Gunnella, V., Franco-Bedoya, S., & Ottaviano, G. (2020). *Rising protectionism and global value chains: quantifying the general equilibrium effects* (ECB Working Paper 2360). https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2360~0b2894ed2d.en.pdf

Carrico, C. (2017). An enhanced analytical framework for evaluating the effects of trade costs along global value chains. *Journal of Global Economic Analysis, 2*(2), 43–111. doi:10.21642/JGEA.020202AF.

Carrico, C., Corong, E., & Van der Mensbrugghe, D. (2020). *The GTAP 10A Multi-Region Input Output (MRIO) Data Base* (GTAP Research Memorandum No. 34). Purdue University. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6164

Chang, H.-J. (2010). Industrial policy: Can we go beyond an unproductive confrontation? *Annual World Bank Conference on Development Economics,* 83-109. https://rrojasdatabank.info/wbdevecon10-9.pdf

Chang, H.J. (2011). Institutions and economic development: Theory, policy and history. *Journal of Institutional Economics, 7*(4), 473-498. doi: 10.1017/S1744137410000378

Chang, H-J., & Andreoni, A. (2020). Industrial policy in the 21st century. *Development and Change, 51*(2), 324-351. doi: 10.1111/dech.12570

Chang, H-J, Andreoni, A. & Kuan, M. L. (2013). *International Industrial Policy Experiences and the Lessons for the UK.* UK Government Office of Science, Evidence Paper 4. https://assets.publishing.service.gov.uk/government/

Chatterjee, T., & Gupta, K. (2014). Trade Liberalisation, Health Care and International Fragmentation: The Role of Health Capital Mobility. *The Pakistan Development Review, 53*(1), 57-65. http://www.jstor.com/stable/24397925

Chen, J., Sousa, C.M.P., & He, X. (2016). The determinants of export performance: a review of literature 2006-2014. *International Marketing Review, 33*(5), 626-670. doi: 10.1108/IMR-10-2015-0212

Chen, W., & Xing, L. (2022). Measuring the intermediate goods' external dependency on the global value chain: A case study of China. *Sustainability*, *14*(7), 4360. doi.org/10.3390/su14074360

Cheng, L.K., Whitten, G.W., & Hua, J. (2019). The national security argument for protection of domestic industries. *Journal of Chinese Economic and Business Studies, 17*(4), 365-388. doi: 10.1080/14765284.2020.1732091

Chevassus-Lozza, E., Gaigne, C., & Le-Mener, L. (2013). Does input trade liberalization boost downstream firms' exports? Theory and firm-level evidence. Journal *of International Economics, 90*, 391-402. doi: 10.1016/j.jinteco.2013.02.004

Church, J. D. (2016). Comparing the Consumer Price Index with the gross domestic product price index and gross domestic product implicit price deflator. *Monthly Labor Review*. doi.org/10.21916/mlr.2016.13

Cieslik, A., Michalek, J., & Nasadiuk, I. (2015). Determinants of export performance of Ukrainian firms. *Quarterly Journal of Economics and Economic Policy, 10*(3), 91-103. doi: 10.12775/EQUIL.2015.026

Cimoli, M., Dosi, G., & Yu, X. (2020). *Industrial policies, patterns of learning and development: An evolutionary perspective.* Laboratory of Economics and Management Working Paper. https://ideas.repec.org/p/ssa/lemwps/2020-08.html

Clark, P., & Rosales, A. (2022). Broadened embedded autonomy and Latin America's Pink Tide: Towards the neo-developmental state. *Globalizations*, 1-18. doi.org/10.1080/14747731.2022.2032986

Clemhout, S., & Wan, H.Y. (1970). Learning-by-doing and infant industry protection. *Economic Studies, 37*, 33-56. https://doi.org/10.2307/2296497

Coe, D.T., Helpman, E., & Hoffmaister, A.W. (1995). *North-South R&D Spillovers.* NBER working paper, No. 5048. https://www.imf.org/external/pubs/ft/wp/2008/wp08104.pdf

Collier, P., & Venables, A.J. (2007). Rethinking trade preferences: How Africa can diversify its exports. *The World Economy, 30*(8), 1326-1345. doi: 10.1111/j.1467-9701.2007.001042.x

Corong, E.L., Hertel, T.W., McDougall, R.A., Tsigas, M.E., & Van der Mensbrugghe, D. (2017). The Standard GTAP Model, Version 7. *Journal of Global Economic Analysis, 1*(2), 1-119. doi:10.21642/JGEA.020101AF

Corong, E.L., & McDougall, R.A. (2020). *Global Data Base Assembly. GTAP 10 Data Base Documentation.* Centre for Global Trade Analysis. Purdue University. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6173

Criscuolo, C., Martin R., Overman H., & Van Reenen, J. (2019). Some causal effects of an industrial policy. *American Economic Review, 109*(1), 48-85. https://doi.org/10.1257/aer.20160034

Das, G. G. (2019). Ability-Biased Technical Change and Productivity Bonus in a Nested Production Structure: A Theoretical Model with Endogenous Hicks-Neutral Technology Spillover. *Scientific Annals of Economics and Business, 66*(3), 415-450. doi: 10.2478/saeb-2019-0030

Das, G. G., & Powell, A. (2015). Absorption capacity, structural similarity and embodied technology spillovers in a macro model: An implementation within a CGE framework. *The Korean Journal of Policy Studies,* 110-133. doi:10.13140/RG.2.1.4297.8403

Das, S., & Srinivasan, K. (1997). Duration of firms in an infant industry: The case of Indian computer hardware. *Journal of Development Economics, 53*, 157-167. https://doi.org/10.1016/S0304-3878(97)00007-2

Datta, A., & Mohtadi, H. (2006). Endogenous imitation and technology absorption in a model of North-South trade. *International Economic Journal, 20*(4), 431-459. doi:10.1080/10168730601027005

Deardorff, A.V. (2001). Fragmentation in simple trade models. *The North American Economics and Finance, 12*(2), 121-137. https://doi.org/10.1016/S1062-9408(01)00043-2

De Backer, K., & Miroudot, S. (2014). *Mapping global value chains.* European central bank. Working paper series 1677. http://dx.doi.org/10.1787/5k3v1trgnbr4-en

De Lannoy, A., Graham, L., Patel, L. & Leibbrandt, M. (2018). What drives youth unemployment and what interventions help? A systematic overview of the evidence and a theory of change. https://www.uj.ac.za/wp-content/uploads/2021/10/youth-unemployment-report-final-interactive.pdf

Del Prete, D., Giovannetti, G., & Marvasi, E. (2017). Global value chains participation and productivity gains for North African firms. *Review of World Economics, 153*(4), 675-701. doi: 10.1007/s10290-017-0292-2

De Miguela, F.J., & Manresa, A. (2008). Removal of farm subsidies in a regional economy: a computable general equilibrium analysis. *Applied Economics, 40*, 2109-2120. doi: 10.1080/00036840600949371

Deng, F., Wang, Y., Li, Z., & Liang, X. (2020). China's technology spillover effects in the countries along the Belt and Road — Evidence from 49 BRI Countries*, Applied Economics, 52*(51) 5579-5594. doi: 10.1080/00036846.2020.1767282

Dixon, P.B., Jerie, M., & Rimmer, M.T. (2016). Modern trade theory for CGE modelling: the Armington, Krugman and Melitz models*. Journal of Global Economic Analysis, 1*(1), 1-110. doi: http://dx.doi.org/10.21642/JGEA.010101AF

Djatsa, F. (2020). Threat perceptions, avoidance motivation and security behaviors *Correlations. Journal of Information Security, 11*, 19-45. https://doi.org/10.4236/jis.2020.111002

Dodzin, S., & Vamvakidis, A. (2004). Trade and industrialisation in developing economies. *Journal of Development Economics, 75*, 319-328. doi: 10.1016/j.jdeveco.2003.08.006

Dosi, G., Roventini, A., & Russo, E. (2020). *Public policies and the art of catching up: matching the historical evidence with a multi-country agent-based model.* Institute of Economics Working Paper Series. https://www.lem.sssup.it/WPLem/files/2020-10.pdf

Draper, P., Angel, J., Krogman, H., Ngarachu, A., & Wentworth, L. (2018). *Between gatekeeper and gateway: Taking advantage of regional and global value chains by addressing barriers to South Africa's to trade competitiveness*. MTI Discussion Paper 7. https://documents.worldbank.org/curated/en/649161539793087628

Draper, P., Freytag, A., & Al Doyaili, S. (2013). Why should Sub-Saharan Africa care about the Doha Development Round? *Economics: The Open-Access, Open-Assessment E-Journal*, *7.* https://dx.doi.org/10.5018/economics-ejournal.ja.2013-19

Eaton, J., & Kortum, S. (2002). Technology, geography and trade. *Econometrica, 70*(5), 1741-1779. http://www.jstor.org/stable/3082019

Economic Commission for Africa. (2016). *Industrial policy for Africa in the new global environment.* Transformative Industrial Policy for Africa, 115, 18-19. https://www.uneca.org/sites/default/files/PublicationFile/tipa-chap5en.pdf

Edeh, J. N., Obodoechi, D. N., & Ramos-Hidalgo, E. (2020). Effect of innovation strategies on export performance: New empirical evidence from developing market firms. *Technological Forecasting & Social Change, 158*, 120167. doi: 10.1016/j.techfore.2020.120167

Edwards, L. (2021). South Africa's international trade. PRISM *Working Paper 2021-1.* Policy Research on International Services and Manufacturing, University of Cape Town. www.prism.uct.ac.za

Edwards, L., Flowerday, W., Rankin, N., Roberts, G., & Schoer, V. (2015). *Restructuring of the South African economy: 1994-2014* (The Economic Society of South Africa). http://2015.essa.org.za/fullpaper/essa_3131.pdf.

Edwards, L., and Jenkins, R. (2015). The impact of Chinese import penetration on the South African manufacturing sector. *The Journal of Development Studies, 51*(4), 447-463, doi: 10.1080/00220388.2014.983912

Edwards, L., Sanfilippo, M., & Sundaram, A. (2018). Importing and firm export performance: New evidence from South Africa. *South African Journal of Economics, 86*(1), 79-95. doi: 10.1111/saje.12154

Ee, Y.C. (2016). Export- led growth hypothesis: Empirical evidence from selected Sub-Saharan African countries. *Procedia Economics and Finance 35*, 232 -240. doi: 10.1016/S2212-5671(16)00029-0

Elbehri, A., & Pearson, K. (2005). *Implementing Bilateral Tariff Rate Quotas in GTAP using GEMPACK*. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=475

Esteve-Pérez, S., & Sahiti, F. (2019). New firm survival in developing countries: Evidence from Kosovo. *The Developing Economies, 57*(3), 257-273. doi: 10.1111/deve.12209

Evenett, S.J. (2019). Protectionism, state discrimination, and international business since the onset of the Global Financial Crisis. *Journal of International Business Policy 2*, 9-36. doi: 10.1057/s42214-019-00021-0

Fajgelbaum, P.D., Goldberg, P.K., Kennedy, P.J., & Khandelwal, A.K. (2020). The return to protectionism. The Quarterly Journal of Economics, *135*(1), 1-55. doi: 10.1093/qje/qjz036

Fally, T. (2011). *On the fragmentation of production in the US*. University of Colorado-Boulder. https://www.etsg.org/ETSG2011/Papers/Fally.pdf

Fal'tsman, V.K. (2020). Three global challenges for the long term growth of developing countries. *Studies on Russian Economic Development, 31*(3), 347-352. doi: 10.1134/S1075700720030053

Fan, H., Li, Y. A., & Yeaple, S.R. (2018). On the relationship between quality and productivity: Evidence from China's accession to the WTO. *Journal of International Economics, 110*, 28-49. doi: 10.1016/j.jinteco.2017.10.001

Farole, T. (2016). Factory Southern Africa? SACU in global value chains. World Bank. https://openknowledge.worldbank.org/handle/10986/23787

Fedderke, J. (2018). South African growth: context, cause and consequence. *The Journal of the Helen Suzman Foundation, 82*, 5-14. www.hsf.org.za

Feenstra, R.C., & Lewis, T.R. (1991). Negotiated trade restrictions with private political pressure. *The Quarterly Journal of Economics 106*, 1287-1307. https://www.jstor.org/stable/2937965

Feng, L., Li, Z., & Swenson, D.L. (2016). The connection between imported intermediate inputs and exports: Evidence from Chinese firms. *Journal of International Economics 101,* 86-101. https://dx.doi.org/10.1016/j.jinteco.2016.03.004

Flatters, F., & Stern, M. (2008). *Trade and industrial policy in South Africa*. USAID RCSA. https://www.dnaeconomics.com/assets/Usematthew/

Foster, C., & Azmeh, S. (2020). Latecomer economies and national digital policy: An industrial policy perspective. *The Journal of Development Studies, 56*(7), 1247-1262. Doi: 10.1080/00220388.2019.1677886

Foster, N. (2008). The impact of trade liberalisation on economic growth. Evidence from a quantile regression analysis. *Kyklos, 61*(4), 543-567. https://doi-org.uplib.idm.oclc.org/10.1111/j.1467-6435.2008.00417.x

Fracasso, A., & Marzetti, G.V. (2015). International trade and R&D spillovers. *Journal of International Economics, 96,* 138–149. http://dx.doi.org/10.1016/j.jinteco.2015.01.010

Franco-Bedoya, S., & Frohm, E. (2020). Global trade in final goods and intermediate inputs: Impact of FTAs and reduced Border Effects. European Central Bank Working Paper No. 20202410. Retrieved from https://ssrn.com/abstract=3601769

Francois, J.F., van Meijl, H., & Tongeren, F. (2005). Trade liberalisation in the Doha Development Round. *Economic Policy 20*(42), 349-391. http://web.a.ebscohost.com.uplib.idm.oclc.org/ehost/pdfviewer/

Franz, J., Dulvy, E. N., & Marock, C. (2022). Engagement of Micro and Small Enterprises in workplace-based learning in South Africa. World Bank. https://openknowledge.worldbank.org/handle/10986/37706

Freund, C., & Rocha, N. (2011). What constrains Africa's growth? *The World Bank Economic Review, 25*(3), 361-386. https://www.jstor.org/stable/41342481

Friedman, T. L. (2005). *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus and Giroux. https://commons.pacificu.edu/inter05/37

Furuoka, F. (2018). Exports and economic growth in Sub-Saharan Africa: New insights from innovative econometric methods. *The Journal of International Trade & Economic Development*, *27*(7), 830-855. doi: 10.1080/09638199.2018.1455890

Fusacchia, I. (2020). Evaluating the impact of the US-China trade war on Euro area economies: A tale of Global Value Chains. *Italian Economic Journal, 6*, 441-468. https://doi.org/10.1007/s40797-019-00109-9

Fusacchia, I., Antimiani, A., & Salvatici, L. (2021). An assessment of import tariff costs for Italian exporting firms. *Economia Politica 38*, 31-56. doi: 10.1007/s40888-020-00202-8

Gaulier, G., Sztulman, A., & Unal, D. (2020). Are global value chains receding? The jury is still out. Key findings from the analysis of deflated world trade in parts and components. *International Economics, 161*, 219-236. doi: 10.1016/j.inteco.2019.12.002

Gault, F., & Zhang, G. (2010). *The role of innovation in the area of development*. OECD. doi: 10.1787/9789264088924-en

Gerlagh, R., & Kuik, O. (2014). Spill or leak? Carbon leakage with international technology spillovers: A CGE analysis. *Energy Economics, 45*, 381–388. doi.org/10.1016/j.eneco.2014.07.017

Gilles, E., Deaza, J., & Vivas, A. (2023). The role of imported intermediates in productivity change. *Economic Systems Research*, *35*(2) 211-227. doi: 10.1080/09535314.2022.2062301

Gillwald, A., Calandro, E., Sadeski, F., & Lacave, M. (2019). Unlocking the potential of the Fourth Industrial Revolution in Africa. Korea-Africa Economic Cooperation, Africa Development Bank. www.afdb.org

Giusti, J. D., Alberti, F. G., & Belfanti, F. (2020). Makers and clusters. Knowledge leaks in open innovation networks*. Journal of Innovation & Knowledge, 5*, 20-28. doi: 10.1016/j.jik.2018.04.001

Go, D., Kearney, M., Robinson, S., & Thierfelder, K. (2004). An Analysis of South Africa's Value Added Tax. *7th Annual Conference on Global Economic Analysis*. Washington DC, USA). https://www.gtap.agecon.purdue.edu/resources/

Goldberg, P., Khandelwal, A., Pavcnik, N., Topalova, P. (2009). Trade liberalization and new imported inputs. *American Economic Review, 99* (2), 494–500. doi:10.1257/aer.99.2.494

Gopinath, G., & Nieman, B. (2014). Trade adjustment and productivity in large crises. *American Economic Review, 104*(3), 793-831. doi: 10.1257/aer.104.3.793

Görg, H. (2000). Fragmentation and trade: US inward processing trade in the EU. *Weltwirtschaftliches Archiv 136*, 403-422. https://doi.org/10.1007/BF02707287

Greenwald, B., & Stiglitz, J. E. (2006). Helping infant economies grow: Foundations of trade policies for developing countries. *American Economic Review, 96*(2), 141-146. doi: 10.1257/000282806777212206

Gries, T., & Grundmann, R. (2020). Modern sector development: The role of exports and institutions in developing countries. *Review of Development Economics, 24*(2), 644-667. doi: 10.1111/rode.12663

Grimmett, J.J. (2007). *Trade preference for developing countries and the WTO*, Congressional Research Service, The Library of Congress, Washington, DC. https://agris.fao.org/agris-search/search.do?recordID=US201300127328

Grossman, G., & Helpman, E. (1991). Innovation and growth in the global economy, MIT Press, Cambridge, MA. https://scholar.harvard.edu/helpman/publications/

Grossman, G., & Horn, H. (1988). Infant industry protection reconsidered: The case of informational barriers to entry. *The Quarterly Journal of Economics, 103*(4), 767-787. doi: 10.2307/1886074

Grossmann, S. H., & Scheufele, R. (2019). PMIs: Reliable indicators for exports. *Review of International Economics, 27*(2), 711-734. doi: 10.1111/roie.12395

Guimbard, H., Jean, S., Mimouni, M., & Pichot, X. (2012). MAcMap-HS6 2007, an exhaustive and consistent measure of applied protection in 2007, *International Economics*, *130*, 99-122. https://EconPapers.repec.org/RePEc:cii:cepiie:2012-q2-130-5.

Guisan, M.C. (2017). Manufacturing and development in countries and areas of Africa, 2000-2010. *Regional and Sectoral Economic Studies, 17*(2), 137-148. http://www.usc.es/-economet/reviews/eers1729.pdf

Halpern, L., Koren, M., & Szeidl, A. (2015). Imported inputs and productivity. *American Economic Review, 105*(12), 3660-3703. doi: 10.1257/aer.20150443

Hamilton, A. (1791). Report on the subject of manufactures. Philadelphia. https://ap.gilderlehrman.org/period/3

Harris, R. (1984). Applied general equilibrium analysis of small open economies with scale economies and imperfect competition. *American Economic Review, 74*(5), 1016-32. Retrieved from https://search-proquest- com.uplib.idm.oclc.org/docview/233042044?accountid=14717

Harris, R., Keay, I., & Lewis, F. (2015). Protecting infant industries: Canadian manufacturing and the national policy, 1870–1913. *Explorations in Economic History 56,* 15–31, doi.org/10.1016/j.eeh.2015.01.001

Harslett, P. (2013). *The GTAP Data Base Construction Procedure*. Purdue University. https://ideas.repec.org/p/gta/workpp/4289.html

Hausmann, R., & Klinger, B. (2008). South Africa's export predicament. *Economics of Transition, 16*(4), 609-637. doi: 10.1111/j.1468-0351.2008.00337.x

Hausmann, R., & Rodrik, D. (2003). Economic development as self-discovery. *Journal of Development Economics, 72*(2), 603–633. doi: 10.1016/S0304-3878(03)00124-X

Hausmann, R., & Rodrik, D. (2006). *Doomed to choose - industrial policy as Predicament*, mimeo. In: John F. Kennedy School of Government. Harvard University. https://www.sss.ias.edu/files/pdfs/Rodrik/Research/doomed-to-choose.pdf

Hayami, Y & Ruttan, V. W. (1985). *Agricultural development. An international perspective*, Baltimore and London: The John Hopkins University Press. http://garfield.library.upenn.edu/classics1988/A1988P408600001.pdf

Hertel, T. W. (2003). The Global Trade Analysis Project: Issues and future directions. GTAP WP https://www.gtap.agecon.purdue.edu/events/board_meetings/2003/documents/Background.pdf

Hertel, T.W. (2012). *Global Applied General Equilibrium Analysis using the GTAP Framewor*. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3751

Hertel, T. W., Hummels, D., Ivanic, & Keeney, R. (2007). How confident can we be of CGE-based assessments of Free Trade Agreements? *Economic Modelling, 24*, 611-635. doi:10.1016/j.econmod.2006.12.002

Hirschman, A. O. (1958). The Strategy of Economic Development. Review by Goodman Bernard. *American Journal of Agricultural Economics, 41*(2), 468-469. doi: 10.2307/1235188

Ho, P.S.W. (2013). Does Mill's case for infant industry protection capture Hamilton's and List's arguments for promoting industrial development? *Review of Political Economy, 25*(4), 546-571. doi: 10.1080/09538259.2013.837323

Hosoe, N. (2018). Impact of border barriers, returning migrants and trade diversion in Brexit: firm exit and loss of variety. *Economic Modelling, 69,* 193-204. doi: 10.1016/j.econmod.2017.09.018

Hu, H., Wang, X., Zhou, H., Jin, Z., & Wei, S. (2022). Global Trade Pattern of Medical Devices and China's Trade Position: Based on Data From 2001 to 2020. *Frontiers in public health*, *10*, 926216. doi.org/10.3389/fpubh.2022.926216

Hübler, M. (2011). Technology diffusion under contraction and convergence: A CGE analysis of China. Energy Economics, *33*(1), 131-142. doi: 10.1016/j.eneco.2010.09.002

Huff, K., McDougall, R., & Walmsley, T. (2000). *Contributing input-output tables to the GTAP data base*. Global Trade Analysis Project (GTAP). http://www.gtap.agecon.purdue.edu/resources/res display.asp?RecordID=304.

Hummels, D., Ishii, J., & Yi, K.M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics, 54*(1), 75-96. https://ideas.repec.org/a/eee/inecon/v54y2001i1p75-96.html

Im, F.G., Farole, T., & Purfield, C.M. (2014). South Africa economic update: Focus on export competitiveness. World Bank. www.worldbank.org/za

Industrial Development Corporation. (2017). *Economic overview: Recent developments in the global and South African economies*. Department of Research and Information. www.idc.co.za

Industrial Development Corporation. (2013). *South African economy: an overview of key trends since 1994.* Department of Research and Information. www.idc.co.za

International Distribution of Electronics Association. (2019). Horticultural lighting: An overview of the market. www.ideaelectronics.com

International Labour Organisation. (2014). *Global employment trends 2014: Risk of a jobless recovery?* Geneva. https://www.ilo.org/global/research/global-reports/global-employment-trends/2014/lang--en/index.htm

InvestSA. (2020). *Fact sheet electronics*. Department of Trade and Industry South Africa. Retrieved from investsa.gov.za/wp-content/uploads/2020/02

Irwin, D.A. (2009). Free trade under fire. *Southern Economic Journal, 69*(3), 745-747. doi: 10.2307/1061708

International Trade and Administration. (2019). *South Africa-import tariffs*. https://www.export.gov/apex/article2?id=South-Africa-import-tariffs

International Trade Administration Commission. (2008). *Revision of the customs duties applicable to machinery and capital equipment classifiable under chapters 84 and 85 of the customs tariff.* Report No. 283. https://www.itac.org.za

International Trade Administration Commission. (2014). *Trade as a driver of structural change for sustainable development. South Africa trade report 2014*. https://www.itac.org.za

Itakura, K. (2019). Incorporating Global Value Chains into the dynamic GTAP model. https://www.gtap.agecon.purdue.edu/resources/download/9374.pdf

Jackson, E.A., & Jabbie, M. (2020). *Import substitution industrialisation (ISI): An approach to global economic sustainability*. Munich Personal RePEc Archive Paper 102316. https://mpra.ub.uni-muenchen.de/102316/

Japan Electronics and Information Technology Industries Association. (2020). *Production forecasts for the global electronics and information technology industries*. https://www.jeita.or.jp/english/press/2020/1216.pdf

Johnson, S., Ostry, J.D., & Subramanian, A. (2010). Prospects for sustained growth in Africa: Benchmarking the constraints. *IMF Staff Papers, 57*, 119-171. doi: 10.1057/imfsp.2009.22

Jones, R.W., & Marjit, S. (2001). The role of international fragmentation in the development process. *The American Economic Review, 91*(2), 363-366. http://www.jstor.org/stable/2677789

Jongwanich, J., & Kohpaiboon, A. (2020). *Effectiveness of industrial policy on firms' productivity: Evidence from Thai manufacturing* (ERIA Discussion paper series 316). https://www.eria.org/uploads/media/discussion-papers

Jovanović, M. (2010). Is globalisation taking us for a ride? *Journal of Economic Integration, 25*(3), 501-549. https://www.jstor.org.uplib.idm.oclc.org/stable/23000870

Ju, J., Wu, Y., & Zheng, L. (2010). The impact of trade liberalization on the trade balance in developing countries. *IMF Staff Papers, 57*(2), 427-449. doi:10.1057/imfsp.2009.19

Juhasz R. (2018). Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade. *American Economic Review, 108*(11), 3339-3376 doi.org/10.1257/aer.20151730

Kalouptsidi, M. (2018). Detection and impact of industrial subsidies: The case of Chinese shipbuilding. *Review of Economic Studies, 85*(2), 1111-58. doi: 10.1093/restud/rdx050

Kalygina, V. V. (2022). International technology transfer as an effective tool of exportoriented import substitution in Russia. *RUDN Journal of Economics, 30*(2), 231-241. doi:10.22363/2313-2329-2022-30-2-231-241

Kaplinsky, R. (2008). What does the rise of china do for industrialisation in Sub-Saharan Africa? *Review of African Political Economy, 35*(115), 7-22. https://www.jstor.org/stable/20406474

Karam, F., & Zaki, C. (2020). A new dawn for MENA firms: Service trade liberalization for more competitive exports. *Applied Economics, 52*(1), 19-35, doi:10.1080/00036846.2019.1624921

Karlsson, C., & Grasjo, U. (2014). *Knowledge flows, knowledge externalities and regional economic development*. CSIR Electronic Working Paper Series. doi: 10.1007/978-3-642-23430-9_25

Kehoe, T.J., Pujol`as, P.S., & Rossbach, J. (2017). Quantitative trade models: Developments and challenges. *Annual Review of Economics, 9*, 295-325. https://doi.org/10.1146/annurev-economics- 080614-115502

Keller, W. (2004). International technology diffusion. *Journal of Economic Literature, 42*(3), 752-782. https://search-proquest-com.uplib.idm.oclc.org/docview/213165426?accountid=14717

Keller, W. (2021). *Knowledge spillovers, trade, and foreign direct investment* (No. w28739). National Bureau of Economic Research. doi: 10.3386/w28739

Kneller, R. (2006). No miracles here: trade policy, fiscal policy and economic growth. *Journal of Development Studies, 43*(7), 1248-1269. https://doi.org/10.1080/00220380701526386

Kogan, K., Ouardighi, F. E., & Chernonog, T. (2016). Learning by doing with spillovers: Strategic complementarity versus strategic substitutability. *Automatica, 67*, 282-294. doi: 10.1016/j.automatica.2016.01.032

Kogan, L., Papanikolaou, D., Schmidt, L. D. W., & Seegmiller, B. (2021). Technology-Skill Complementarity and Labor Displacement: Evidence from Linking Two Centuries of Patents with Occupations. NBER Working Paper 29552. doi: 10.3386/w29552

Koopman, R., Hancock, J., Piermartini, R., & Bekkers, E. (2020). The value of the WTO. *Journal of Policy Modeling, 42*(4), 829-849. Doi: 10.1016/j.jpolmod.2020.03.008

Kose, M.A., Prasad, E.S., & Taylor, A.D. (2011). Threshold in the process of international financial integration. *Journal of International Money and Finance, 30* (1), 147-179. doi:10.1016/j.jimonfin.2010.08.005

Kowalski, P., Gonzalez, J.L., Ragoussis, A., & Ugarte, C. (2015). *Participation of developing countries in global value chains: implications for trade and trade-related policies*. OECD Trade Policy Papers, No. 179, OECD Publishing, Paris. doi: 10.1787/5js33lfw0xxn-en

Kozul-Wright, R., & Poon, D. (2018). Asian development after the Asian Drama, WIDER Working Paper, No. 2018/135, ISBN 978-92-9256-577-0, The United Nations University World Institute for Development Economics Research. doi.org/10.35188/UNU-WIDER/2018/577-0

Krugman, P. (1995). Growing world trade: Causes and consequences. *Brookings Papers on Economic Activity, 1,* 327-377. doi: 10.2307/2534577

Krugman, P. (1987). The narrow moving band, the Dutch disease, and the competitive consequences of Mrs. Thatcher. *Journal of Development Economics, 27*, 41-55. https://doi.org/10.1016/0304-3878(87)90005-8

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *American Economic Review, 70*(5), 950-59. https://search-proquest-com.uplib.idm.oclc.org/docview/233048123?accountid=14717

Lall, S. (2005). *Is African industry competing?* Working Paper no. 121. Queen Elizabeth House, University of Oxford. https://www.citeseerx.ist.psu.edu

Lall, S., & Albaladejo, M. (2004). China’s competitive performance: A threat to East Asian manufactured exports? *World Development, 32*(9), 1441-66. doi.org/10.1016/j.worlddev.2004.03.006

Lall, S., Weiss, J. & Oikawa, H. (2007). China's Competitive Threat to Latin America: An Analysis for 1990–2002. *Oxford Development Studies, 33*(2): 163–94. doi:10.1080/13600810500137764

Lall, S., Albaladejo, M., & Zhang, J. (2010). Mapping fragmentation: Electronics and automobiles in East Asia and Latin America. *Oxford Development Studies, 32*(3), 407-432. doi: 10.1080/1360081042000260601

Lam, R. C. (2013). Export and growth: A linkage effect perspective. *International Journal of Development Issues, 12*(1) 53–66. doi: 10.1108/14468951311322118.

Leahy, D., & Neary, P. (1999). Learning by doing, precommitment, and infant-industry protection. *Review of Economic Studies, 66*(2), 447–474. https//repec:oup:restud:v:66:y:1999:i:2:p:447-474.

Lee, J. (1997). The maturation and growth of infant industries. The case of Korea. *World Development 25*, 1271–1281. https://doi.org/10.1016/S0305-750X(97)00035-1

Le, V., & Valadkhani, A. (2014). Are exporting manufacturing SMEs more efficient than non-exporting ones? Evidence from Australia's business longitudinal database. *Economic Analysis and Policy, 44*(3), 310-317. http://dx.doi.org/10.1016/j.eap.2014.07.002

Levy, P. (2009). Imaginative obstruction: Modern protectionism in the global economy. *Georgetown Journal of International Affairs, 10*(2), 7-14. http://www.jstor.org/stable/43133568

Li, R. (2017). *Overcoming the challenges for manufacturing in Africa, how we made it in Africa.* Africa Business Insight. https://www.howwemadeitinafrica.com/overcoming-challenges-manufacturing-africa/59794/

Lileeva, A., & Trefler, D. (2010). Improved access to foreign markets raises plant-level productivity for some plants. *Quarterly Journal of Economics 125*(3), 1051-99. http://web.a.ebscohost.com.uplib.idm.oclc.org/ehost/pdfviewer/pdfviewer?vid=2&sid=035b5b71-7494-4c69-bcdb-a6959f980835%40sessionmgr4006

Lin, J. (2012). *New structural economics: A framework for rethinking development and policy*. World Bank. https://openknowledge.worldbank.org/handle/10986/19919

Lin, J., & Chang, H.J. (2009). Should industrial policy in developing countries conform to comparative advantage or defy it? A debate between Justin Lin and Ha-Joon Chang. *Development Policy Review, 27*(5), 483-502. doi: 10.1111/j.1467-7679.2009.00456.x.

List, F. (1841). *National System of Political Economy*. New York and London: Garland Publishing Inc (1974). Retrieved from https://oll.libertyfund.org/titles/list-the-national-system-of-political-economy

Liu, N., & Fan, F. (2020). Threshold effect of international technology spillovers on China's regional economic growth. *Technology Analysis & Strategic Management, 32*(8), 923-935. doi: 10.1080/09537325.2020.1729977

Loewald, C. (2018). South African macroeconomics and growth. *The Journal of the Helen Suzman Foundation, 82*, 15-19. https://www.hsf.org.za

Lopez, R. A. (2006). Imports of intermediate inputs and plant survival. *Economics Letters, 92*, 58-62. doi: 10.1016/j.econlet.2006.01.025

Lu, S. (2015). Does Japan's accession to the Trans-Pacific Partnership mean an opportunity or a threat to the US textile industry? A quantitative evaluation. *Journal of the Textile Institute*, *106*(5), 536-549. doi: 10.1080/00405000.2014.929271

Lu, S. (2016). Impact of the Trans-Pacific Partnership (TPP) on US textile and apparel manufacturing: A quantitative evaluation. *Journal of International Trade Law and Policy, 15*(2), 134-152. doi: 10.1108/JITLP-02-2016-0009

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22*(1), 3-42. doi:10.1016/0304-3932(88)90168-7

Luzio, E., & Greenstein, S. (1995). Measuring the performance of a protected infant industry. The case of Brazilian microcomputers. *Review of Economics and Statistics, 77*(4), 622–633. https://www.repec:tpr:restat:v:77:y:1995:i:4:p:622-33

Mabugu, R., & Chitiga, M. (2009). Liberalising trade in South Africa: A survey of computable general equilibrium studies. *South African Journal of Economics, 77*(3), 445-464. https://doi.org/10.1111/j.1813-6982.2009.01221.x

MacDonald, S., Pan, S., Somwaru, A., & Tuan, F. (2010). China's role in world cotton and textile markets: A joint computable general equilibrium/partial equilibrium approach. *Applied Economics, 42*, 875-885. doi: 10.1080/00036840701720911

Mainar-Causape, A.J., Ferrari, E., & McDonald, S. (2018). *Social accounting matrices: basic aspects and main steps for estimation.* JRC Technical Reports. European Commission. doi: 10.2760/010600

Malefane M.R., & Odhiambo, M.N. (2017). The dynamics of trade openness in South Africa: An exploratory review. *International Journal for Quality Research, 11*(4), 887-902. doi: 10.18421/IJQR11.04-10

Manova, K., & Yu, Z. (2017). Multi-product firms and product quality. *Journal of International Economics, 109*, 116-137. doi: 10.1016/j.jinteco.2017.08.006

Matsuyama, K. (1990). Perfect equilibria in a trade liberalization game. *American Economic Review, 80,* 480-492. https://web.a.ebscohost.com.uplib.idm.oclc.org/ehost/pdfviewer/pdfviewer?vid=6&sid=8455edc9-d46d-4cc5-b419-aeb19807bd55%40sdc-v-sessmgr03.

Matthee, M., Rankin, N., Webb, T., & Bezuidenhout, C. (2018). Understanding manufactured exporters at the firm level: new insights from using SARS administrative data. *South African Journal of Economics, 86*(S1), 96-119. doi: 10.1111/saje.12158

McDonald, S., & Walmsley, T. (2008). Bilateral free trade agreements and customs unions: The impact of the EU Republic of South Africa Free Trade Agreement on Botswana. *The World Economy, 31*(8), 993-1029. doi: 10.1111/j.1467-9701.2008.01112.x

McDougall, R., & Golub, A. (2009). *GTAP-E, A revised energy-environmental version of the GTAP model.* Centre for Global Trade Analysis, Purdue University. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2959

Melitz, M.J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica, 71*(6), 1695-1725. doi: 10.1111/1468-0262.00467

Melitz, M.J. (2005). When and how should infant industries be protected? *Journal of International Economics, 66*, 177-196. doi: 10.1016/j.jinteco.2004.07.001

Melitz, M.J., & Trefler, D. (2012). Gains from trade when firms matter. *Journal of Economic Perspectives*, *26*(2), 91-118. doi: 10.1257/JEP.26.2.91

Mijiyawa, A. (2017). Drivers of structural transformation: The case of the manufacturing sector in Africa. *World Development, 99*,141-159. http://dx.doi.org/10.1016/j.worlddev.2017.07.007

Mill, J.S. (1848). *Principles of political economy.* In: Robson, J.M. (Ed.), Collected works of John Stuart Mill (pp. 918-919). University of Toronto Press. https://oll.libertyfund.org/titles/mill-the-collected-works-of-john-stuart-mill-volume-ii-the-principles-of-political-economy-i

Miravete, E.J. (2003). Time-consistent protection with learning by doing. *European Economic Review, 47*, 761–790. https://www.sssc.upenn.edu/~miravete

Mitra, S., & Gupta, K. (2017). Fragmentation, skill formation and international capital mobility. *The Singapore Economic Review, 63*(1), 1-16. doi: 10.1142/S0217590817500023

Mondal S. (2023). International trade and global value chain: An overview. MPRA Paper. Retrieved from https://mpra.ub.uni-muenchen.de/116018/

Morris, M., & Reed, L. (2008). Review of the Impact of the China Restraint Agreement on the Clothing and Textile Industry in South Africa. (PRISM Working paper). Cape Town, South Africa: University of Cape Town. http://hdl.handle.net/11427/19875

Motelle, S., & Biekpe, N. (2015). Financial integration and stability in the Southern African Development Community. *Journal of Economics and Business, 79*, 100-117. http://dx.doi.org/10.1016/j.jeconbus.2015.01.002

Mustafa, D. I. (2020). Infant industries protectionism: The case of automobile industry in Malaysia. *International Journal of Business and Economics, 9*(2), 68-72. doi: 10.11648/j.ijber.20200902.12

Mutambara, T. E. (2017). How has trade between South Africa and China evolved over the past decade? *Transnational Corporations Review, 9*(2), 97-111. doi:10.1080/19186444.2017.1326721

Narayanan, G.B., Aguiar, A., & McDougall, R. (2015). *Global trade, assistance, and production: The GTAP 9 Data Base*. Center for Global Trade Analysis. Purdue University. https://www.gtap.agecon.purdue.edu/databases/v9/v9 doco.asp.

Narayanan, G.B., Ciuriak, D., & Singh, H.V. (2016). *Quantifying the mega-regional trade agreements: A review of the models.* In TPP and India: Implications of Mega-Regionals for Developing Economies. https://www.iisd.org/publications/quantifying-mega-regional-trade-agreements-review-models

Narayanan, G.B., & Walmsley, T. (2008). *The GTAP 7 Data Base*. Center for Global Trade Analysis, Purdue University. https://www.gtap.agecon.purdue.edu

National Skills Authority (NSA). (2019). Report on the Evaluation of the National Skills Development Strategy (NSDS III) 2011-2016. https://www.nationalskillsauthority.org.za

Njike, A. (2020). *Trade in value-added and the welfare gains of international fragmentation*. Munich Personal RePEc Archive Paper 100427, Munich. https://ideas.repec.org/p/pra/mprapa/100427.html

Norman, A., & Stiglitz, J.E. (2012). *Good growth and governance in Africa: Rethinking development strategies.* Oxford University Press, New York. https://www8.gsb.columbia.edu/faculty/jstiglitz/sites/jstiglitz/files/2010_Good_Growth_Governance_Africa.pdf

Nuetah J. A., & Xin, X. (2017). Global agricultural trade liberalization: Is Sub-Saharan Africa a gainer or loser? *The Journal of International Trade and Economic Development, 26*(1), 65-88. http://dx.doi.org/10.1080/09638199.2016.1205120

Ofa, S. V., & Karingi, S. (2014). Trade in intermediate inputs and trade facilitation in Africa’s regional integration. *African Development Review, 26*(1), 96-110. https://ideas.repec.org/a/bla/afrdev/v26y2014is1p96-110.html

Organisation for Economic Cooperation and Development. (2013). *Interconnected economies: benefiting from global value chains*, OECD Publishing, Paris. https://www.oecd.org

Ohyama, A., Braguinsky, S., & Murphy, K. (2004). Entrepreneurial ability and market selection in an infant industry. Evidence from the Japanese cotton spinning industry. *Review of Economic Dynamics, 7*, 354-381. https://doi.org/10.1016/j.red.2003.08.002

Okafor, L.E. (2020). Export market destinations, imported intermediates, and productivity: Firm-level evidence from Ghana, *The International Trade Journal*, doi: 10.1080/08853908.2020.1718567

Okamoto Y., & Sjoholm F. (2000). Productivity in the indonesean automotive industry. *ASEAN Economic bulletin, 17*(1), 60 – 73. doi:10.1355/AE17-1F

Opoku, E.E., & Yan, I.K. (2019). Industrialization as driver of sustainable economic growth in Africa. *The Journal of International Trade & Economic Development*, *28*(1), 30-56. doi: 10.1080/09638199.2018.1483416

Pack, H., & Saggi, K. (2006). Is there a case for industrial policy: A critical survey. *World Bank Research Observer, 21*(2), 267-297. doi: 10.1093/wbro/lkl001

Panagariya, A. (2011). A re-examination of the infant industry argument for protection. *Margin: The Journal of Applied Economic Research, 5*(1), 7-30. doi: 10.1177/097380101000500102

Pandey, N., de Coninck, H., & Sagar, A. D. (2022). Beyond technology transfer: Innovation cooperation to advance sustainable development in developing countries. *WIREs Energy and Environment, 11*(2). doi: 10.1002/wene.422

Papaconstantinou, G., Sakurai, N., & Wyckoff, A. (1996). Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries, *OECD Science, Technology and Industry Working Papers*, No. 1996/01. https://doi.org/10.1787/686654085563.

Parada, J.J. (2018). Veblen's imperial Germany and the industrialisation of Latin America*. Journal of Economic Issues, 52* (3) 638-645. doi: 10.1080/00213624.2018.1495987

Park, Y.S., Konge, L., & Artino, A. R. (2020). The positivism paradigm of research. *Academic Medicine, 95*(5), 690-694. doi: 10.1097/ACM.0000000000003093

Paucek, I., Appolloni, E., Pennisi, G., Quaini, S., Gianquinto, G., & Orsini, F. (2020). LED Lighting Systems for Horticulture: Business Growth and Global Distribution. *Sustainability and Agricultural Economics*, *12*(18)*,* 7516. doi.org/10.3390/su12187516

Paul, M., & Kumar, R.A. (2020). *Import intensity of India's manufactured exports-An industry level analysis.* Institute for Studies in Industrial Development. WP 220. https://www.isid.org.in

Pauw, K. (2004). *Functional forms used in CGE models: modelling production and commodity flows.* Background Paper 2003:5. PROVIDE. www.elsenburg.com/provide

Petricevic, O., & Teece, D.J. (2019). The structural reshaping of globalisation: Implications for strategic sectors, profiting from innovation, and the multinational interprise. *Journal of International Business Studies, 50*(9), 1487-1512. doi.org/10.1057/s41267-019-00269-x

Pieterse, D., Farole, T., Odendaal, M., & Steenkamp, A. (2016). *Supporting export competitiveness through port and rail network reforms. A case study of South Africa* (WP 7532). World Bank. https://documents.worldbank.org/curated/en/826871468000289228.

Pigato, M. A., Black, S. J., Dussaux, D. C. R., Mao, Z., Mckenna, J. M., Rafaty, R. M., . . . Touboul, S. (2020). Technology transfer and innovation for low-carbon development, WB. https://openknowledge.worldbank.org/bitstream/handle/10986/33474/9781464815003.pdf?sequence=2

Power, P. (2008). What does the rise of China do for industrialisation in Sub-Saharan Africa? *Review of African Political Economy, 35*(115), 7-22, doi: 10.1080/03056240802011360

Price, G. N., & Elu, J.U. (2014). Does regional currency integration ameliorate macroeconomic shocks in sub-Saharan Africa? The case of the 2008-2009 global financial crisis. *Journal of Economic Studies, 41*(5), 737-750. doi: 10.1108/JES-08-2011-0092

Qadir, U. (2020). Analysing the national tariff policy. *The Pakistan Development Review, 59*(1), 143-149. doi: 10.30541/v59i1pp.143-149

Raffer, K. (2020). Friedrich List and Dutch disease: Two sides of the same coin. *Brazilian Journal of Political Economy, 40*(3), 493-509. doi: 10.1590/0101-31572020-3118

Rahardja, S., & Varela, G. J. (2015). *The role of imported intermediate inputs in the Indonesian economy.* World Bank. https://openknowledge.worldbank.org

Ravikumar, B., Riezman, R. G., & Zhang, Y. (2022). Private Information and Optimal Infant Industry Protection. FRB St. Louis WP No. 2022-13, SSRN. doi.org/10.20955/wp.2022.013

Rekiso, Z. S. (2019). Economics of Late Development and Industrialization: Putting Gebrehiwot Baykedagn (1886–1919) in context. *Cambridge Journal of Economics*, *43*(1), 223-248. https://doi-org.uplib.idm.oclc.org/10.1093/cje/bey001

Rekiso, Z. S. (2020). Trade deficits as development deficits: Case of Ethiopia. *Structural Change and Economic Dynamics, 52*, 344-353. Doi: 10.1016/j.strueco.2019.12.006

Richardson, G.B. (1972). The organisation of industry. *Economic Journal, 82*(327), 883-896. doi: 10.2307/2230256.

Roberts, J. (2003). Symposium on infant industries. *Oxford Development Studies, 31*(1). doi: 10.1080/1360081032000047159

Rodrik, D. (2004). *Industrial Policy for the Twenty-First Century*. Harvard University. http://cemi.ehess.fr/docannexe/file/2738/rodrik_2004.pdf

Rodrik, D. (2008). Understanding South Africa's economic puzzles. *Economics of Transition, 16*(4), 769-797. doi: 10.1111/j.1468-0351.2008.00343.x

Romer, P. M. (1994). The origins of endogenous growth. *Journal of Economic Perspectives, 8*(1), 3-22. https://search-proquest-com.uplib.idm.oclc.org/

Rutherford, T.F., & Tarr, D.G. (2002). Trade liberalization, product variety and growth in a small open economy: a quantitative assessment. *Journal of International Economics 56*(2)*,* 247–272. https://doi.org/10.1016/S0022-1996(01)00121-0

Ruzekova, V., Kittova, Z., & Steinhauser, D. (2020). Export performance as a measure of competitiveness. *Journal of Competitiveness, 12*(1), 145-160. doi: 10.7441/joc.2020.01.09

Salim, R. A., & Hossain, M.A. (2011). The linkage between export and income: Further evidence from Bangladesh. *Singapore Economic Review, 56*(1) 79–95. doi: 10.1142/S0217590811004110

Saliminezhad, A., & Lisaniler, F. (2018). Validity of unbalanced growth theory and sectoral investment priorities in Indonesia: Application of feature ranking methods. *The Journal of International Trade & Economic Developmen*t, *27*(5), 521-540. doi: 10.1080/09638199.2017.1398270

Santos-Paulino, A., & Thirlwall, A. P. (2004). The impact of trade liberalisation on exports, imports and the balance of payments of developing countries*. Economic Journal, 114*(493), 50-72. https://doi-org.uplib.idm.oclc.org/10.1111/j.0013-0133.2004.00187.x

Saure, P. (2007). Revisiting the infant industry argument. *Journal of Development Economics, 84*(1), 104-117. doi:10.1016/j.jdeveco.2006.10.001

Schott, J.J., Kotschwar, B. & Muir, J. (2013). *Understanding the Trans-Pacific Partnership*. Peterson Institute for International Economics. https://ideas.repec.org/b/iie/ppress/6727.html

Sercovich, F.C., & Teubal, M. (2013). An evolutionary view of the infant industry argument. *Technology Analysis and Strategic Management, 25*(7), 799-815. doi: 10.1080/09537325.2013.815713

Small Enterprise Development Agency. (2020). Annual review, 2019. https://www.seda.org.za

Shahbaz, M., Shahzad, S.J.H., Alam, S., & Apergis, N. (2018). Globalisation, economic growth and energy consumption in the BRICS region: The importance of asymmetries. *The Journal of International Trade & Economic Development, 27*(8), 985-1009. doi: 10.1080/09638199.2018.1481991

Sharma, C., & Mishra, R. K. (2022). Imports, technology, and employment: Job creation or creative destruction. *Managerial and Decision Economics, 43*(4). doi.org/10.1002/mde.3671

Shen, J., Dunn, D., & Shen, Y. (2007). Challenges facing U.S. manufacturing and strategies. *Journal of Industrial Technology, 23*(2), 2-10. https://www.iastatedigitalpress.com/jtmae/article/id/14218/

Shin, N., Kraemer, K.L., & Dedrick, J. (2012). Value Capture in the Global Electronics Industry: Empirical Evidence for the "Smiling Curve" Concept. *Industry and Innovation,19(*2), 89-107. doi: 10.1080/13662716.2012.650883

Simachev, Y., Kuzyk, M., & Zudin, N. (2016). Import dependence and import substitution in Russian manufacturing: A business viewpoint. *Foresight and STI Governance, 10*(4), 25-45. doi: 10.17323/1995-459X.2016.4.25.45.

Slaughter, M.J. (2004). *Infant-industry protection and trade liberalization in developing countries*. USAID's Bureau of Economic Growth, Agriculture and Trade. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.630.4966&rep=rep1&type=pdf

Smith, A. (1776). *An Inquiry into the nature and causes of the Wealth of Nations*. Metalibri digital library. https://www.ibiblio.org/ml/libri/s/SmithA_WealthNations_p.pdf

Smith, A., & Venables, A.J. (1988). Completing the internal market in the European community: some industry simulations. *European Economic Review, 32*(7), 1501-25. https://pdf.sciencedirectassets.com/271652

Soeng, R., & Cuyvers, L. (2018). Domestic institutions and export performance: Evidence for Cambodia. *The Journal of International Trade & Economic Development, 27*(4), 389-408. doi: 10.1080/09638199.2017.1386230

Somwaru, A. L. (2013). Does trade liberalization and its associated increased economic activity affect permanently the value and pattern of trade flows*. Applied Economics, 45*, 3263-3277. http://dx.doi.org/10.1080/00036846.2012.703312

Sousa, F.J., (2010). Metatheories in research: Positivism, postmodernism, and critical realism. *Advances in Business Marketing and Purchasing, 16*, 455-503. doi: 10.1108/S1069-0964(2010)0000016012

Stefan, A. S. (2012). A review of Free trade under fire, by Douglas Irwin*. Romanian Journal of Political Science, 12*(2), 130-134. https://www.sar.org.ro/polsci

Stern, M., & Ramkolowan, Y. (2021). Understanding South Africa's trade policy and performance. ERSA. econrsa.org/system/files/publications/policy_papers/policy_paper_26.pdf.

Stiglitz, J. (2017). *Strategies, policies, institutions and financing, Industrialise Africa*. African Development Bank Group. http://www.afdb.org/

Strange, G. (2020). Debating free international trade. *American Journal of Economics and Sociology, 79*(1), 25-47. doi: 10.1111/ajes.12310

Subramanian, A., & Jonsson, G. (2001). Dynamic gains from trade: evidence from South Africa. *IMF Staff Papers, 48*(1), 197-224. doi: 10.5089/9781451846461.001

Sultanuzzaman, R., Fan, H., Mohamued, E.A., Hossain, I., & Islam, M.A. (2019). Effects of export and technology on economic growth: Selected emerging Asian economies. *Economic Research-Ekonomska Istraživanja, 32*(1), 2515-2531. doi: 10.1080/1331677X.2019.1650656

Sutherland E. (2020). The fourth industrial revolution – The case of South Africa. *South African Journal of Political Studies, 47*(4), 1-20. doi.org/10.1080/02589346.2019.1696003

Suwanprasert, W. (2017). A note on Jobs, Jobs, Jobs: A New Perspective on Protectionism of Costinot (2009). *Economics Letters, 157*, 163–166. doi: 10.1016/j.econlet.2017.05.036

Takii, S. (2019). *Imported intermediate inputs and plants' export dynamics. Evidence from Indonesian plant-product-level data.* Economic Research Institute for ASEAN and East Asia DP. http://hdl.handle.net/11540/9798

Tampubolon J., & Nababan T.S. (2022). ASEAN's factory economy in the fourth industrial revolution era. *Economy of regions*, *18*(1), 49-63. https://doi.org/10.17059/ekon.reg.2022-4-4.

Tanaka, Mi. (2017). *Exporting Sweatshops? Evidence from Myanmar*. https://ies.keio.ac.jp/upload/20171020appliedpaper-2.pdf

Tedelex Trading to shut down factory. (2010, March). The Eyewitness News. Retrieved from https://ewn.co.za/2010/03/15/Tedelex-Trading-to-shut-down-factory

The Department of Trade and Industry (2017). *The DTI annual report, 2016/2017*. https://www.thedti.gov.za

The business research company. (2022). The global general electronic components market report. Retrieved from https://www.thebusinessresearchcompany.com/report/general-electronic-components-market

Thierfelder, K., & McDonald, S. (2012). Globe *v1: A SAM based global CGE model using GTAP data.* Departmental Working Papers United States Naval Academy Department of Economics. https:// EconPapers.repec.org/RePEc:usn:usnawp:39.

Thurlow, J., & van Seventer, D. E. (2002). *A standard computable general equilibrium model for South Africa.* Trade and Macroeconomics Division, International Food Policy Research Institute. http://www.cgiar.org/ifpri/divs/tmd/dp.htm

Timmer, M. P., Los, B., Stehrer, R., & de Vries, G. J. (2013). Fragmentation, incomes and jobs: An analysis of European competitiveness. *Economic Policy, 28*(76), 613-661. Doi: 10.1111/1468-0327.12018

Torreggiani, S., & Andreoni, A. (2019). Dancing with dragons: Chinese import penetration and the performances of manufacturing firms in South Africa, UNU-WIDER Working Paper No. 2019/63. doi.org/10.35188/UNU-WIDER/2019/697-5

Torreggiani, S., & Andreoni, A. (2022). Rising to the challenge or perish? Chinese import penetration and its impact on growth dynamics of manufacturing firms in South Africa. SSRN. doi.org/10.2139/ssrn.4112040

United Nations. (2019). *World Economic Situation and Prospects*. Retrieved from https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP2019_BOOK-ANNEX-en.pdf

United Nations Conference on Trade and Development. (2020). *Country classification*. https://unctadstat.unctad.org/en/classifications.html

United Nations Conference on Trade and Development. (2021). Technology and innovation report 2021. Catching technological waves, innovation with equity. https://unctad.org/system/files/official-document/tir2020_en.pdf

United Nations Industrial Development Organisation. (2020). Industrial development report. https://www.unido.org/resources-publications-flagship-publications-industrial-development-report-series/idr2020

United Nations Statistics Department. (2018). Classification by Broad Economic Categories Rev.5. https://unstats.un.org/unsd/trade/classifications/SeriesM_53_Rev.5_17-01722-E-Classification-by-Broad-Economic-Categories_PRINT.pdf

Van Biesebroeck, J. (2005). Exporting raises productivity in Sub-Saharan African manufacturing firms. *Journal of International Economics, 67,* 373-391. doi:10.1016/j.jinteco.2004.12.002

Van de Groenendaal, H. (2016). *The electronics industry has a great future in South Africa.* Electronics South Africa. EE Publishers. https://www.ee.co.za/article/electronics-industry-great-future-sa.html.

Van Meijl, H., & Van Tongeren, F. (1999). *Endogenous international technology spillovers and biased technical change in the GTAP model*. Global Trade Analysis Project. https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=318

Wade, R. (2014). *Development strategies in a globalised world: Policymaking in an evolving framework of global governance*. UNCTAD. https://www.unctad.org

Wade, R., & Lall, S. (2003). Symposium on infant industries. *Oxford Development Studies, 31*(1), 3-18. doi: 10.1080/1360081032000047159

Warburton, C.E.S. (2010). International trade law and trade theory. *Journal of International Trade Law and Policy, 9*(1), 64-68. doi: 10.1108/14770021011029618

Weiss, J. (2018). Lewis on industrialisation and industrial policy. *Journal of International Development, 30*, 61-79. doi: 10.1002/jid

Wild, S. (2018, September 7). *South Africa is launching a new satellite to monitor our seas*. Business Insider SA. Retrieved from https://www.businessinsider.co.za

Winters, L.A., & Masters, A. (2013). Openness and growth: Still an open question? *Journal of International Development, 25*(8), 1061-1070. doi: 10.1002/jid.2973

World Bank. (2018). South Africa economic update. https://pubdocs.worldbank.org/en/798731523331698204/South-Africa-Economic-Update-April-2018.pdf

World Trade Organisation. (2022). World tariff profiles. https://www.wto.org/statistics

Wu, M. (2012). Antidumping in Asia's emerging giants. *Harvard International Law Journal, 53*(1), 1-84. doi/10.3316/agispt.20122335

Wu, W.-C. (2019). Big government sentiment and support for protectionism in East Asia. *International Political Science Review*, *40*(1), 73-89. https://doi.org/10.1177/0192512116682359

Xu, B. (2006). Infant industry and political economy of trade protection. *Pacific Economic Review, 11*(3), 363-378. doi: 10.1111/j.1468-0106.2006.00320.x

Xu, J., & Cao, Y. (2019). Innovation, the flying geese model, IPR protection, and sustainable economic development in China. *Sustainability*, *11*(20), 5707. doi: 10.3390/su11205707

Xu, J., & Mao, Q. (2018). On the relationship between intermediate input imports and export quality in China. *Economics of Transition and Instutional Change, 26*(3), 429-467. doi: 10.1111/ecot.12155

Yole Development. (2017). Horticultural LED lighting: Market, industry and technology trends. Market and Technology Report. https://s3.i-micronews.com/uploads/2017/11/Flyer-Horticultural-LED-Lighting-Market-Industry-and-Technology-Trends-.pdf

Yong, L. (2017). *Industrialise Africa: Strategies, policies, institutions and financing.* African Development Bank Group. https://www.afdb.org

Young, A. (1991). Learning by doing and the dynamic effects of international trade*. The Quarterly Journal of Economics, 106*(2), 369-405. https://web.a.ebscohost.com.

Yu, H., Zhang, J., Zhang, M., & Fan, F. (2022). Cross-national knowledge transfer, absorptive capacity, and total factor productivity: the intermediary effect test of international technology spillover. *Technology Analysis & Strategic Management, 34*(6), 625-640. doi: 10.1080/09537325.2021.1915476

Yu, M. (2015). Processing trade, tariff reductions and firm productivity: Evidence from Chinese firms. *The Economic Journal, 125*(585), 943-988. doi: 10.1111/ecoj.12127

Zhang, J. (2020). International production fragmentation, trade in intermediate goods and environment. *Economic Modelling, 87*, 1-7. doi.org/10.1016/j.econmod.2019.06.015

Zhong, R.Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: A review. *Engineering 3,* 616-630. doi.org/10.1016/J.ENG.2017.05.015

Appendix A

A1: Detailed sectoral list

Number	Code	Description
1	Pdr	Rice: seed, paddy (not husked)
2	wht	Wheat: seed, other
3	gro	Other Grains: maize (corn), sorghum, barley, rye, oats, millets, other cereals
4	v_f	Veg & Fruit: vegetables, fruit and nuts, edible roots and tubers, pulses
5	osd	Oil Seeds: oil seeds and oleaginous fruit
6	c_b	Cane & Beet: sugar crops
7	pfb	Fibres crops
8	ocr	Other Crops: stimulant; spice and aromatic crops; forage products; plants and parts of plants used primarily in perfumery, pharmacy, or for insecticidal, fungicidal or similar purposes; beet seeds (excluding sugar beet seeds) and seeds of forage plants; natural rubber in primary forms or in plates, sheets or strip, living plants; cut flowers and flower buds; flower seeds, unmanufactured tobacco; other raw vegetable materials nec
9	ctl	Cattle: bovine animals, live, other ruminants, horses and other equines, bovine semen
10	oap	Other Animal Products: swine; poultry; other live animals; eggs of hens or other birds in shell, fresh; reproductive materials of animals; natural honey; snails, fresh, chilled, frozen, dried, salted or in brine, except sea snails; edible products of animal origin n.e.c.; hides, skins and furskins, raw; insect waxes and spermaceti, whether or not refined or coloured
11	rmk	Raw milk
12	wol	Wool: wool, silk, and other raw animal materials used in textile
13	frs	Forestry: forestry, logging and related service activities
14	fsh	Fishing: hunting, trapping and game propagation including related service activities, fishing, fish farms; service activities incidental to fishing
15	coa	Coal: mining and agglomeration of hard coal, lignite and peat
16	oil	Oil: extraction of crude petroleum, service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	Gas: extraction of natural gas, service activities incidental to oil and gas extraction excluding surveying (part)
18	oxt	Other Mining Extraction (formerly omn): mining of metal ores; other mining and quarrying
19	cmt	Cattle Meat: fresh or chilled; meat of buffalo, fresh or chilled; meat of sheep, fresh or chilled; meat of goat, fresh or chilled; meat of camels and camelids, fresh or chilled; meat of horses and other equines, fresh or chilled; other meat of mammals, fresh or chilled; meat of mammals, frozen; edible offal of mammals, fresh, chilled or frozen

Number	Code	Description
20	omt	Other Meat: meat of pigs, fresh or chilled; meat of rabbits and hares, fresh or chilled; meat of poultry, fresh or chilled; meat of poultry, frozen; edible offal of poultry, fresh, chilled or frozen; other meat and edible offal, fresh, chilled or frozen; preserves and preparations of meat, meat offal or blood; flours, meals and pellets of meat or meat offal, inedible; greaves
21	vol	Vegetable Oils: margarine and similar preparations; cotton linters; oil-cake and other residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes; animal fats
22	mil	Milk: dairy products
23	pcr	Processed Rice: semi- or wholly milled, or husked
24	sgr	Sugar and molasses
25	ofd	Other Food: prepared and preserved fish, crustaceans, molluscs and other aquatic invertebrates; prepared and preserved vegetables, pulses and potatoes; prepared and preserved fruits and nuts; wheat and meslin flour; other cereal flours; groats, meal and pellets of wheat and other cereals; other cereal grain products (including corn flakes); other vegetable flours and meals; mixes and doughs for the preparation of bakers' wares; starches and starch products; sugars and sugar syrups n.e.c.; preparations used in animal feeding; lucerne (alfalfa) meal and pellets; bakery products; cocoa, chocolate and sugar confectionery; macaroni, noodles, couscous and similar farinaceous products; food products n.e.c.
26	b_t	Beverages and Tobacco products
27	tex	Manufacture of textiles
28	wap	Manufacture of wearing apparel
29	lea	Manufacture of leather and related products
30	lum	Lumber: manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	Paper & Paper Products: includes printing and reproduction of recorded media
32	p_c	Petroleum & Coke: manufacture of coke and refined petroleum products
33	chm	Manufacture of chemicals and chemical products
34	bph	Manufacture of pharmaceuticals, medicinal chemical and botanical products
35	rpp	Manufacture of rubber and plastics products
36	nmm	Manufacture of other non-metallic mineral products
37	i_s	Iron & Steel: basic production and casting
38	nfm	Non-Ferrous Metals: production and casting of copper, aluminium, zinc, lead, gold, and silver
39	fmp	Manufacture of fabricated metal products, except machinery and equipment
40	ele	Manufacture of computer, electronic and optical products
41	eeq	Manufacture of electrical equipment
42	ome	Manufacture of machinery and equipment n.e.c.
43	mvh	Manufacture of motor vehicles, trailers and semi-trailers
44	otn	Manufacture of other transport equipment
45	omf	Other Manufacturing: includes furniture
46	ely	Electricity; steam and air conditioning supply

Number	Code	Description
47	gdt	Gas manufacture, distribution
48	wtr	Water supply; sewerage, waste management and remediation activities
49	cns	Construction: building houses factories offices and roads
50	trd	Wholesale and retail trade; repair of motor vehicles and motorcycles
51	afs	Accommodation, Food and service activities
52	otp	Land transport and transport via pipelines
53	wtp	Water transport
54	atp	Air transport
55	whs	Warehousing and support activities
56	cmn	Information and communication
57	ofi	Other Financial Intermediation: includes auxiliary activities but not insurance and pension funding
58	ins	Insurance (formerly isr): includes pension funding, except compulsory social security
59	rsa	Real estate activities
60	obs	Other Business Services nec
61	ros	Recreation & Other Services: recreational, cultural and sporting activities, other service activities; private households with employed persons (servants)
62	osg	Other Services (Government): public administration and defense; compulsory social security, activities of membership organizations n.e.c., extra-territorial organizations and bodies
63	edu	Education
64	hht	Human health and social work
65	dwe	Dwellings: ownership of dwellings (imputed rents of houses occupied by owners)

Available from https://www.gtap.agecon.purdue.edu/databases/v10/v10_sectors.aspx

Appendix B

B1: Sets as adopted in the GTAP model

Sets	
NSAV_COMM	Non-Savings Commodities (NS)
TRAD_COMM	Traded Commodities (TC)
DEMD_COMM	Demanded Commodities (DC)
PROD_COMM	Produced Commodities (PC)
ENDW_COMM	Endowment Commodities (EC)
ENDWS_COMM	Sluggish Endowment Commodities (ECS)
ENDWM_COMM	Mobile Endowment Commodities (ECM)
CGDS_COMM	Capital Goods Commodities ("cgds")
ENDWC_COMM	Capital Endowment Commodity ("capital")

Subsets	
PROD_COMM	in NSAV_COMM
DEMD_COMM	in NSAV_COMM
CGDS_COMM	in NSAV_COMM
ENDW_COMM	in DEMD_COMM
TRAD_COMM	in DEMD_COMM
TRAD_COMM	in PROD_COMM
CGDS_COMM	in PROD_COMM
ENDWS_COMM	in ENDW_COMM
ENDWM_COMM	in ENDW_COMM
ENDWC_COMM	in NSAV_COMM
ENDWC_COMM	in ENDW_COMM

B2: Value flows

Value flows evaluated at agents' prices

$EVOA_{ir}$ value of endowment commodity i output or supplied, in region r, evaluated at agent's prices

$EVOA_{i,r} = PS_{i,r} * QO_{i,r}$ *with i = ENDW_COMM and r = REG*

$EVFA_{ijr}$ value of purchases of demanded commodity i by firms in sector j, in region r, evaluated at agent's prices

$EVFA_{ijr} = PFE_{ijr} * QFE_{ijr}$ *i = TRAD_COMM; j = ENDW_COMM; r = REG*

$VDFA_{ijr}$ value of purchases of domestic tradeable commodity i by firms in sector j of region r evaluated at agents' prices

$VDFA_{ijr} = PFD_{ijr} * QFD_{ijr}$ *i = TRAD_COMM; j = ENDW_COMM; r = REG*

$VIFA_{ijr}$ value of purchases of imported tradeable commodity i by firms in sector j of region r evaluated at agents' prices

$VIFA_{ijr} = PFM_{ijr} * QFM_{ijr}$ *i = TRAD_COMM; j = ENDW_COMM; r = REG*

$VDPA_{ir}$ value of expenditure on domestic tradable commodity i, by private household in region r evaluated at agent's prices

$VDPA_{ir} = PPD_{ir} * QPD_{ir}$ *i = TRAD_COMM; r = REG*

$VIPA_{ir}$ value of expenditure on imported tradeable commodity i by firms in sector j of region r evaluated at agents' prices

$VIPA_{ir} = PPM_{ir} * QPM_{ir}$ *i = TRAD_COMM; r = REG*

$VDGA_{i}$ value of government's expenditure on domestic tradable commodity i, in region r, evaluated at agent's prices

$VDGA_{ir} = PGD_{ir} * QGD_{ir}$ *i = TRAD_COMM; r = REG*

$VIGA_{i}$ value of government's expenditure on imported tradable commodity i, in region r, evaluated at agent's prices

$\mathbf{VIGA_{ir} = PGM_{ir} * QGM_{ir}}$ *i = TRAD_COMM; r = REG*

$\mathbf{SAVE_r}$ value of (net) savings in region r

$\mathbf{SAVE_r = PSAVE_r * QSAVE_r}$ *r = REG*

$\mathbf{VKB_r}$ value of beginning-of-period capital stock in region r

$\mathbf{VKB_r = PCGDS_r * KB_r}$ *r = REG*

$\mathbf{VDEP_r}$ value of capital depreciation expenditure in region r

$\mathbf{VDEP_r = PCGDS_r * KB_r}$ *r = REG*

Value flows evaluated at market prices

$\mathbf{VFM_{ijr}}$ value of purchases of endowment commodity i by firms in sector j in region r, evaluated at market prices

$\mathbf{VFM_{ijr} = PM_{ir} * QFE_{ijr}}$ *i = ENDWM_COMM; j = PROD_COMM; r = REG*

$\mathbf{VFM_{ijr} = PMES_{ijr} * QFE_{ijr}}$ *i = ENDWS_COMM; j = PROD_COMM; r = REG*

$\mathbf{VDFM_{ijr}}$ value of purchases of domestic tradable commodity i by firms in sector j in region r, evaluated at market prices

$\mathbf{VDFM_{ijr} = PM_{ir} * QFD_{ijr}}$ *i = TRAD_COMM; j = PROD_COMM*

$\mathbf{VIFM_{ijr}}$ value of purchases of imported tradable commodity i by firms in sector j in region r, evaluated at market prices

$\mathbf{VIFM_{ijr} = PIM_{ir} * QFM_{ijr}}$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

$\mathbf{VDPM_{ir}}$ value of private household's purchases of domestic tradable commodity i in region r, evaluated at market prices

$\mathbf{VDPM_{ir} = PM_{ir} * QPD_{ir}}$ *i = TRAD_COMM; r = REG*

$\mathbf{VIPM_{ir}}$ value of private household's purchases of imported tradable commodity i in region r, evaluated at market prices

$\mathbf{VIPM_{ir} = PIM_{ir} * QPM_{ir}}$ *i = TRAD_COMM; r = REG*

$\mathbf{VDGM_{ir}}$ value of government's expenditure on domestic tradable commodity i, in region r, evaluated at market prices

$\mathbf{VDGM_{ir} = PM_{ir} * QGD_{ir}}$ *i = TRAD_COMM; r = REG*

$\mathbf{VIGM_{ir}}$ value of government's expenditure on imported tradable commodity i, in region r, evaluated at market prices

$\mathbf{VIGM_{ir} = PIM_{ir} * QGM_{ir}}$ *i = TRAD_COMM; r = REG*

$\mathbf{VXMD_{irs}}$ value of exports of tradable commodity i from source r to destination s, evaluated at (exporter's) market prices

$\mathbf{VXMD_{irs} = PM_{ir} * QXS_{irs}}$ *i = TRAD_COMM; r = REG; s= REG*

$\mathbf{VIMS_{irs}}$ value of imports of tradable commodity i from source r to destination s, evaluated at (importer's) market prices

$\mathbf{VIMS_{irs} = PMS_{ir} * QXS_{irs}}$ *i = TRAD_COMM; r = REG; s = REG*

$\mathbf{VST_{ir}}$ value of sales of tradable commodity i to the international transport sector in region r, evaluated at market prices

$\mathbf{VST_{ir} = PM_{ir} * QST_{ir}}$ *i = MARG_COMM; r = REG*

Value flows evaluated at world prices

$VXWD_{irs}$ value of exports of tradable commodity i from source r to destination s, evaluated at world (fob) prices

$\mathbf{VXWD_{irs} = PFOB_{irs} * QXS_{irs}}$ *i = TRAD_COMM; r = REG; s = REG*

$VIWS_{irs}$ value of imports of tradable commodity i from source r to destination s, evaluated at world (cif) prices

$\mathbf{VIWS_{irs} = PCIF_{irs} * QXS_{irs}}$ *i = TRAD_COMM; r = REG; s = REG*

Value Flows

VOA_{ir} value of non-saving commodity i output or supplied in region r evaluated at agents' prices

$\mathbf{VOA_{ir} = EVOA_{ir}}$ *i = ENDW_COMM; r = REG*

$\mathbf{VOA_{ir} = S_j VFA_{jir}}$ *i = PROD_COMM; j = DEMD_COMM; r = REG*

VFA_{ijr} value of purchases of demanded commodity i by firms in sector j of regin r evaluated at agents' prices

$\mathbf{VFA_{ijr} = EVFA_{ijr}}$ *i = ENDW_COMM; j = PROD_COMM; r = REG*

$\mathbf{VFA_{ijr} = VDFA_{ijr} + VIFA_{ijr}}$ *i =TRAD_COMM; j = PROD_COMM; r = REG*

VOM_{ir} value of non-saving commodity i output or supplied in region r evaluated at market prices

$\mathbf{VOM_{ir} = S_j VFM_{ijr}}$ *i = ENDW_COMM;j = PROD_COMM; r = REG*

$\mathbf{VOM_{ir} = VDM_{ir} + VST_{ir} + S_s VXMD_{irs}}$ *i = MARG_COMM; r = REG; s = REG*

$\mathbf{VOM_{ir} = VDM_{ir} + S_s VXMD_{irs}}$ *i = NMRG_COMM; r = REG; s = REG*

$\mathbf{VOM_{ir} = VOA_{ir}}$ *i = CGDS_COMM; r = REG*

VDM_{ir} value of domestic sales of tradable commodity i in region r evaluated at market prices

$VDM_{ir} = VDPM_{ir} + VDGM_{ir} + S_j VDFM_{ijr}$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

VIM_{ir} value of aggregate imports of tradable commodity i in region r evaluated at market prices

$VIM_{ir} = VIPM_{ir} + VIGM_{ir} + S_j VIFM_{ijr}$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

VPA_{ir} value of private household expenditure on tradable commodity i in region r evaluated at agents' prices

$VPA_{ir} = VDPA_{ir} + VIPA_{ir}$ *i = TRAD_COMM; r = REG*

$PRIVEXP_r$ total consumption expenditure by private household in regin r

$PRIVEXP_r = S_i VPA_{ir}$ *i = TRAD_COMM*

VGA_{ir} value of government expenditure on tradable commodity i in region r evaluated at agents' prices

$VGA_{ir} = VDGA_{ir} + VIGA_{ir}$ *i = TRAD_COMM; r = REG*

$GOVEXP_r$ total consumption expenditure by government in region r

$GOVEXP_r = S_i VGA_{ir}$ *i = TRAD_COMM; r = REG*

$INCOME_r$ total expenditure equals net income in region r

$INCOME_r = PRIVEXP_r + GOVEXP_r + SAVE_r$ *r = REG*

$REGINV_r$ gross investment in region r that equals value of output of "capital goods" sector

$REGINV_r = S_k VOA_{kr}$ *k = CGDS_COMM*

$NETINV_r$ net investment in region r

$NETINV_r = S_k VOA_{kr} - VDEP_r$ *k = CGDS_COMM*

GLOBINV global net investment

$$\mathbf{GLOBINV = S_r NETINV = S_r SAVE_r} \qquad r = REG$$

INVKERATIO$_r$ ratio of gross investment to end-of-period capital stock in region r

$$\mathbf{INVKERATIO_r = REGINV_r / (VKB_r + NETINV_r)} \qquad r = REG$$

GRNETRATIO$_r$ ratio of gross to net rate of return on capital in regin r (VOA$_{capital,r}$ is gross return to capital)

$$\mathbf{GRNETRATIO_r = S_k VOA_{kr} / (S_k VOA_{kr} - VDEP_r)} \qquad with\ k = ENDWC\_COMM;\ r = REG$$

GDP$_r$ gross domestic product in region r (trade is valued at worl prices)

$$\mathbf{GDP_r = S_i VPA_{ir} + S_i VGA_{ir} + S_k VOA_{kr} + S_i S_s VXWD_{irs} + S_m VST_{ms} - S_i S_s VIWS_{irs}} \qquad i = TRAD\_COMM;\ k = CGDS\_COMM;\ r = REG;\ s = REG$$

VT international margin suply

$$\mathbf{VT = S_i S_r VST_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

VXW$_{ir}$ value of exports of tradable commodity i from source r evaluated at world (fob) prices

$$\mathbf{VXW_{ir} = S_s VXWD_{irs} + VST_{ir}} \qquad i = MARG\_COMM;\ r = REG$$

$$\mathbf{VXW_{ir} = S_s VXWD_{irs}} \qquad i = NMRG\_COMM;\ r = REG$$

VXWREGION$_r$ value of exports from source r evaluated at world (fob) prices

$$\mathbf{VXWREGION_r = S_i VXW_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

VXWCOMMOD$_i$ value of exports of tradable commodity i evaluated at world (fob) prices

$$\mathbf{VXWCOMMOD_i = S_r VXW_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

VIW$_{ir}$ value of imports of tradable commodity i into region r evaluated at world (cif) prices

$$\mathbf{VIW_{ir} = S_s VIWS_{isr}} \qquad i = TRAD\_COMM;\ r = REG;\ s = REG$$

VIWREGION$_r$ value of imports into region r evaluated at world (cif) prices

VIWREGION $_r$ **=** S_i**VIW** $_{ir}$ *i = TRAD_COMM; r = REG*

VIWCOMMOD $_i$ value of imports of tradable commodity i evaluated at world (cif) prices

VIWCOMMOD $_i$**=** S_r**VIW** $_{ir}$ *i = TRAD_COMM; r = REG*

VXWLD value of worldwide commodity exports evaluated at world (fob) prices

VXWLD= S_r**VXWREGION** $_r$ *r = REG*

PW_PM $_{ir}$ ratio of world (fob) to domestic market prices for tradable commodity i in region

PW_PM $_{ir}$ **=** S_s**VXWD** $_{irs}$ **/** S_s**VXMD** $_{irs}$ *i = TRAD_COMM; r = REG; s = REG*

VOW $_{ir}$ value of output of tradable commodity i in region r, evaluated at world (fob) prices

VOW $_{ir}$ **= VDM** $_{ir}$ *** PW_PM** $_{ir}$ **+** S_s**VXWD** $_{irs}$ **+ VST** $_{ir}$ *i = MARG_COMM; r = REG; s = REG*

VOW $_{ir}$ **= VDM** $_{ir}$ *** PW_PM** $_{ir}$ **+** S_s**VXWD** $_{irs}$ *i = NMRG_COMM; r = REG; s = REG*

VWOW $_i$ value of world supply of tradable commodity i evaluated at world (fob) prices

VWOW $_i$ **=** S_r**VOW** $_{ir}$*i = TRAD_COMM; r = REG*

VTMFSD $_{mirs}$ int'l margin usage, by margin, freight, source, and destination

m = MARG_COMM;i = TRAD_COMM; r = REG; s = REG

VTFSD $_{irs}$ aggregate value of svces in the shipment of i from r to s

VTFSD $_{irs}$ = S_m**VTMFSD** $_{mirs}$

In a balanced data base **VIWS** $_{irs}$ = **VXWD** $_{irs}$ **+ VTFSD** $_{irs}$

i = TRAD_COMM; m = MARG_COMM; r = REG; s = REG

VTMPROV $_m$ international margin services provision

VTMPROV $_m$ **=** S_r**VST** $_{mr}$ *m = MARG_COMM; r = REG*

$VTRPROV_r$ international margin supply, by region

$VTRPROV_r = S_m VST_{mr}$ *m = MARG_COMM; r = REG*

$VTMUSE_m$ international margin services usage, by type

$VTMUSE_m = S_i S_r S_s VTMFSD_{mirs}$ *m = MARG_COMM; i = TRAD_COMM; r = s = REG*

In a balanced data base, VTMPROV = VTMUSE

$VTMUSESHR_{mirs}$ share of i,r,s usage in global demand for m

$VTMUSESHR_{mirs} = VTFSD_{irs} / VT$ *m = MARG_COMM; i = TRAD_COMM; r = s = REG*

if **$VTMUSE_m$** <> 0.0 then **$VTMUSESHR_{mirs} = VTMFSD_{mirs} / VTMUSE_m$**

$VTSUPPSHR_{mr}$ share of region r in global supply of margin m

$VTSUPPSHR_{mr} = VTRPROV_r / VT$ if **$VTMPROV_m$** <> 0.0 then **$VTSUPPSHR_{mr} = VST_{mr} / VTMPROV_m$**

m = MARG_COMM; r = REG

VTUSE international margin services usage;

$VTUSE = S_m S_i S_r S_s VTMFSD_{mirs}$ *m = MARG_COMM; i = TRAD_COMM; r = s = REG*

$VWOU_i$ value of world output of i at user prices

$VWOU_i = S_s[(VPA_{is} + VGA_{is}) + S_j VFA_{ijs}]$

s = REG; j = PROD_COMM

$VENDWREG_r$ value of primary factors, at mkt prices, by region

$VENDWREG_r = S_i\ VOM_{ir}$ *i = ENDOW_COMM; r = REG*

VENDWWLD value of primary factors, at mkt prices, worldwide

$VENDWWLD = S_r\ VENDWREG_r$ r = REG

$VPAEV_{ir}$ private household expend. on i in r valued at agent's prices, for EV calculation

$VPAEV_{ir} = qpev_{ir}$ *i = TRAD_COMM, r = REG*

$VPAREGEV_{r}$ private consumption expenditure in region r, for EV calculation

$VPAREGEV_{r} = S_{i}VPAEV_{ir}$ *i = TRAD_COMM, r = REG*

YG_{r} regional government consumption expenditure, in region r *r = REG*

B3: Parameters and elasticities

Technology Parameters

$ESUBVA_{j}$ with *j = PROD_COMM*

substitution parameter between primary factors in the CES value-added nest of the nested CES production function of sector j of all regions

(i.e. elasticity of substitution between primary production factors; for example, in a situation where land doesn't play a role in production, hence labor and capital are the only primary factors, this parameter indicates how sensitive is the K/L ratio to a 1 percent change in the wage/rental ratio)

$ESUBD_{i}$ with *i = TRAD_COMM* substitution parameter between domestic and composite imported commodities in the Armington utility/production structure of agent/sector i in all regions

$ESUBM_{i}$ with *i = TRAD_COMM*

substitution parameter among imported commodities from different sources in the Armington utility/production structure of agent/sector i in all regions.

CDE Preference Parameters and Associated Elasticities

SUBPAR$_{ir}$ with *i = TRAD_COMM; r = REG*

substitution parameter for tradable commodity i in the CDE minimum expenditure function of region r

INCPAR$_{ir}$ with *i = TRAD_COMM*; r = REG

expansion parameter for tradable commodity i in the CDE minimum expenditure function of region r.

ALPHA$_{ir}$ 1 - sub. parameter in the CDE minimum expenditure function

$\mathbf{ALPHA_{ir} = 1 - SUBPAR_{ir}}$ *i = TRAD_COMM; r = REG*

APE$_{ikr}$ Allen partial elst.of sub between composite i and k in r

$\mathbf{APE_{ikr} = ALPHA_{ir} + ALPHA_{kr} - S_n CONSHR_{nr} * ALPHA_{nr}}$ *i = k= n = TRAD_COMM; r = REG*

$\mathbf{APE_{iir} = 2.0 * ALPHA_{ir} - S_n CONSHR_{nr} * ALPHA_{nr} - ALPHA_{ir} / CONSHR_{ir}}$

EY$_{ir}$ income elasticity of private household demand for i in r

$\mathbf{EY_{ir} = (1/S_n\ CONSHR_{nr} * INCPAR_{nr}) * (INCPAR_{ir} * (1.0 - ALPHA_{ir}) + S_n CONSHR_{nr} * INCPAR_{nr} * ALPHA_{nr}) + (ALPHA_{ir} - S_n CONSHR_{nr} * ALPHA_{nr})}$

i = n = TRAD_COMM; r = REG

EP$_{ikr}$ uncompensated cross-price elasticity private household demand for i wrt k in r

$\mathbf{EP_{ikr} = (APE_{ikr} - EY_{ir}) * CONSHR_{kr}}$ *i = k = TRAD_COMM; r = REG*

Mobility Parameter

ETRAE$_i$ with *i = ENDW_COMM*

transformation parameter between uses for a sluggish primary factor i in the one level CET production function

(i.e. this parameter indicates how easy/difficult it is to transfer a sluggish factor (say, capital) from one sector to another; the closer is ETRAE to zero, the more *immobile* is the factor between alternative uses)

RORFLEX$_r$ with *r = REG* flexibility of expected net rate of return on capital stock in region r with respect to investment (if a region's capital stock increases by 1%, then it is expected that the net rate of return on capital will decline by RORFLEX%)

RORDELTA

binary coefficient that determines the mechanism of allocating investment across regions (when RORDELTA=1, investment is allocated across regions to equate the change in the expected rates of return, rore(r), when RORDELTA=0, investment is allocated across regions to maintain the existing composition of capital stocks).

B4: Shares

SHRDFM$_{ijr}$ share of domestic sales of tradable commodity i used by firms in sector j of regin r evaluated at market prices

SHRFM$_{ijr}$ = VDFM$_{ijr}$ / VDM$_{ir}$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

SHRDPM$_i$ share of domestic sales of commodity i used by private household in region r evaluated at market prices

SHRDPM$_{ir}$ = VDPM$_{ir}$ / VDM$_{ir}$ *i = TRAD_COMM; r = REG*

SHRDGM$_i$ share of domestic sales of commodity i used by the government in region r evaluated at market prices

SHRDGM$_{ir}$ = VDGM$_{ir}$ / VDM$_{ir}$ *i = TRAD_COMM; r = REG*

SHRIFM$_{ijr}$ share of aggregate imports of tradable commodity i used by firms in sector j of regin r evaluated at market prices

$$\mathbf{SHRIFM_{ijr} = VIFM_{ijr} / VIM_{ir}} \qquad i = TRAD\_COMM;\ j = PROD\_COMM;\ r = REG$$

SHRIPM$_{ir}$ share of aggregate imports of commodity i used by private household in region r evaluated at market prices

$$\mathbf{SHRIPM_{ir} = VIPM_{ir} / VIM_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

SHRIGM$_{ir}$ share of aggregate imports of commodity i used by the government in region r evaluated at market prices

$$\mathbf{SHRIGM_{ir} = VIGM_{ir} / VIM_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

FMSHR$_{ijr}$ share of imports in the composite for tradable commodity i used by firms in sector j of region r evaluated at agents' prices

$$\mathbf{FMSHR_{ijr} = VIFA_{ijr} / VFA_{ijr}} \qquad i = TRAD\_COMM;\ j = PROD\_COMM;\ r = REG$$

PMSHR$_{ir}$ share of imports in the composite for tradable commodity i used by private household in region r evaluated at agents' prices

$$\mathbf{PMSHR_{ir} = VIPA_{ir} / VPA_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

GMSHR$_{ir}$ share of impotrs in the composite for tradable commodity i used by the government in region r evaluated at agents' prices

$$\mathbf{GMSHR_{ir} = VIGA_{ir} / VGA_{ir}} \qquad i = TRAD\_COMM;\ r = REG$$

CONSHR$_{ir}$ budget share of the composite for tradable i in total private household expenditure in regin r evaluated at agents' prices

$$\mathbf{CONSHR_{ir} = VPA_{ir} / PRIVEXP_{r}} \qquad i = TRAD\_COMM;\ r = REG$$

MSHRS$_{irs}$ market share of source r in the aggregate imports of tradable commodity i in region s evaluated at market prices

$$\mathbf{MSHRS_{irs} = VIMS_{irs} / S_{r}VIMS_{irs}} \qquad i = TRAD\_COMM;\ r = s = REG$$

SVA_{ijr} share of endowment commodity i in value-added of sector j of region r evaluated at agents' prices

$SVA_{ijr} = VFA_{ijr} / S_k VFA_{kjr}$ *i = ENDW_COMM; j = PROD_COMM; k = ENDW_COMM; r = REG*

$REVSHR_{ijr}$ share of endowment commodity i used by fiorms in sector j of regin r evaluated at market prices

$REVSHR_{ijr} = VFM_{ijr} / S_k VFM_{kjr}$ *i = ENDW_COMM; j = PROD_COMM; k = PROD_COMM; r = REG*

$FOBSHR_{irs}$ share of fob price in the cif price for tradable commodity i exported from source r to destination s

$FOBSHR_{irs} = VXWD_{irs} / VIWSCOST_{irs}$ *i = TRAD_COMM; r = s = REG*

$XSHRPRIV_r$ private expenditure share in regional income

$XSHRPRIV_r = PRIVEXP_r / INCOME_r$ *r = REG*

$XSHRGOV_r$ government expenditure share in regional income

$XSHRGOV_r = GOVEXP_r / INCOME_r$ *r = REG*

$XSHRSAVE_r$ saving share in regional income

$XSHRSAVE_r = SAVE_r / INCOME_r$ *r = REG*

$SHRDM_{ir}$ share of domestic sales of i in r *i = TRAD_COMM; r = REG*

$SHRDM_{ir} = VDM_{ir} / VOM_{ir}$

$SHRST_{mr}$ share of sales of m to global transport services in r *m = MARG_COMM; r = REG*

$SHRST_{mr} = VST_{mr} / VOM_{mr}$

$SHRXMD_{irs}$ share of export sales of i to s in r *i = TRAD_COMM; r = s = REG*

$\mathbf{SHRXMD_{irs} = VXMD_{irs} / VOM_{ir}}$ *i = TRAD_COMM; r = s = REG*

$\mathbf{SHREM_{ijr}}$ share of mobile endowments i used by sector j at mkt prices

$\mathbf{SHREM_{ijr}} = \mathbf{VFM_{ijr} / VOM_{ir}}$ *i = ENDWM_COMM; j = PROD_COMM; r = REG*

$\mathbf{TRNSHR_{irs}}$ share of transport price in the cif price for tradable commodity i exported from source r to destination s

$\mathbf{TRSHR_{irs}= VTFSD_{irs} / VIWSCOST_{irs}}$

i = TRAD_COMM; r = s = REG

$\mathbf{XWCONSHR_{ir}}$ expansion-parameter-weighted consumption share

$\mathbf{XWCONSHR_{ir} = CONSHR_{ir}*INCPAR_{ir}/UELASPRIV_{r}}$ *i = TRAD_COMM; r = REG*

$\mathbf{XSHRPRIVEV_{r}}$ private expenditure share in regional income, for EV calculation *r = REG*

$\mathbf{XSHRPRIVEV_{r} = PRIVEXPEV_{r}/INCOMEEV_{r}}$ *r = REG*

$\mathbf{XSHRGOVEV_{r}}$ government expenditure share in regional income, for EV calculation *r = REG*

$\mathbf{XSHRGOVEV_{r} = GOVEXPEV_{r}/INCOMEEV_{r}}$ *r = REG*

$\mathbf{XSHRSAVEEV_{r}}$ saving share in regional income, for EV calculation *r = REG*

$\mathbf{XSHRSAVEEV_{r} = SAVEEV_{r}/INCOMEEV_{r}}$ *r = REG*

$\mathbf{XWCONSHREV_{ir}}$ expansion-parameter-weighted consumption share, for EV calculation

$\mathbf{XWCONSHREV_{ir} = CONSHREV_{ir}*INCPAR_{ir}/UELASPRIVEV_{r}}$ *i = TRAD_COMM, r = REG*

$\mathbf{CONSHREV_{ir}}$ share of private household consn devoted to good i in r, for EV calculation

$\mathbf{CONSHREV_{ir} = VPAEV_{ir}/VPAREGEV_{r}}$

$\mathbf{STC_{ijr}}$ share of i in total costs of j in r

$STC_{ijr} = VFA_{ijr} / S_k VFA_{kjr}$ *i = k = DEMD_COMM; j = PROD_COMM; r = REG*

B5: Quantity variables

QO_{ir} quantity of non-saving commodity i output or supplied in region r

i = NSAV_COMM   r = REG

$QOES_{ijr}$ quantity of sluggish endowment i supplied to sector j firm of region r

i = ENDWS_COMM; j = PROD_COMM; r = REG

QDS_{ir} quantity of domestic sales of tradable commodity i in region r

i = TRAD_COMM; r = REG

QXS_{irs} quantity of exports of tradable commodity i from source r to destination s

i = TRAD_COMM; r = s = REG

QST_{ir} quantity of sales of marginal commodity i to the international transport sector in region r

i = MARG_COMM; r = REG

QFE_{ijr} quantity of endowment i demanded by sector j firm in region r

i = ENDW_COMM; j = PROD_COMM; r = REG

QVA_{jr} quantity index of land-labor-capital composite (value-added) in sector j firm in region r

j = PROD_COMM; r = REG

QF_{ijr} quantity of composite tradable commodity i demanded by sector j firm in region r

i = TRAD_COMM; j = PROD_COMM; r = REG

QFD_{ijr} quantity of domestic tradable i demanded by sector j firm in region r

i = TRAD_COMM; j = PROD_COMM; r = REG

$\mathbf{QFM_{ijr}}$ quantity of imported tradable i demanded by sector j firm in region r

i = TRAD_COMM; j = PROD_COMM; r = REG

$\mathbf{QP_{ir}}$ quantity of composite tradable i demanded by private household in region r

i = TRAD_COMM; r = REG

$\mathbf{QPD_{ir}}$ quantity of domestic tradable i demanded by private household in region r

i = TRAD_COMM; r = REG

$\mathbf{QPM_{ir}}$ quantity of imported tradable i demanded by private household in region r

i = TRAD_COMM; r = REG

$\mathbf{QG_{ir}}$ quantity of composite tradable commodity i demanded by government household in region r

i = TRAD_COMM; r = REG

$\mathbf{QGD_{ir}}$ quantity of domestic tradable commodity i demanded by government household in region r

i = TRAD_COMM; r = REG

$\mathbf{QGM_{ir}}$ quantity of imported tradable commodity i demanded by government household in region r

i = TRAD_COMM; r = REG

$\mathbf{QIM_{ir}}$ quantity of aggregate imports of tradable commodity i demanded by region r using market prices as weights

i = TRAD_COMM; r = REG

$\mathbf{QIW_{ir}}$ quantity of aggregate imports of tradable commodity i demanded by region r using cif prices as weights

i = TRAD_COMM; r = REG

$\mathbf{QXW_{ir}}$ quantity of aggregate exports of tradable commodity i supplied from region r using fob prices as weights *i = TRAD_COMM; r = REG*

$QIWREG_r$ volume of merchandise imports demanded by region r

r = REG

$QXWREG_r$ volume of merchandise exports supplied by region r

r = REG

$QIWCOM_i$ volume of global merchandise imports of tradable commodity i

i = TRAD_COMM; r = REG

$QXWCOM_i$ volume of global merchandise exports of tradable commodity i

i = TRAD_COMM; r = REG

QXWWLD volume of world trade

QOW_i quantity index for world supply of tradable commodity i

i = TRAD_COMM

$EXPAND_{ir}$ Change in investment levels relative to endowment stock

i = ENDWC_COMM; r = REG

$QOWU_{ir}$quantity index for world supply of good i at user prices *i = TRAD_COMM; r = REG*

$QTMFSD_{mirs}$ international usage margin m on i from r to s *m = MARG_COMM; i = TRAD_COMM; r = s = REG*

QTM_m global margin usage *m = MARG_COMM*

$QCGDS_r$ quantity of capital goods sector supplied in region r *r = REG*

$QSAVE_r$ quantity of savings demanded in region r *r = REG*

GLOBALCGDS quantity of global supply of capital for net investment

$KSVCES_r$ quantity of capital services in region r *r = REG*

KB_r quantity of beginning-of-period capital stock in region r *r = REG*

KE_r quantity of end-of-period capital stock in region r *r = REG*

$QGDP_r$ quantity index for GDP in region r *r = REG*

WALRAS_DEM quantity demanded in the omitted market - equals global demand for savings

WALRAS_SUP quantity supplied in the omitted market - equals global supply of new capital goods composite

POP_r population in region r *r = REG*

$COMPVALAD_{ir}$ composition of value added for good i and region r *i = TRAD_COMM; r = REG*

B6: Price variables

PM_{ir} market price of non-saving commodity i in region r

i = NSAV_COMM; r = REG

$PMES_{ijr}$ market price for sluggish endowment i supplied to firm j in region r

i = ENDWS_COMM; j = PROD_COMM; r = REG

PS_{ir} supply price of non-saving commodity i in region r

i = NSAV_COMM; r = REG

PFE_{ijr} demand price for endowment i by firms in sector j of region r

i = ENDW_COMM; j = PROD_COMM; r = REG

PVA_{jr} price of value-added in sector j

j = PROD_COMM; r = REG

PF_{ijr} demand price for composite tradable i by firms in sector j of region r *i = TRAD_COMM; j = PROD_COMM; r = REG*

PFD_{ijr} demand price for domestic tradable i by firms in sector j of region r

i = TRAD_COMM; j = PROD_COMM; r = REG

PFM_{ijr} demand price for imported tradable i by firms in sector j of region r

i = TRAD_COMM; j = PROD_COMM; r = REG

PP_{ir} private household's demand price for composite tradable i in region r

i = TRAD_COMM; r = REG

PPD_{ir} private household's demand price for domestic tradable i in region r

i = TRAD_COMM; r = REG

PPM_{ir} private household's demand price for imported tradable i in region r

i = TRAD_COMM; r = REG

PG_{ir} government household's demand price for composite tradable i in region r

i = TRAD_COMM; r = REG

PGD_{ir} government household's demand price for domestic tradable i in region r

i = TRAD_COMM; r = REG

PGM_{ir} government household's demand price for imported tradable i in region r

i = TRAD_COMM; r = REG

$PSAVE_{r}$ price of savings in region r

r = REG

$PCGDS_{r}$ price of investment good in region r - equals PS(cgds,r)

r = REG

$PGDP_{r}$ price index for GDP in region r

r = REG

PPRIV$_r$ price index for private household expenditure in region r

r = REG

PGOV$_r$ price index for government household expenditure in region r

r = REG

PFOB$_{irs}$ world fob price of tradable commodity i exported from source r to destination s (prior to including transport margins)

i = TRAD_COMM; r = s = REG

PCIF$_{irs}$ world cif price of tradable commodity i imported from source r to destination s) after including transport margins)

i = TRAD_COMM; r = s = REG

PMS$_{irs}$ market price by source of tradable commodity i imported from source r to destination s

i = TRAD_COMM; r = s = REG

PIM$_{ir}$ market price of aggregate imports of tradable commodity i in region r

i = TRAD_COMM; r = REG

PIW$_{ir}$ world price of aggregate imports of tradable commodity i in region r

i = TRAD_COMM; r = REG

PXW$_{ir}$ price index for aggregate exports of tradable commodity i from region r

i = TRAD_COMM; r = REG

PIWREG$_r$ price index of merchandise imports in region r

r = REG

PXWREG$_r$ price index of merchandise exports from region r

r = REG

$PIWCOM_i$ price index of global merchandise imports of tradable commodity i

i = TRAD_COMM

$PXWCOM_i$ price index of global merchandise exports of tradable commodity i

i = TRAD_COMM

PXWWLD price index of world trade

PR_{ir} ratio of domestic market price to market price of imports for tradable commodity i in region r

i = TRAD_COMM; r = REG

PW_i world price index for total supply of tradable commodity i in region r

i = TRAD_COMM

PSW_r price index received for tradable commodities produced in region r including sales of net investment to the global bank

r = REG

PDW_r price index paid for tradable commodities used in region r including purchases of savings from the global bank

r = REG

TOT_r terms of trade for region r

r = REG

PT_m price of margin services supplied

m = MARG_COMM

PCGDSWLD world average price of capital goods (net investment weights)

PWU_i world price index for total good i supplies at user prices

i = TRAD_COMM

PTRANS$_{irs}$ cost index for international transport of i from r to s

i = TRAD_COMM; r = s = REG

RENTAL$_r$ rental rate on capital stock in regin r - equals PS(CGDS,r)

r = REG

RORC$_r$ current net rate of return on capital stock in region r

r = REG

RORE$_r$ expected net rate of return on capital stock in region r

r = REG

RORG global net rate of return on capital stock

P$_r$ price index for disposition of income by regional household

PFACTREAL$_{ir}$ ratio of return to primary factor i to cpi in r

i = ENDOW_COMM; r = REG

PFACTOR$_r$ market price index of primary factors, by region

PFACTWLDworld price index of primary factors

B7: Technical change variables

AO$_{ir}$ output augmenting technical change in sector j of region r

j = PROD_COMM; r = REG

AFE_{ijr} primary factor i augmenting technical change in sector j of region r

i = ENDW_COMM; j = PROD_COMM; r = REG

AF_{ijr} intermediate input i augmenting technical change in sector j of region r

i = TRAD_COMM; j = PROD_COMM; r = REG

AVA_{jr} value-added augmenting technical change in sector j of region r

j = PROD_COMM; r = REG

AMS_{irs} import i from region r augmenting tech change in region s

i = TRAD_COMM, r = s = REG

$AOSEC_{j}$ output tech change of sector j, worldwide

j = PROD_COMM

$AOREG_{r}$ output tech change in region r

r = REG

$AOALL_{jr}$ output augmenting technical change in sector j of r

j = PROD_COMM; r = REG

$ESUBT_{j}$ elasticity of substitution among composite intermediate inputs in production

j = PROD_COMM

$AFCOM_{i}$ intermediate tech change of input i, worldwide

i = TRAD_COMM

$AFSEC_{j}$ intermediate tech change of sector j, worldwide

j = PROD_COMM

$AFREG_{r}$ intermediate tech change in region r

r = REG

$AFALL_{ijr}$ intermediate input i augmenting tech change by j in r

i = TRAD_COMM,j = PROD_COMM; r = REG

$AFECOM_{i}$ factor input tech change of input i, worldwide

i = ENDW_COMM

$AFESEC_{j}$ factor input tech change of sector j, worldwide

j = PROD_COMM

$AFEREG_{r}$ factor input tech change in region r

r = REG

$AFEALL_{ijr}$ primary factor i augmenting tech change sector j in r

i = ENDW_COMM; j = PROD_COMM; r = REG

AMS_{irs} reduction in effective price associated with delivery of i from r to s

i = TRAD_COMM; r = REG; s = REG

$ATMFSD_{mirs}$ tech change in m's shipping of i from region r to s

m = MARG_COMM; i = TRAD_COMM; r = s = REG

ATM_{m} tech change in mode m, worldwide;

m = TRAD_COMM

ATF_{i} tech change shipping of i, worldwide

i = TRAD_COMM

ATS_{r} tech change shipping from region r

r = REG

ATD_{s} tech change shipping to s

s = REG

ATALL$_{mirs}$ tech change in m's shipping of i from region r to s

m = MARG_COMM; i = TRAD_COMM; r = REG; s = REG

AU$_{r}$ input-neutral shift in utility function

r = REG

B8: Policy variables

TO$_{ir}$ power of the tax on output (or income) of non-savings commodity i in region r

i = NSAV_COMM; r = REG

TF$_{ijr}$ power of the tax on endowment commodity i demanded by sector j of regin r

i = ENDW_COMM; j = PROD_COMM; r = REG

TFD$_{ijr}$ power of the tax on domestic tradable commodity i demanded by sector j of region r

i = TRAD_COMM; j = PROD_COMM; r = REG

TFM$_{ijr}$ power of the tax on imported tradable commodity i demanded by sector j of region r

i = TRAD_COMM; j = PROD_COMM; r = REG

TPD$_{ir}$ power of the tax on domestic tradable commodity i purchased by private household in region r

i = TRAD_COMM; r = REG

TPM$_{ir}$ power of the tax on imported tradable commodity i purchased by private household in region r

i = TRAD_COMM; r = REG

TGD$_{ir}$ power of the tax on domestic tradable commodity i purchased by government household in region r

i = TRAD_COMM; r = REG

TGM_{ir} power of the tax on imported tradable commodity i purchased by government household in region r

i = TRAD_COMM; r = REG

TXS_{irs} power of the tax on exports of tradable commodity i from source r to destination r (levied in region r)

i = TRAD_COMM; r = s = REG

TMS_{irs} power of the tax on imports of tradable commodity i from source r to destination s (levied in region s)

i = TRAD_COMM; r = s = REG

TX_{ir} power of the variable export tax on exports of tradable commodity from region r - destination generic

i = TRAD_COMM; r = REG

TM_{ir} power of the variable import tax (levy) on imports of tradable commodity i in region s - source generic

i = TRAD_COMM; r = REG

TP_r region-wide shock to tax on purchases by private household in region r

r = REG

$ATPM_{ir}$ actual tax on imported traded commodity i purchased by private households in region r

i = TRAD_COMM; r = REG

$ATPD_{ir}$ actual tax on domestic traded commodity i purchased by private households in region r

i = TRAD_COMM; r = REG

$DGTAX_{ir}$ tax on government consumption of domestic good i in region r

r = REG

$IGTAX_{ir}$ tax on government consumption of imported good i in region r

r = REG

TGC_r government consumption tax payments in r

$TGC_r = S_i DGTAX_{ir} + IGTAX_{ir}$ *i = TRAD_COMM; r = REG*

$DPTAX_{ir}$ tax on private consumption of domestic good i in region r

$DPTAX_{ir} = VDPA_{ir} - VDPM_{ir}$ *i = TRAD_COMM; r = REG*

$IPTAX_{ir}$ tax on private consumption of imported good i in region r

$IPTAX_{ir} = VIPA_{ir} - VIPM_{ir}$ *i = TRAD_COMM; r = REG*

TPCr private consumption tax payments in r

$TPC_r = S_i DPTAX_{ir} + IPTAX_{ir}$ *i = TRAD_COMM; r = REG*

$DFTAX_{ijr}$ tax on use of domestic intermediate good i by j in r

$DFTAX_{ijr} = VDFA_{ijr} - VDFM_{ijr}$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

$IFTAX_{ijr}$ tax on use of imported intermediate good i by j in r

$IFTAX_{ijr} = VIFA_{ijr} - VIFM_{ijr}$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

TIU_r firms' tax payments on intermediate goods usage in r

$TIU_r = S_j S_i (DFTAX_{ijr} + IFTAX_{ijr})$ *i = TRAD_COMM; j = PROD_COMM; r = REG*

$ETAX_{ijr}$ tax on use of endowment good i by industry j in region r

$ETAX_{ijr} = VFA_{ijr} - VFM_{ijr}$ *i = ENDW_COMM; j = PROD_COMM; r = REG*

TFU_r firms' tax payments on primary factor usage in r

$TFU_r = S_i S_j ETAX_{ijr}$ *i = ENDW_COMM; j = PROD_COMM; r = REG*

$PTAX_{ir}$ output tax on good i in region r

$\mathbf{PTAX_{ir} = VOM_{ir} - VOA_{ir}}$ *i = NSAV_COMM; r = REG*

$\mathbf{TOUT_r}$ production tax payments in r

$\mathbf{TOUT_r = S_iPTAX_{ir}}$ *i = PROD_COMM; r = REG*

$\mathbf{XTAXD_{irs}}$ tax on exports of good i from source r to destination s

$\mathbf{XTAXD_{irs} = VXWD_{irs} - VXMD_{irs}}$ *i = TRAD_COMM; r = s = REG*

$\mathbf{TEX_r}$ export tax payments in r

$\mathbf{TEXr = S_iS_sXTAXD_{irs}}$ *i = TRAD_COMM; r = s = REG*

$\mathbf{MTAX_{irs}}$ tax on imports of good i from source r in destination s

$\mathbf{MTAX_{irs} = VIMS_{irs} - VIWS_{irs}}$ *i = TRAD_COMM; r = s = REG*

$\mathbf{TIM_r}$ import tax payments in r

$\mathbf{TIM_r = S_iS_sMTAX_{isr}}$ *i = TRAD_COMM; r = s = REG*

$\mathbf{TOTTAX_r}$ Total tax receipts in r

$\mathbf{TOTTAX_r = TPC_r + TGC_r + TIU_r + TFU_r + TOUT_r + TEX_r + TIM_r + TINC_r}$ *r = REG*

$\mathbf{TGCR_r}$ change in ratio of government consumption tax to INCOME in region r *r = REG*

$\mathbf{TPCR_r}$ change in ratio of private consumption tax to INCOME in region r *r = REG*

$\mathbf{TIUR_r}$ change in ratio of tax on intermediate usage to INCOME in region r *r = REG*

$\mathbf{TFUR_r}$ change in ratio of tax on primary factor usage to INCOME in region r *r = REG*

$\mathbf{TOUTR_r}$ change in ratio of output tax to INCOME in region r nbsp; *r = REG*

$\mathbf{TEXPR_r}$ change in ratio of export tax to INCOME in region r *r = REG*

$\mathbf{TIMPR_r}$ change in ratio of import tax to INCOME in region r *r = REG*

TINC$_r$ income tax payments in r

TINC$_r$ = S$_i$PTAX$_{ir}$ *i = ENDOW_COMM; r = REG*

TINCR$_r$ change in ratio of income tax to INCOME in region r *r = REG*

DTAXR$_r$ change in ratio of taxes to INCOME in r *r = REG*

B9: Regional household preference parameters and shifters

DPARPRIV$_r$ private consumption distribution parameter

DPARPRIV$_r$ = UELASPRIV$_r$*XSHRPRIV$_r$/UTILELAS$_r$ *r = REG*

DPARGOV$_r$ government consumption distribution parameter

DPARGOV$_r$ = XSHRGOV$_r$/UTILELAS$_r$ *r = REG*

DPARSAVE$_r$ saving distribution parameter

DPARSAVE$_r$ = XSHRSAVE$_r$/UTILELAS$_r$ *r = REG*

DPARSUM$_r$ sum of distribution parameters *r = REG*

dpav$_r$ change in average distribution parameter *r = REG*

dpsum$_r$ change in sum of the distribution parameters *r = REG*

dppriv$_r$ change in private consumption distribution parameter *r = REG*

dpgov$_r$ change in government consumption distribution parameter *r = REG*

dpsave$_r$ change in saving distribution parameter *r = REG*

B10: Slack variables

profitslack$_{jc}$ slack variable in the ZEROPROFITS equation (this is exogenous as long as output level, QO(j), is determined endogenously)

j = PROD_COMM; r = REG

cgdslack$_{r}$ slack variable in the CAPGOODS equation (this is exogenous as long as output level of new capital goods, QO("cgds"), is determined endogenously

r = REG

endwslack$_{ir}$ slack variable in the MKTCLENDWM and ENDW_SUPPLY equations (this is exogenous as long as primary factor rental rates, PMi and PMESij are determined endogenously)

i = ENDWS_COMM; r = REG

tradslack$_{ir}$ slack variable in the MKTCLTRD equation (this is exogenous as long as market price of tradable, PMi, is determined endogenously)

i = TRAD_COMM; r = REG

incomeslack$_{r}$ slack variable in the INCOME equation (this is exogenous as long as income, Y, is determined endogenously)

r = REG

psaveslack$_{r}$ slack variable in the SAVINGS equation (this is exogenous as long as level of savings, QSAVE, is determined endogenously)

r = REG

walraslack slack variable in the WALRAS equation (this is endogenous as long as price of savings, PSAVE, is determined exogenously which is the case in a standard GE closure. When any one of the GE links is broken, this is swapped with PSAVE, the numeraire price, thereby forcing global savings to equal global investment).

incomeslack$_{r}$ slack variable in the expression for regional income *r = REG*

B11: Value and income variables

vxwfob$_{ir}$ percentage change in value of exports of tradable commodity i from source region r using fob weights (is identical to the linearized form of VXW_{ir})

i = TRAD_COMM; r = REG

vxwreg$_{r}$ percentage change in value of merchandise exports from region r using fob weights (is identical to the linearized form of $VXWREGION_{r}$)

r = REG

vxwcom$_{i}$ percentage change in value of global merchandise exports of tradable commodity i using fob weights (is identical to the linearized form of $VXWCOMMOD_{i}$)

i = TRAD_COMM

viwcif$_{ir}$ percentage change in value of imports of tradable commodity i into region r using fob weights (is identical to the linearized form of VIW_{ir})

i = TRAD_COMM; r = REG

viwreg$_{r}$ percentage change in value of merchandise imports into region r using cif weights (is identical to the linearized form of $VIWREGION_{ir}$)

r = REG

viwcom$_{i}$ percentage change in value of global merchandise imports of tradable commodity i using fob weights (is identical to the linearized form of $VIWCOMMOD_{i}$)

i = TRAD_COMM

vxwwld percentage change in value of worlwide commodity exports using fob weights (is identical to the linearized form of VXWLD)

valuew$_{i}$ percentage change in value of global supply of tradable commodity i using fob weights (is identical to the linearized form of $VWOW_{i}$)

i = TRAD_COMM

valuewu$_{i}$ value of world supply of good i at user prices

i = TRAD_COMM

$vgdp_r$ percentage change in value of GDP in region r (is identical to the linearized form of GDP_r)

r = REG

y_r percentage change in regional household income (is identical to the linearized form of INCOME)

r = REG

yp_r percentage change in private household expenditure (is identical to the linearized form of PRIVEXP).

r = REG

FY_r primary factor income in r net of depreciation

$FY_r = S_i VOM_{ir} - VDEP_r$ *i = ENDW_COMM; r = REG*

$fincome_r$ pc change in factor income variable in r net of depreciation *r = REG*

B12: Utility variables

U_r per capita utility from aggregate household expenditure in region r *r = REG*

UP_r per capita utility from private household expenditure in region r *r = REG*

UG_r aggregate utility from government household expenditure in region r *r = REG*

$UTILELAS_r$ elasticity of cost of utility wrt utility

$UTILELAS_r = (UELASPRIV_r * XSHRPRIV_r + XSHRGOV_r + XSHRSAVE_r)/DPARSUM_r$ *r = REG*

$uelas_r$ pc change in elasticity of cost of utility wrt utility *r = REG*

$uepriv_r$ pc change in utility elasticity of private cons expenditure *r = REG*

$uelasev_r$ pc change in elasticity of cost of utility wrt utility, for EV calculation *r = REG*

uepriveev$_r$ pc change in utility elasticity of private cons expenditure, for EV calculation *r = REG*

B13: Welfare variables

EV$_r$ equivalent variation, in $ US million (positive figure indicates welfare improvement) *r = REG*

WEV equivalent variation, in $ US million, for the world (positive figure indicates welfare improvement)

ugev$_r$ per capita utility from gov't expend., for EV calculation *r = REG*

upev$_r$ per capita utility from private expend., for EV calculation *r = REG*

qsaveev$_r$ total quantity of savings demanded, for EV calculation *r = REG*

ypev$_r$ private consumption expenditure, in region r, for EV calculation *r = REG*

ygev$_r$ government consumption expenditure, in region r, for EV calculation *r = REG*

qpev$_{ir}$ private household demand for commodity i in region r, for EV calculation *i = TRAD_COMM, r = REG*

yev$_r$ regional household income, in region r, for EV calculation

ysaveev$_r$ NET savings expenditure, for EV calculation

dpavev$_r$ average distribution parameter shift, for EV calculation *r = REG*

B14: Trade balance variables

DTBAL$_r$ change in trade balance of region r , in US$ million (positive figure indicates increases in exports exceeds increases in imports)

r = REG

DTBALi$_{ir}$ change in trade balance for tradable commodity i in region r , in US$ million (positive figure indicates increases in exports exceeds increases in imports)

i = TRAD_COMM; r = REG

Available from GTAP website at https://www.gtap.agecon.purdue.edu/models/setsVariables.asp

Appendix C

```
Equation E_EV_ALT

# decomposition of Equivalent Variation #

EV_ALT(r) = -[0.01 * UTILELASEV(r) * INCOMEEV(r)]

            * [DPARPRIV(r) * loge(UTILPRIVEV(r) / UTILPRIV(r)) * dppriv(r)

            + DPARGOV(r) * loge(UTILGOVEV(r) / UTILGOV(r)) * dpgov(r)

            + DPARSAVE(r) * loge(UTILSAVEEV(r) / UTILSAVE(r)) * dpsave(r)]

      + [0.01 * EVSCALFACT(r)]

      * [sum{c,COMM, sum{a,ACTS, PTAX(c,a,r) * [qca(c,a,r) - pop(r)]}}

      + sum{e,ENDW, sum{a,ACTS, INCTAX(e,a,r) * [qes(e,a,r) - pop(r)]}}
            + sum{e,ENDW, sum{a,ACTS,
                ETAX(e,a,r) * [qfe(e,a,r) - pop(r)]}}
            + sum{c,COMM, sum{a,ACTS, MFTAX(c,a,r) * [qfm(c,a,r) - pop(r)]}}

            + sum{c,COMM, sum{a,ACTS, DFTAX(c,a,r) * [qfd(c,a,r) - pop(r)]}}
            + sum{c,COMM, MPTAX(c,r) * [qpm(c,r) - pop(r)]}
            + sum{c,COMM, DPTAX(c,r) * [qpd(c,r) - pop(r)]}
            + sum{c,COMM, MGTAX(c,r) * [qgm(c,r) - pop(r)]}

            + sum{c,COMM, DGTAX(c,r) * [qgd(c,r) - pop(r)]}
            + sum{c,COMM, MITAX(c,r) * [qim(c,r) - pop(r)]}

            + sum{c,COMM, DITAX(c,r) * [qid(c,r) - pop(r)]}
            + sum{c,COMM, sum{d,REG, XTAXD(c,r,d) * [qxs(c,r,d) - pop(r)]}}

![[!            + sum{c,COMM, sum{s,REG, MTAX(c,s,r) * [qxs(c,s,r) -
pop(r)]}}  !]]!
            + sum{c,COMM, sum{aa,AGENTS, sum{s,REG, MATAX(c,aa,s,r) *
[qamds(c,aa,s,r) - pop(r)]}}}
```

```
        + sum{e,ENDW, sum{a,ACTS, EVOS(e,a,r) * [qes(e,a,r) - pop(r)]}}

        - VDEP(r) * [kb(r) - pop(r)]

        + sum{a,ACTS, VOS(a,r) * ao(a,r)}
            + sum{a,ACTS, VVA(a,r) * ava(a,r)}
            + sum{c,COMM, sum{a,ACTS, VFP(c,a,r) * aint(a,r)}}
            + sum{a,ACTS, sum{e,ENDW, VFP(e,a,r) * afe(e,a,r)}}
            + sum{a,ACTS, sum{c,COMM, VFP(c,a,r) * afa(c,a,r)}}
            + sum{m,MARG, sum{c,COMM, sum{s,REG,
              VTMFSD(m,c,s,r) * atmfsd(m,c,s,r)}}}

![[!            + sum{c,COMM, sum{s,REG, VMSB(c,s,r) * ams(c,s,r)}}
      !]]!
            + sum{c,COMM, sum{s,REG, sum{aa,AGENTS, VMAB(c,aa,s,r) *
amsa(c,aa,s,r)}}}

        + sum{c,COMM, sum{s,REG, VFOB(c,r,s) * pfob(c,r,s)}}
            + sum{m,MARG, VST(m,r) * pds(m,r)}
            + NETINV(r) * pinv(r)
            - sum{c,COMM, sum{s,REG, VFOB(c,s,r) * pfob(c,s,r)}}
            - sum{m,MARG, VTMD(m,r) * pt(m)}
            - SAVE(r) * psave(r)]

        + 0.01 * INCOMEEV(r) * pop(r);
```

Source: GTAP v7 model