AN EMPIRICAL ANALYSIS OF THE IMPACT OF TRADE ON PRODUCTIVITY IN SOUTH AFRICA'S MANUFACTURING SECTOR

by

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SUMMARY

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This study contributes to the debate regarding the impact of trade on manufacturing productivity and labour demand over the period 1980 to 2002. The analysis extends existing work in a number of ways. First, total factor productivity is decomposed into efficiency and technical change in order to provide more directions to policy makers. Second, an industry specific time varying measure of total factor productivity is estimated from an underlying production function using panel data of South African industrial sectors. Third, total factor productivity is interacted with trade measures, industry characteristics and macroeconomic factors to determine its key drivers. Finally, the impact of trade on derived labour demand is examined.

Panel data econometric techniques are applied to estimate productivity loss due to technical inefficiency in South African manufacturing industries. Technical

change and efficiency are estimated using stochastic frontier approaches that allow inefficiency to be either time invariant, or to evolve in a time varying decay mode. A generalised time index is employed to introduce more flexibility on the measurement of technical change. The results account for periods of technical progress as well as regress and indicate the presence of significant room for efficiency improvement, while the pattern of technical change was found to have been particularly slow over the period. The fact that a substantial amount of intermediate inputs into South African manufacturing are imported implies that significant improvement in industry efficiency will be related to the openness of trade policy in South Africa. More importantly, efficiency scores are also likely to be related to how labour force adjusts to these imported inputs. Skill improvements for the labour force are, therefore, fundamental, because the mix of goods manufactured and the factor proportions used to produce them depend on the skill competencies of local technicians. Skills are important for the labour force to produce at its full potential, avoiding waste in inputs and time.

The estimation of the determinants of total factor productivity is able to account, in a simultaneous context, for the impact of trade policy, industry level characteristics and the role of macroeconomic factors. The results suggest positive payoffs for industrial productivity of an appropriately managed liberalisation of the external sector. Liberalisation of the external sector is good for competition and learning. Learning is available through increased access to world class intermediate inputs and technology.

The evolution of derived labour demand in manufacturing is investigated using the dynamic Generalised Method of Moments estimator (GMM). The results indicate greater induced efficiency effects from some products entering South Africa that are produced at lower cost abroad than obtain for similar products in South Africa; such commodities have tended to displace South African products and labour. Increased import penetration serves to reduce inefficiency and encourages the use of new technology. The positive impact of export expansion on derived labour demand supports results from efficiency estimates that indicate the importance of skilled labour. Increased trade requires emphasis on skill development for the labour force, because intra-industry trade benefits can only arise in an environment in which the skill competencies of labour are improved. In a nutshell, trade has the potential to exact factor adjustment. It is therefore, important to identify the product specific effects that are inimical to some manufacturing sectors and which effects serve to reduce the level of employment in manufacturing for the sake of policy intervention.

Increased trade with developed countries is found to provide South Africa with global production networks, where it supplies to the world market. In this arrangement, South Africa benefits from the use of the latest internationally available production and marketing techniques. These networks are important for accelerating the country's development by transferring technology and innovation, as well as bringing new ideas, to increase its competitive advantage. This comparative advantage should be used to expand the untapped trade potential, particularly with the rest of Africa. However, more needs to be done to improve the technical competencies of industrial labour. Policies are also still required to significantly improve the speed of labour market adjustment.

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Notation and Used

This part of the thesis lists the symbols and abbreviations used in the main text. The symbols that are not standard, if not explained here will be explained in areas where they first emerge in the text.

Symbol	**Interpretation**
N	Number of observations or firms
T	Number of time points
$\hat{\beta}$	Estimate of β
ΔY	Change in Y
∞	Infinity
E	Expectation operator

Acronym	**Meaning**
DEA	Data Envelopment Analysis
EU	European Union
EU-SAFTA	European Union-South Africa Free Trade Agreement
et al	et alii – and others
GATT	General Agreement on Trade and Tariffs
GEIS	Generalised Export Incentive Scheme
GLS	Generalised Least Squares
GMM	Generalised Method of Moments
ISIC	International Standard Industrial Classification
LP	Linear Programming
LSDV	Least Squares Dummy Variables
MC	Marginal Cost
MLE	Maximum Likelihood Estimation

OLS	Ordinary Least Squares
SADC	Southern Africa Development Community
SARB	South African Reserve Bank
STATSSA	Statistics South Africa
TC	Technical Change
TE	Technical Efficiency
TFP	Total Factor Productivity
TIPS	Trade and Industrial Policy Strategies Secretariat
VCM	Varying-Coefficient Model

CHAPTER 1

TRADE AND MANUFACTURING: AN OVERVIEW

1.1 INTRODUCTION AND BACKGROUND

This chapter provides an overview of the issues that are analysed in the rest of the study. It starts with brief introductory remarks on the debate regarding the links between productivity, labour demand and trade in Section 1.2. Section 1.2 also provides the key hypotheses that are investigated. The problem statement, the underlying motivations for the study and the point of departure from existing work are presented in Section 1.3. Section 1.4 details the concluding remarks that suggest that the jury is still out on the theoretical and empirical underpinnings of the trade, productivity and labour demand nexus, providing justification for further empirical analysis to inform the debate. Section 1.5 provides an outline for the remainder of the thesis.

1.1.2 An overview of the debate.

Trade liberalisation results from policies that remove restrictions on the free movement of goods and services. The policies include the removal of import quotas, the lowering of import tariffs, the diminishing of export restrictions and the lowering of export taxes. The end result of these measures should be a decrease in the price of imports, and an increase in the price of exports if markets are working and strong supply elasticities obtain (Djikstra, 2000:1568). In sum, these measures should lead to an increase in imports and exports as outcomes[1].

[1] Openness refers to trade outcomes while trade liberalisation denotes explicitly the reduction of domestic trade policy barriers.

There are a number of suggestions as to why the impact of increased trade on manufacturing in South Africa should be a matter of concern. One suggestion is that productivity growth and technical change are more robust in manufacturing industries than in other sectors of the economy, which implies that technological spillovers from industry to the rest of the economy may be critical for economic growth. In addition, the growth of manufactured exports is considered to be an indicator of dynamic efficiency, which is important for overall sustained growth of the economy (Dijkstra, 2000:1567). Trade expansion is also important, because it affects the efficiency with which factors of production, such as labour, are used in industries, and it has implications for the level of employment in the manufacturing sector.

More specifically, the debate regarding the effect of trade expansion on manufacturing concerns two interrelated issues. The first relates to the relationship between trade and manufacturing productivity[2] and the second relates to the effect of trade on derived labour demand. These issues remain largely contested (Deraniyagala and Fine, 2001:4). For instance, in the neoclassical growth model, trade does not affect the steady state rate of output growth, because growth is determined exogenously given technological progress (Funke and Ruhwedel 2001:226). However, because of imperfections, a number of possibilities can occur as a result of trade policies. In some models, trade policy affects the steady state level of savings and capital accumulation. The impact on growth can, therefore, be positive or negative depending on how capital accumulation and savings respond. The effects of trade in the neoclassical model are only transitional, changes that occur only while the economy converges towards the steady state (Gunnar and Subramanian, 2000:4). Models

[2] A fundamental debate concerns the seemingly miraculous development in East Asia and hence the relative importance of TFP in explaining the Asian Miracle.

following Solow (1957) explain output growth by the accumulation of factor inputs and the growth of total factor productivity[3].

Trade literature also differentiates between the static[4] and dynamic gains from trade expansion (Dijkstra, 2000:1568). The static effects can arise from an improvement in either allocative or technical efficiency. An improvement in technical efficiency occurs when the same output is produced with fewer resources or more output is produced with the same amount of resources. Allocative efficiency improvement occurs if resources are better allocated over the whole economy. Improvements in technical and allocative efficiency are one off changes resulting from the change in relative prices, which follow trade expansion. Dynamic gains tend to be long term and evolve from the elimination of rent seeking and gains from technical efficiency and entrepreneurial effort. When markets are characterized by entry barriers, the absence of foreign competition allows domestic producers to enjoy monopoly power and excess profits, making dynamic gains unattainable (Tybout et al 1991; 231). Increasing returns to scale are also cited as an important source of dynamic gains from trade. These gains result because firms operating in more open trade regimes operate at lower average costs due to higher levels of output available through participating in world markets. An improvement in dynamic efficiency is expected to lead to a permanently higher growth rate. The higher growth rate results from more investment, research, innovation, learning and productivity (Dijkstra 2000:1568).

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[3] An alternative perspective is that the rapid output growth stems from rapid rates of factor accumulation and not of total factor productivity. East Asian economies are said to have been effective at mobilising and sustaining high rates of investment. Manufacturing productivity, therefore, did not benefit from access to broad export markets or from enhanced inflows of FDI and technology transfer. Young (1995) argues that high rates of capital accumulation accounted for the bulk of the increase in manufacturing productivity over time in the Asian tigers.

[4] The static benefits from trade liberalisation are emphasised in the Ricardian and neoclassical theories.

While traditional trade theory makes the static effects of trade expansion clear cut, the contention regarding the relationship between trade and productivity arises because there are no clear and general presumptions regarding the dynamic benefits of trade (Deraniyagala and Fine, 2001:4). There have been few rigorous theoretical models designed to show how trade and growth could be dynamically linked. Some traditional arguments have emphasised the export channel as a possible dynamic link. In this framework, trade enhances total factor productivity performance by promoting innovation, cost-cutting and acquisition of new technology. Though these arguments are appealing, the analytical underpinnings are regarded as insufficient. The trade and productivity debate also relates to whether policy can influence productivity growth, as is suggested in the endogenous growth literature (Funke and Ruhwedel, 2001:226).

Models of endogenous growth first isolate technical development and then look for possible mechanisms through which improvements in productivity (notably due to innovation, imitation, product variety, human capital and public infrastructure via the sphere of policy) are important for ongoing economic growth. Endogenous[5] growth models allow for the impact of trade on output growth to be either positive or negative. Even in these improved approaches, scepticism persists. Scepticism continues because any possible trade and growth outcomes can be rationalised by changing analytical assumptions[6].

The second issue regards the effect of increases in trade volumes on the level of derived labour demand in manufacturing. Opponents of expanded trade argue

[5] Recently, endogenous growth-trade theorists have provided a range of formal models in which trade contributes to economic growth by, among other things, increasing the variety and quality of intermediate inputs, increasing the diffusion of knowledge, amplifying the learning-by-doing effects, and increasing the size of the markets (Iscan, 1998:1). Trade policy in endogenous growth models can affect growth through technological change. Implications from these models are, however, sensitive to assumptions imposed on the nature of technology spillovers.

[6] An interesting discussion on the role of scope and the extent of technology spillovers is provided in Kim (2000).

that foreign firms may out-compete domestic producers leading to fewer domestic jobs in the manufacturing sector, because lower domestic output is the end result of higher import competition. Trade proponents, on the other hand, posit that free trade expands export markets, resulting in greater demand for manufactured products, greater domestic production and, hence, more jobs. The consensus, however, appears to be that trade volumes do affect, in some way, the efficiency with which firms use labour as well as the distribution of output within sectors between the more and less efficient firms. However, since the issue of labour demand in the manufacturing sector is of critical importance, the direct investigation of the impact of international competition on manufacturing employment remains of vital importance both to academia, policy makers and entrepreneurs.

1.1.3 Linking trade, productivity and labour demand in industry

Theoretically the link between trade liberalisation, productivity and labour demand is less clear than previously asserted (Fajnzylber and Maloney, 2004:2). Indeed, Krishna et al (2001) find that industry labour demand seems to be unresponsive to openness. However, Fagerberg (2000:409) argues that in the first half of the 20th century growth of output, productivity and employment were strongly correlated. Employment in industries based on new technologies expanded rapidly at the expense of more traditional industries, suggesting an important role for structural change in explaining overall productivity growth. More recently, this relationship has been blurred. For example, new technology in electrical machinery has expanded at a very rapid rate but there has not been a similar large increase in the share of that industry in employment.

It is important to investigate the impact of trade on derived labour demand because this issue still attracts considerable debate. For example, Ghose (2000) reports that in developing countries that emerged as important exporters of manufactures to industrialised countries, growth of trade had a large positive impact on employment and wages[7]. In this vein he argues that the popular apprehensions about the effects of trade liberalisation, though not wholly unfounded, are grossly exaggerated. However, the investigation of the impact of trade on derived labour demand is complicated by a number of factors. First, there are controversies on the appropriate methodology of using available statistical data for assessing the effects of trade on labour markets. Second, most estimates, irrespective of the methodology used, show the effect of trade to be rather small (Greenaway et al: 489).

An important problem also relates to the fact that debates on the subject of trade and derived labour demand have largely been about the effects of trade liberalisation on labour markets in industrialised countries. The effect of trade liberalisation on manufacturing employment in developing countries has so far received inadequate attention in investigative work. Because of inadequate research in this area, there remains serious apprehension in developing countries regarding the employment effects of trade liberalisation. When global competitiveness is emphasised, many feel, trade liberalisation could encourage capital intensity in manufacturing, thereby reducing its capacity to create jobs. In some countries, export oriented manufacturing has also often been associated with low wages and poor working conditions (Ghose, 2000:4).

In spite of this debate, the link between trade, productivity and industry labour demand is informed by various parts of economic theory (Naastepad and

[7] Indeed, Roberts and Thoburn (2001, 2002) argue that employment and wage changes have been one of the major channels through which trade liberalisation generates poverty in the South African economy. In their study they argue that trade liberalisation led textile firms to experience fierce import competition leading to a fall in employment in the sector. This study suggests that liberalisation and restructuring increased productivity largely through cost minimisation and down sizing measures, but failed to support strong growth in production.

Kleinknecht, 2004). In the neo-classical substitution framework, the causality runs from relative prices to relative factor prices. A fall in the price of labour relative to the price of capital induces industries to substitute labour for capital, thus reducing the capital intensity of production. The decline in the capital intensity of production reduces the productivity of labour. In this framework, the impact of trade is dependent on what happens to relative prices. Domestic real wage increases relative to those abroad reduce international competitiveness and hence lower export growth. Domestic real wage increases may result in profit squeeze thereby reducing industry investment and productivity.

In the vintage analysis, the productivity of capital depends on age (or vintage) of capital, more recent vintages are assumed to be more productive than older ones. Through trade, industries can improve productivity because they can acquire more recent vintages of capital. In a related way, if the real wage rises it becomes more efficient for industries to import new more productive vintages of capital to raise labour productivity to the higher real wage. Furthermore, under the induced technological change theory, higher relative wage rate increases the labour saving bias of newly developed technology (Funk, 2002).

More recently, endogenous growth theory has emphasised that a profit maximising capitalist's decision to invest in R&D depends on the share of wages in total costs, the higher the wage share, the more profitable it becomes to devote resources to increasing the productivity of labour (Foley and Michl, 1999). There are several mechanisms through which productivity growth may be affected. For example, trade can facilitate learning by investing. This occurs because the introduction of new capital enables the firm to learn how to produce more. In addition, anticipation of higher profits potential from increased trade suggests that technological advance may stimulate capital formation, because the opportunity to modernise equipment promises a higher rate of return on investment.

In the demand driven models of technological change (Verdoorn, 1949 and Geroski and Walters, 1995) innovative activity and labour productivity growth are stimulated by buoyant demand prospects. Trade could foster innovation to the extent that it leads to an increase in effective demand for the products of manufacturing industries. If an economy can increase its pace of technological progress by means of capital imports that embody the latest technology, and by cross boarder transfer of knowledge, the higher will be its TFP growth (Wolf, 1996). In view of the debate regarding the theoretical links between trade, productivity and derived labour demand in industry, it is important to investigate these issues within the South African context. To open this investigation, Section 1.1.4 outlines the problem statement and motivation of the study.

1.1.4 Problem statement, motivation and point of departure

This study is motivated by the need to provide a perspective regarding the effects of trade on productivity and labour demand in South Africa's manufacturing sector. These issues are deemed important, because increased trade generates two effects. First, it exposes the sector to more competition. Second, it widens opportunities for exporting to a larger international market. Strong competitive pressures could result from a surge in imports or in attempts to break into an expanded international export market. To benefit from trade, productive efficiency, product quality and labour efficiency must be improved. Success in efficiency improvement will create access to larger markets, providing enhanced opportunities for employment. Productivity and employment change in the manufacturing sector are, therefore, important components of the growth, employment and trade nexus. Policy makers and industry agents need to obtain knowledge about the manufacturing sector in order to introduce measures aimed at improving productivity and, possibly, labour demand in a sufficiently robust manner.

Empirical implementation proceeds in three steps. First, an underlying production function is estimated to obtain industry specific, but time varying, measures of total factor productivity. Second, total factor productivity (TFP) is decomposed into efficiency and technical change. Because the two components of productivity are analytically very different, it is important to distinguish between them if lessons that inform policy are to be derived. Failure to take account of technical change in measuring TFP produces biased estimates that would suggest all firms are operating with maximum efficiency (Mahadevan, 2001). The production function for the manufacturing sector is obtained by pooling cross sectional data of 28 manufacturing industries over the 1980-2002 period. This sample contains a longitudinal data set of 644 observations (28 industries in 23 years). The explicit specification of the production function allows us to use statistical methods and inference to evaluate the reliability of the results. Indeed, a longstanding problem in the analysis of production functions has been the inability to separate technical change from efficiency in purely cross-sectional or time series data. The availability of panel data may help in addressing some of these concerns (Kumbhakar, 1991:43).

Third, total factor productivity is interacted with trade measures, macroeconomic factors and industrial characteristics to determine its key drivers. Emphasis on delineating productivity determinants is placed on the channels through which trade intensity affects manufacturing productivity. Empirical implementation relies on interacting productivity with determinants that exhibit significant variation across industries over time. Lastly, a logical concluding analysis is the investigation of the impact of trade on derived labour demand in the manufacturing sector. Derived labour demand is investigated within a context that permits the disagregation of imports by origin for the 28 standard industry codes of the South African manufacturing industry. Investigating derived labour demand in a panel data context is more informative, because benefits from more variability, more degrees of freedom and more efficiency are derived (Baltagi, 2000:5). These benefits are unavailable within time series or strictly cross sectional based studies. It is argued that, with increased competition arising from globalisation, employment and productivity growth in manufacturing have become some of the most important variables of interest in any economy. Therefore, employment and productivity growth are critical indicators monitored by both households and policy-makers regarding the performance of the economy (Tomiura, 2003:118).

This study is an attempt to provide further empirical evaluations of the growth effects of trade, because the empirical evidence on the dynamic effects of trade on productivity and employment remains inconclusive. The works of Gunnar and Subramanian (2000), Fedderke (2001), Fedderke and Vaze (2001), Petersson (2002), and Naude, Oostendorp and Sserumaga-Zake (2002) represent some of the most comprehensive attempts at investigating the dynamic gains from trade in South Africa. However, these studies open a number of areas for further investigation at the empirical level. Given this caveat, this study will attempt to make contributions in four areas. These areas are itemised and discussed in the sub-sections that follow, below.

1.1.3.1 Panel data application

Panel data is employed in estimation to take advantage of time varying trade measures and macroeconomic shocks, as well as available industry specific characteristics on the manufacturing chapters. These industry specific characteristics are important from productivity and employment points of view. Previous attempts relied either purely on aggregated time series or on purely cross-section data or were just descriptive. Allowing for large variability at a disaggregated level helps generate more meaningful results.

1.1.3.2 Components of total factor productivity.

The study helps to identify the components of total factor productivity by taking advantage of the longitudinal structure of the manufacturing data set. An underlying production function is used to decompose manufacturing productivity into efficiency and technical change. This decomposition, not only provides more avenues for policy making, it also helps to indicate how these effects panned-out in the aggregate, in response to expanded trade. The identification of the components of productivity in manufacturing is important because, despite wide reaching trade reforms, little is known about the relationship between trade, domestic competition and manufacturing efficiency in South Africa[8].

[8] There is a strong case for investigating the effects of trade in South Africa because the potential gains from increased trade, if any, should be large. Trade offers the greatest scope for learning opportunities in an economy that was initially protected and has technology catch-up to undertake. If trade induces efficiency, then the potential gains for the country should be large. Pack (1993), however, argues that firm productivity in Africa can only be increased by interventions aimed at improving skills and technical capacity of firms to absorb new technology. Such improvements are necessary before firms can become internationally competitive.

1.1.3.3 Determinants of total factor productivity.

Manufacturing sector total factor productivity and its determinants are consistently modelled. The study generates productivity estimates that are sector specific and time varying as well. It then searches for the channels through which measures of trade orientation interact with industrial characteristics and the macroeconomic environment to determine the level of productivity. Investigating the channels through which trade affects productivity is an interesting angle, and, since the analysis is confined to an identical country panel, it allows for a consideration of variables that determine productivity simultaneously.

1.1.3.4 Understanding derived labour demand in manufacturing.

The analysis contributes to a better understanding of derived labour demand in manufacturing. The analysis models the impact of the increase in trade volumes on derived labour demand within a context that permits disaggregation of imports by origin at the three-digit level for the 28 standard industry codes of the South African manufacturing industry over the period 1988-2002. This sample contains a longitudinal data set of 420 observations (28 industries in 15 years)[9]. This detailed data set is important for an appreciation of the response of South Africa's manufacturing sector to international exposure and competition. More specifically, the study looks at how exposure may have led to efficiency in the use of labour. After outlining the approach that the study explicitly follows, Section 1.2 summarises the main hypotheses that are investigated.

[9] Unlike in the production function case, concorded data for imports by origin of comparable format is only available over the period 1988 to 2002.

1.2 HYPOTHESES INVESTIGATED

This study investigates how trade liberalisation affected productivity and derived labour demand in South Africa's manufacturing sector. More specifically, the following related hypotheses are examined:

(i) Trade has a positive and robust impact on manufacturing sector total factor productivity; and

(ii) Increases in trade volumes, both in terms of exports and imports, cause, on average, reductions in derived labour demand in the manufacturing sector.

The first hypothesis is investigated in Chapter 2 and 3, while the second hypothesis is the subject of Chapter 4. In Section 1.3 below a discussion of the evolution of trade policy in South Africa is provided in order to set ground for the analysis that follows in subsequent chapters.

1.3 TRADE POLICY IN SOUTH AFRICA

One of the key aspects of South African trade policy has been trade liberalisation[10]. There are suggestions of a much longer period of experimentation with trade liberalisation in the country (Fedderke and Vaze, 2001). In the 1970s trade liberalisation focussed on the replacement of quantitative restrictions with tariffs. During this period, there were high tariff walls and extensive import controls, as the attainment of growth was premised on import substitution. In the middle of the decade, attempts were made to mitigate the anti-export bias and emphasis shifted towards export promotion to stem the decline in manufacturing production. A number of export schemes were introduced to assist exporters during the 1970s.

[10] A comprehensive treatment of liberalisation is also available in the government's "Growth, Employment and Redistribution: A macroeconomic Strategy," articulated in 1996.

The 1980s did not witness substantial liberalisation in the trade regime. The result was a marked increase in anti-export bias. By 1985 the country switched from a positive list of permitted imports to a negative list of prohibited imports, which covered 23 per cent of imports and an import surcharge of 10 per cent was introduced (Gunnar and Subramanian, 2000). The declaration of sanctions in the middle of the decade led policy makers to retaliate by imposing exchange controls and a moratorium on payments to foreign creditors. The trade regime became increasingly controlled as the import surcharge on some items was increased to 60 per cent in 1988. By the end of the decade, the trade regime was highly complex. The country had the most tariff lines (more than 13,000), most tariff rates, the widest range of tariffs and one of the highest levels of tariff dispersion in the developing world, implying a highly distorted system of protection (TIPS 2001:27 and Gunnar and Subramanian, 2000:6).

At the onset of the 1990s, protection consisted of a plethora of quantitative restrictions, customs duties and import surcharges. The trade regime was also subject to frequent changes and remained largely complex. The overall binding statutory tariff had a wide dispersion, and consumer goods in manufacturing enjoyed the highest protection. To control imports, three rates of import surcharge were applicable, namely: 10 per cent, 15 per cent and 40 per cent (Gunnar and Subramanian, 2000:8).

During this period, the official policy stance was export-oriented industrialisation. Rapid industrialisation was to be achieved through the Generalised Export Incentive Scheme (GEIS) which was introduced in 1990 to provide a tax-free subsidy to exporters. The scheme was tied to the value of exports, the degree of processing of the export item and the extent of local content in the product. In 1995, the GEIS was scaled down and payments made under it became taxable. By 1996, it was limited to manufactured commodities only, before being eliminated in the following year (Roberts, 2001).

The 1990s, therefore, coincide with the period in which trade liberalisation gained momentum. For example, as the country signed into the General Agreement on Tariffs and Trade (GATT) in 1994, it offered to the WTO a five-year tariff reduction and rationalisation program. The key aspects of the new tariff program included a reduction to six, from over 100, in the number of tariff categories, while the average weighted import duties were also to be reduced substantially (TIPS, 2001:11).

Emphasis on export orientation from 1994 onwards required an adjustment of the competitiveness of the existing industrial structure, which had been built up through import substitution to enable it to deliver prices that were in line with those obtaining in the world market. To achieve price equalisation, emphasis during this period was on reducing tariffs and following a realistic exchange rate policy. Lowering tariffs would, in particular, serve to strengthen the export orientation of South Africa's manufacturing sector given that the previous regime of tariff protection had created an anti-export bias. The regime of protection did not promote manufacturing competitiveness or productivity growth. Since the broad economic policy strategy was biased towards manufactured exports as a stimulant to economic growth, the reduction in tariffs was also seen as a mechanism to contain input prices, improve cost competitiveness and facilitate an increase in manufactured product exports (Rangasamy and Harmse, 2003:711).

It was in this vein that the offer to GATT displayed a commitment to opening the economy to foreign competition. Industrial protection was to be substantially reduced over a five-year period from an average of 12 per cent in 1994 to about 5 per cent in 2001. The average import weighted tariff rates were to be reduced to well within the WTO bound rates, that is from 34 per cent to 17 per cent for consumer goods, from 8 per cent to 4 per cent for intermediate goods and from 11 per cent to 5 per cent for capital goods. Average import weighted tariffs, since the GATT offer, were reduced from 28 per cent in 1990 to 10 per cent in 1998. For industrial products they were reduced from 11.4 per cent to 8.6 per cent in 2000. The average for the economy as a whole saw applied rates fall from 11.3 per cent in 1990 to 7.3 per cent in 2001 (Gunnar and Subramanian, 2000:7 and TIPS, 2001:15).

South Africa essentially pursued a two-pronged strategy to trade expansion. The strategy involved unilateral and multilateral variants. At the unilateral level, the government regularly announced schedules of tariff reviews. These unilateral reductions in some cases even went beyond the WTO commitments and saw average import weighted tariffs in manufacturing decline from 15.8 per cent in 1994 to 10.3 per cent in 1998 (Roberts, 2001). At the multilateral level, a three-pronged process was followed. The first level concerned the WTO mechanism and was mainly undertaken since the Uruguay Round took effect in 1995. There was an undertaking to reduce the number of tariff lines from over 13,000 at the six-digit level by 15 per cent in 1996 and 30 per cent by 1999. In addition, there was an increase in the number of bindings on industrial products from 55 per cent to 98 per cent. Another important undertaking, was the replacement of all quantitative restrictions with tariffs and a reduction of the number of tariff rates to six, namely 0 per cent, 5 per cent, 10 per cent, 15 per cent, 20 per cent and 30 per cent. Exemption was made to textiles, clothing and motor vehicle industries; these sectors were to liberalise over an eight-year period. Average weighted import duties were also to be reduced from 35 per cent to 17 per cent for consumption goods, 8 per cent to 4 per cent for intermediate goods and 11 per cent to 5 per cent for capital goods (TIPS, 2001:11).

Table 1 indicates the tariff phase down schedule provided under the WTO mechanism. It shows, for example, that tariffs on textiles were expected to fall from 30.1 per cent in 1994 to 17.3 per cent in 2004. Average tariffs on motor vehicles and accessories were set to fall from 55.4 per cent to 22.1 per cent, while the overall average tariff rates would drop from 11.7 per cent to 4.9 per cent over the same period.

Table 1: Tariff phase down under the WTO

Description	1994	1995	2000	2001	2002	2003	2004
Textiles	30.1	33.8	20.3	18.7	17.3	17.3	17.3
Clothing, exc. Footwear	73.7	73.6	42.4	37.7	33.2	33.2	33.2
Leather and leather products	14.9	14.8	14.8	14.8	14.8	14.8	14.8
Footwear	37.5	41.6	29.1	29.1	29.1	29.1	29.1
Wood and wood products	13.9	3.6	3.1	3.1	3.1	3.1	3.1
Paper and paper products	9.6	9.3	7.9	7.3	6.8	6.2	5.6
Printing and publishing	8.1	1.3	1.0	1.0	1.0	1.0	1.0
Industrial chemicals	9.3	7.5	1.6	1.6	1.6	1.6	1.6
Other chemicals	9.0	3.8	2.5	2.5	2.5	2.5	2.5
Rubber products	30.5	14.5	14.6	14.4	14.0	14.0	14.0
Plastic products	19.8	14.7	12.0	12.0	12.0	12.0	12.0
Glass and glass products	11.8	9.5	7.6	7.6	7.6	7.6	7.6
Non metallic mineral products nec	10.6	8.7	7.7	7.7	7.7	7.7	7.7
Basic iron and steel products	7.6	4.4	3.9	3.9	3.9	3.9	3.9
Non-ferrous metal products	2.3	2.3	2.0	2.0	1.9	1.7	1.7
Metal products, excl. machinery	13.1	8.2	7.4	7.4	7.4	7.4	7.4
Non-electrical machinery	6.5	1.4	1.3	1.3	1.3	1.3	1.3
Electrical machinery	11.0	6.1	5.7	5.7	5.7	5.7	5.7
Radio and television & comm.	12.1	5.1	2.3	2.3	2.3	2.3	2.3
Professional equipment	7.2	0.2	0.3	0.3	0.3	0.3	0.3
Motor vehicles, parts & access.	55.4	33.5	24.8	23.2	22.1	22.1	22.1
Other transport equipment	1.4	0.4	0.2	0.2	0.2	0.2	0.2
Furniture	28.1	21.4	18.9	18.9	18.9	18.9	18.9
Other manufacturing	2.9	1.0	4.9	4.9	4.9	4.9	4.9
Mining	2.7	0.6	0.4	0.4	0.4	0.4	0.4
Total	11.7	7.2	5.3	5.1	4.9	4.9	4.9

Source: Trade Policy Strategies (2001).

The second multilateral strategy concerned the EU-SA FTA that took effect in 2000 as an asymmetric agreement. This entailed liberalisation of tariffs on 95 per cent of EU imports from South Africa between 2000-2003. South Africa was required to free 80 per cent of tariffs on imports from the EU spread over a 12-year period. In this agreement, exemption was granted to clothing, textiles, footwear and automotive products. The third level of multilateral trade negotiations has involved the United States Africa Growth and Opportunities

Act that came into effect in 2001. This act provides South Africa as a qualifying country with reduced duties for exports of clothing to the US market. Another multilateral tier concerned the SADC protocol that came into force in 1996 and required 69 per cent of the SADC imports to be zero rated upon the full implementation of the protocol and full liberalisation by 2012. South Africa was to liberalise most of its imports from SADC countries faster than these countries were to free imports from South Africa (TIPS, 2001). Due to these changes, the South African trade regime appears considerably liberalised. Most quantitative restrictions were eliminated; the number of tariff lines was reduced from over 13,000 in 1990 to 7,831 in 2001. The number of tariff bands was reduced from over 200 to 35. The tariff regime by 2002 was relatively simplified, because the number of lines facing a specific tariff was scaled down by half from 500 to 227 (TIPS, 2001:14). Table 2, below, provides the details.

Table 2: Changes in manufacturing tariff structure

Tariffs	**1990**	**1998**	**2000**	**2001**
Maximum tariff	1,389	72	55	55
Average import weighted tariff	28	10	8.6	6.5
Average un weighted tariff	30	14	6.7	6.7
Number of tariff bands	>200	72	39	35
Standard deviation	43	15	9.6	9.4
Number of tariff lines	>13,000	7,814	7,824	7,831
Percentage of lines with non-ad valorem duties	28	26	25	25
Average import weighted surcharge	6	0	0	0
Import surcharge bands	10,15 & 40	Eliminated	Eliminated	Eliminated
Export subsidy	17	Eliminated	Eliminated	Eliminated
Quantitative restrictions on imports	14	Virtually Eliminated	Virtually Eliminated	Virtually Eliminated
Memorandum items	1990	1998	2000	2001
Trade tax revenue as a share of total revenue	7.9	4.0	4.0	3.6
Import taxes as a share of imports	10.8	4.1	4.2	3.9
Export subsidies as a share of GDP	0.3	0.0	0.0	0.0

Notes: Average import weighted surcharge and quantitative restrictions on imports figure for 1990 refers to 1992.

Source: Gunnar and Subramanian (2000), South Africa Reserve Bank (2003) and Trade Policy Strategies (2003).

In summary, the period 1994-2003 can be characterised by steps in rationalising the tax structure and removing quantitative restrictions. Industrial policy made great strides to eliminate loss making enterprises, price controls, entry and exit restrictions on private enterprises, discriminatory tax and subsidy policies, as well as soft budget constraints on state owned enterprises. Privatisation of some public enterprises was promoted to improve efficiency. The policies of market opening, deregulation and privatisation were expected to spur productivity, foster export competitiveness and improve resource allocation.

The underlying belief was that increased manufactured exports[11] could help underpin rapid investment and productivity growth (Rangasamy and Haramse, 2003). Competition would improve the quality of manufactured output, encourage generation of new products and the adoption of new techniques. This latter response could enlist the desired increase in total factor productivity (Fedderke, 2001). In spite of these wide ranging moves in regard to the trade regime, little rigorous empirical work has examined the trade, productivity and employment nexus in the context of South Africa. This study makes a modest contribution towards filling this analytical gap.

To refocus emphasis on the central role that manufacturing is set to play in the South African economy, an Integrated Manufacturing Strategy (IMS) was launched in 2002 as a collective position aimed at improving competitiveness in the industrial sector. This is to be attained, among other ways, through technology improvement and innovation. The strategy stresses integration with the international economy through increased trade, particularly through

[11] One of the objectives of trade liberalisation in Africa is to increase manufactured exports. South Africa government considers growth in manufactured exports as a necessary condition for attainment of high and sustainable economic growth- the reason for offering increasing incentives for exports under its" Growth, Employment and Redistribution Strategy" (GEAR).

increased knowledge intensity in production[12]. The (IMS) is set to build on the efforts of the last decade (1994-2003), where trade policy was driven by the need to weaken the effects of factors that discriminated against productive efficiency and export development in the form of taxation, protectionism and exchange rate misalignment. In spite of the substantial reforms in the trade regime, there still remain fundamental issues to be addressed. In particular, the pace of tariff liberalisation appears to have slowed since 1996; only small reductions in tariff bands and modest declines in the maximum tariff were effected, yet persistent high dispersion in the tariff rates still obtained. As a further example, industrial tariffs remained in 69 categories compared to the 17 targeted by 2004 (TIPS, 2001:12). The challenge for policy is that less progress seems to have been made on creating greater uniformity in the range and number of tariffs. As a result, there still remained more bands than envisaged.

It was also increasingly being recognised that the simplification of the tariff structure remains the key priority on administrative grounds. More importantly, the dispersed tariff structure implies that protection remained uneven and gains from openness were limited, and, as a result, manufactured exports cannot be optimally encouraged. By 2004, tariff peaks still existed in processed foods, motor vehicles and components, tobacco products, rubber products and clothing and textiles. There was still evidence of anti-export bias and the rate of effective protection remained high in some sectors[13] (TIPS, 2001:24). After reviewing the changes that have occurred in South African trade policy, Section 1.4 outlines the key issues in manufacturing industry employment, the restructuring as well as the adjustments that have occurred in response to policy reforms.

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[12] This policy is in contrast to the use of tariffs, quantitative restrictions and export incentives as the main trade incentives to drive the industrialisation process in the 1980's and early 1990's.

[13] It was suspected that the extent of protection on the final product arising from tariffs imposed on intermediate inputs (a high effective rate of protection) was high in textiles, leather, footwear, clothing, motor vehicles and parts, food processing and to some degree, chemicals and rubber products.

1.4 EMPLOYMENT ISSUES IN MANUFACTURING

Table 3 shows that during the last two decades approximately 0.35 million jobs were lost in South Africa's manufacturing sector, representing a 19 per cent contraction in employment. Overall, the whole sector was affected negatively in terms of job losses, but the job losses differed substantially across the 2–digit SIC industry classification. The manufacturing categories under chapter 34 experienced job losses in excess of 50 per cent, while chapters 30, 31, 35, and 38 experienced losses of between 18 and 35 per cent. However, chapters 32, 33, 37 and 39 recorded job gains of between 3 and 35 percent over the same period. Production in real terms was estimated to have increased by about 56 per cent; real wages generally increased over the same period.

Table 3: Variability in employment, production and wages

SIC	Employment			Production (R Million)			Wage rates		
	1980	2002	% change	1980	2002	% change	1980	2002	% change
30	220994.4	178920.0	-19.0	49520.7	69452.3	40.3	56948.6	68392.1	20.1
31	270825.0	207437.0	-23.4	20139.0	20650.6	2.5	33837.0	39397.5	16.4
32	132642.2	179559.5	35.4	22117.3	35335.0	59.8	78044.1	60951.6	-21.9
33	146766.2	181996.5	24.0	34398.6	27442.0	-20.2	86765.7	135896.9	56.6
34	84831.2	40594.5	-52.2	10204.5	10300.5	0.9	36578.5	60078.9	64.3
35	344431.5	228894.8	-33.5	73103.5	93620.8	28.1	58432.7	77632.2	32.9
36	70850.0	79340.3	12.0	8406.3	11173.7	32.9	26957.6	26930.7	-0.1
37	17702.0	18234.3	3.0	4248.5	4514.7	6.3	54122.8	42403.9	-21.7
38	112953.8	86879.0	-23.1	33403.5	62777.6	87.9	78996.0	124678.8	57.8
39	52911.3	68791.3	30.0	9777.2	32882.4	236.3	42199.2	75565.6	79.1
Total	1904523.6	1552433.6	-18.5	328215.9	512400.2	56.1	42120.5	50683.4	16.9

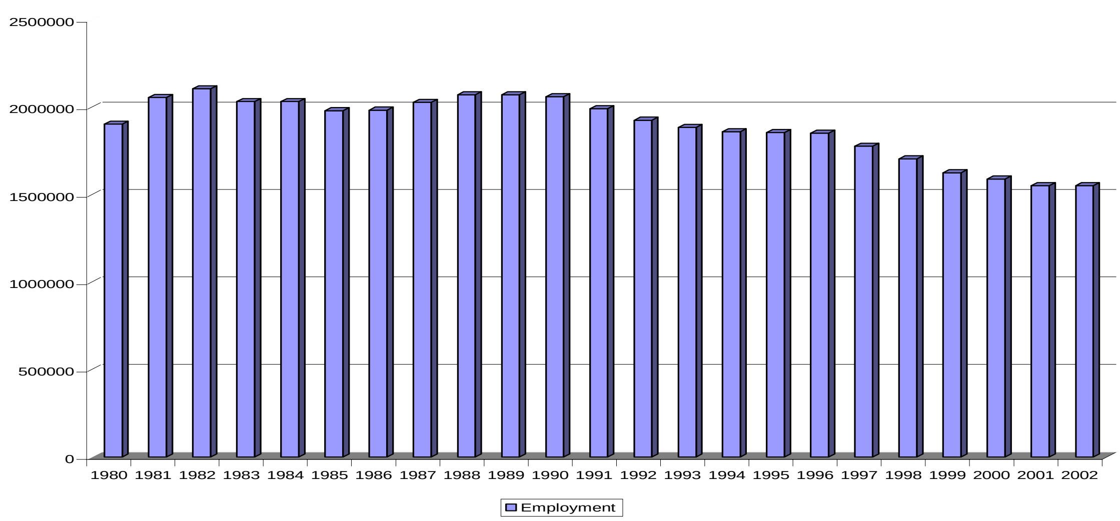
SIC	SIC description
30	Food, beverages and tobacco
31	Textiles, wearing apparel, leather and footwear
32	Wood, Paper, printing, publishing products and recorded media
33	Coke, petroleum, chemicals, rubber and plastic products
34	Glass and non metallic mineral products
35	Iron, steel non ferrous metals, metal products, machinery and equipment
36	Electrical machinery
37	TV, radio, communication, professional and scientific equipment
38	Motor vehicles, parts and other transport equipment
39	Furniture and other manufactured products

Notes: (a). Variability reported here is at the two digit level of classification. (b). Total for sectors 3-5 in SIC classification. (c). Percentage change is computed over the period 1980 to 2002.
Source: Trade Policy Strategies, www.tips.org.za.

The shifts in employment that occurred during this period were in response to significant transition, adaptation and the organisational change that was occurring in South African manufacturing. For the industrial sector, these years represent a period of substantial restructuring and structural change. The main change experienced in the manufacturing sector was an increase in production that was driven by rapid improvements in labour productivity. Some of the key components of this restructuring saw an expansion of capacity in some sectors, modernisation of manufacturing technology and a trend to contain growth in labour input costs.

The decline in employment, in part, reflected the impact of the rationalisation of labour resources in general, but, more specifically, indicated the rise in outsourcing of core activities by manufacturers to increase labour efficiency within a new and more competitive environment (SARB, 2003:85). Figure 1, below, plots the evolution of labour demand by the manufacturing sector during the period under review.

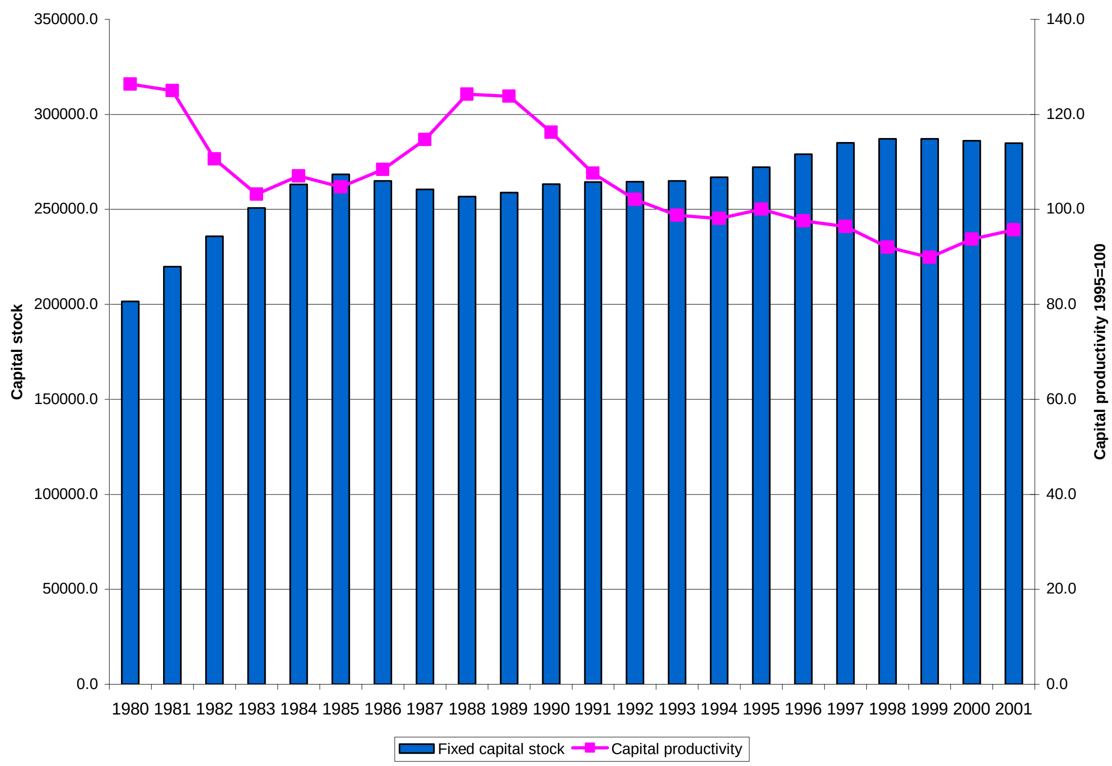
Figure 1: Evolution of employment in the manufacturing sector, 1980-2002



Source: www.tips.org.za

The labour market adjustment alluded to above was a result of the implementation of technologically advanced and more skill-intensive methods of production (SARB, 2003:87), of which, the latter impact reflected the increased capital intensity of South African manufacturing production processes. Increased capital intensity in production in the manufacturing sector is evident, though the productivity of capital has been declining since the peak attained in 1988. Figure 2, below, traces the evolution of the fixed capital stock and its productivity in the manufacturing sector.

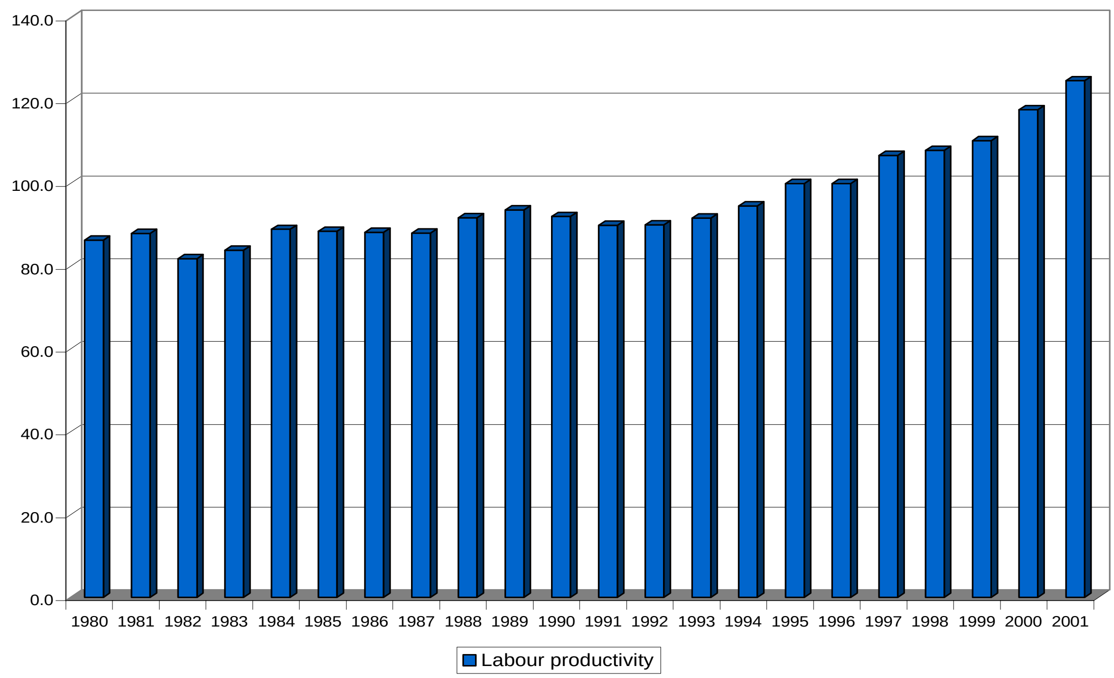
Figure 2: Capital stock and productivity in manufacturing sector, 1980-2001



Source: www.tips.org.za

An interesting aspect regarding South African manufacturing during this period was the combination of decreased employment and rising output per person. Given the restructuring that is alluded to above, it is no wonder that growth in manufacturing production was essentially driven by increased labour productivity. Figure 3 plots the evolution of labour productivity in the manufacturing sector. The improvement in labour productivity is particularly marked over the period 1994 to 2001.

Figure 3: Labour productivity in the manufacturing sector, 1980-2001



Notes : Index computed at constant 1995 prices
Source: www.tips.org.za

Table 4 shows that the South African manufacturing industry became increasingly integrated into the international economy, especially through trade and foreign direct investment between 1980 and 2002. Even at the two digit level of classification, the integration for imports and exports shows that average shares of these aggregates rose for the whole manufacturing sector. With penetration rates of 85 and 92 per cent, respectively, chapters 33 and 37 represent the most open sectors in terms of import penetration. Sector 30 remains the most closed in terms of these trade outcomes. However, a greater diversity of experiences across industries is unearthed, especially when one moves from the two-digit to the three-digit categorisation. In the three-digit classification, only three sectors (namely tobacco, paper & paper products and coke & refined petroleum products) recorded a decline in import penetration. Table 5 shows the variability of import penetration rates over the period 1980 to 2002.

Table 4: Two digit level variability in selected trade measures, 1980 and 2002

SIC Division	Import penetration			Export share		
	1980	2002	% Change 1980-2002	1980	2002	% Change 1980-2002
30	3.2	5.4	68.2	5.0	7.7	56.2
31	18.3	39.0	114.0	8.6	25.0	190.3
32	19.2	24.6	27.7	8.4	25.2	199.9
33	49.5	84.8	71.4	18.2	71.9	295.0
34	13.2	24.1	83.0	6.1	14.2	134.1
35	18.1	33.9	86.9	16.8	43.5	158.0
36	25.1	38.4	53.0	2.5	14.0	454.1
37	56.1	91.6	63.4	7.7	62.7	711.7
38	32.0	65.0	103.4	2.8	48.2	1651.9
39	15.8	32.9	108.9	15.6	44.8	187.3
Total (3-5)	17.3	29.7	71.7	7.7	23.9	211.6

Source: Trade Policy Strategies, w.w.w.tips.org

Table 5: Import share and variability within three-digit sector, 1980 and 2002

Sector	Import penetration		Within sector			
	1980	2002	Mean	Maximum	Minimum	Standard deviation
Food (301-304)	4.1	9.8	6.9	10.0	4.1	2.0
Beverages (305)	3.9	5.5	4.4	6.2	3.2	0.8
Tobacco (306)	1.7	0.8	2.0	3.2	0.8	0.7
Textiles (311-312)	16.0	30.9	22.3	30.9	16.0	4.7
Wearing apparel (313-315)	8.2	19.0	9.9	19.9	5.0	4.3
Leather & leather products (316)	20.5	21.0	27.3	40.4	17.7	8.2
Footwear (317)	10.1	46.2	19.1	46.2	4.2	12.0
Wood & wood products (321-322)	8.7	15.1	10.0	15.1	6.1	2.4
Paper & paper products (323)	16.4	10.0	13.0	16.4	10.0	2.2
Printing, publishing & recorded media (324-326)	13.4	24.1	17.4	24.1	11.5	3.3
Coke & refined petroleum products (331-333)	30.5	28.8	19.3	30.5	10.7	4.8
Basic chemicals (334)	33.1	50.0	40.6	53.1	28.5	7.7
Other chemicals & man-made fibres (335-336)	16.9	32.2	21.3	32.2	13.6	4.8
Rubber products (337)	12.4	36.1	21.8	36.6	11.9	8.7
Plastic products (338)	6.2	19.4	10.3	19.4	6.2	3.9
Glass & glass products (341)	20.3	26.3	20.2	29.0	14.0	4.3
Non-metallic minerals (342)	6.0	21.8	10.9	21.8	5.8	5.3
Basic iron & steel (351)	6.0	15.5	9.8	16.0	3.6	3.9
Basic non-ferrous metals (352)	14.3	19.4	18.4	31.9	9.0	4.9
Metal products excluding machinery (353-355)	8.1	19.7	11.3	19.7	6.5	3.8
Machinery & equipment (356-359)	44.0	80.9	53.7	80.9	34.2	13.9
Electrical machinery (361-366)	25.1	38.4	28.6	38.4	17.2	5.5
Television & communication equipment (371-373)	35.4	89.1	55.2	91.0	27.9	20.9
Professional & scientific equipment (374-376)	76.7	94.2	76.4	94.2	63.6	10.2
Motor vehicles, parts & accessories (381-383)	34.8	45.1	32.5	45.1	23.9	5.0
Other transport equipment (384-387)	29.2	84.9	48.0	87.0	19.0	22.8
Furniture (391)	3.0	27.3	7.5	27.3	2.4	6.9
Other industries (392)	28.5	38.6	26.3	38.0	17.1	5.4

Source: Trade Policy Strategies, www.tips.org.

For export shares, variability is also apparent at the three-digit level. Most sectors increased their export shares with basic metals, transport equipment, chemical products and electrical equipment being the high export sectors. These divisions also benefited from reciprocal trade agreements and improved price competitiveness brought about by the depreciation of the Rand in 2002. In response, the output volumes in these sectors expanded rapidly compared to other groups, especially during the period 1994 to 2002. The net result was that the combined share in total manufacturing production of the sectors that were prominent in exportation increased from 44 per cent in 1993 to 50 per cent in 2002 (SARB, 2003:81). Table 6 shows the evolution of the export shares in manufacturing over the review period.

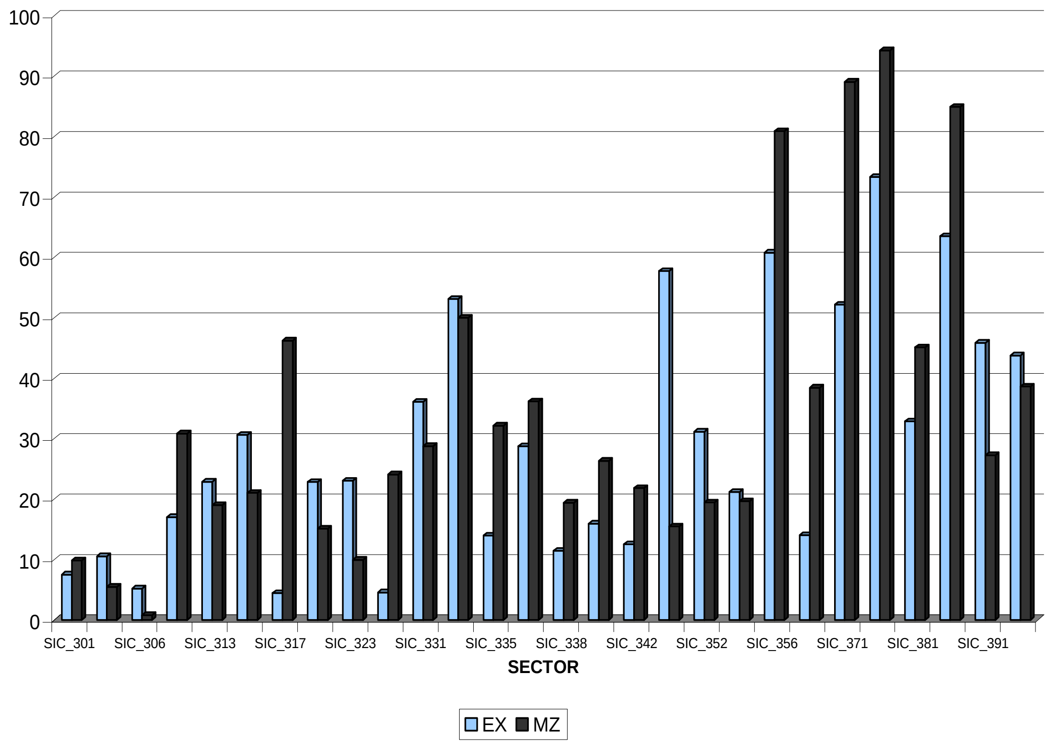
Table 6: Export share and variability within three digit sector, 1980 and 2002

Sector	Export share		Within Sector			
	1980	2002	Mean	Maximum	Minimum	Standard deviation
Food (301-304)	11.6	7.5	7.8	11.6	5.9	1.4
Beverages (305)	1.6	10.5	4.4	10.5	0.8	3.3
Tobacco (306)	1.7	5.2	3.7	7.6	0.6	2.1
Textiles (311-312)	6.2	17.0	13.0	17.0	6.0	3.1
Wearing apparel (313-315)	3.0	22.9	9.7	22.9	3.0	6.0
Leather & leather products (316)	14.2	30.6	26.2	43.2	11.2	11.4
Footwear (317)	2.5	4.5	2.5	5.7	0.5	1.6
Wood & wood products (321-322)	2.7	22.8	12.3	22.8	4.7	5.4
Paper & paper products (323)	9.5	23.0	18.9	29.2	8.4	6.2
Printing, publishing & recorded media (324-326)	0.6	4.5	1.7	4.5	0.3	1.3
Coke & refined petroleum products (331-333)	16.1	36.1	16.4	36.7	8.8	7.7
Basic chemicals (334)	15.1	53.1	32.1	53.1	12.3	14.2
Other chemicals & man-made fibres (335-336)	1.7	14.0	5.3	14.0	1.0	4.2
Rubber products (337)	2.8	28.8	10.5	28.8	1.5	8.9
Plastic products (338)	0.8	11.4	4.3	11.4	0.5	3.5
Glass & glass products (341)	7.3	15.9	10.0	15.9	3.3	3.8
Non-metallic minerals (342)	4.8	12.5	6.7	12.6	2.0	3.6
Basic iron & steel (351)	18.5	57.7	38.8	57.7	14.3	14.3
Basic non-ferrous metals (352)	42.4	31.2	47.0	76.2	34.2	11.4
Metal products excluding machinery (353-355)	1.7	21.1	9.6	22.1	1.4	7.2
Machinery & equipment (356-359)	4.5	60.8	19.3	62.7	2.5	18.4
Electrical machinery (361-366)	2.5	14.0	6.5	14.0	1.2	4.4
Television & communication equipment (371-373)	0.9	52.2	15.1	59.3	0.5	19.3
Professional & scientific equipment (374-376)	14.5	73.3	29.5	76.5	6.1	23.3
Motor vehicles, parts & accessories (381-383)	2.7	32.9	12.0	32.9	2.1	9.0
Other transport equipment (384-387)	2.3	63.5	23.1	70.8	2.1	26.0
Furniture (391)	2.9	45.9	17.2	45.9	1.1	16.3
Other industries (392)	28.3	43.8	27.5	43.8	18.1	6.0

Source: Trade Policy Strategies, www.tips.org.

As a reflection of intra industry trade, movements in import penetration and export shares appeared to be correlated positively at the three-digit level. With the exception of a few outliers, the general trend suggested that sectors, with the highest levels of absolute import penetration also had high export shares. For example, import penetration and export shares in 2002 for professional & scientific equipment were 94 and 73 per cent; other transport equipment 85 and 64 per cent; machinery & equipment 81 and 61 per cent; and television, radio and telecommunications equipment 89 and 52 per cent, respectively. Figure 4 graphs the combined import penetration ratios and export shares.

Figure 4: Import penetration and export shares, 2002



Notes: Graphed are the import penetration (MZ) and export share (EX) measured in percentages in 2002. The numbers on the horizontal axis are the SIC codes for 28 three-digit industries.
Source: Trade Policy Strategies, www.tips.org.

1.5 STRUCTURE OF THE THESIS

The remainder of the thesis is organised as follows, Chapter 2 concentrates on production efficiency analysis with emphasis on understanding total factor productivity and its components. It reviews literature on stochastic frontiers and efficiency measurement and explains the methodology for decomposing the sources of total factor productivity into efficiency and technical change. Efficiency and technical change in South African manufacturing is estimated, enabling the results from the estimation to be used to establish how the evolution of the productivity components related to the liberalisation episodes. The results from the empirical analysis are provided, as well as the key conclusions that emerge.

Chapter 3 focuses on the determinants of total factor productivity and emphasises the channels through which trade affects manufacturing productivity. Again South African manufacturing data is used to investigate the suggested theoretical links. Chapter 4 investigates the effect of trade on derived labour demand. An interesting aspect of this part of the research is the use of a unique South African data set to investigate labour market and trade issues. The concluding chapter nests all the empirical results generated in chapters 2, 3, and 4 to provide implications for policy. This final chapter suggests some directions for future research and investigation.

1.6 CONCLUDING REMARKS

Theoretical and empirical literature continues to deliver disparate predictions regarding the impact of expanded trade on productivity and derived labour demand in manufacturing. While traditional international trade appears to make some clear predictions about the static effects of trade on welfare, the dynamic effects are much less clear. In view of the fact that theoretical development is yet to resolve the debate about the relationship between increased trade, productivity and employment in manufacturing, empirical analysis is still required to bear on these issues.

A significant amount of trade liberalisation occurred in South Africa over the last decade of the study period[14]. In response, volumes of exports and imports increased and the manufacturing sector experienced significant structural change. From the mid 1990s, especially, output growth in the manufacturing sector rebounded. However, there was a mixed picture regarding employment performance, with a general decline in the trend of labour absorption, reflecting possible efficiency gains in the use of labour due to increased competition. Capital intensity in manufacturing processes increased, implying that the rebound in output growth was supported by continuously strong increases in labour productivity. Increased competition for the sector was reflected in the growth in export orientation as well as import penetration measures.

Against this background, it is important to examine the links between expanded trade, productivity and employment behaviour in the manufacturing sector[15]. Indeed, given the increasing openness of the economy, one is led to ask whether there is a possible link between greater exposure to trade, productivity and labour market adjustment. An empirical exploration of these issues is important, since data that documents the wide variety of experiences of the individual industrial sectors exists at a disaggregated level (Tomiura, 2003:121). Since the impact of competition on productivity as well as labour demand in each industry is likely to vary depending on the industry's access to international markets

[14] Factors such as technical change, trade liberalisation and globolisation contributed substantially to the steady transformation of the South African economy (SARB, 2003:79).
[15] A related subject is investigated by Du Toit and Moolman (1999).

through exports or exposure to imports (Revenga, 1992), it is important not to neglect the considerable inter-industry variation that exists within South African manufacturing. Variations in sectoral productivity performance, employment change and trade intensity measures are illustrations of the existence of substantial inter-industry heterogeneity in many other variables (Greenaway, Hine and Wright, 1999:488). This investigation explicitly takes into consideration the aspect of variability in empirical analysis.

In the following chapter, production efficiency analysis is provided. The chapter explains the methodology of decomposing the sources of total factor productivity into efficiency and technical change, within the framework of an underlying production function.

CHAPTER 2

EFFICIENCY AND TECHNICAL CHANGE IN MANUFACTURING

2.1 INTRODUCTION

Little is known about the extent of technical change and the level of manufacturing efficiency in South Africa during the last 25 years; yet, improved efficiency can be an important source of welfare gains, because firms are led to adopt new technology and reorganise operations to compete at the world market, while production shifts towards firms with better productive efficiency[16] (Pavcnik, 2000:3). The important policy issue of whether more exposure to increased trade improves the efficiency of industries requires more empirical investigation to generate an acceptable consensus in Africa. Indeed, while most analysts believe that increased trade raises manufacturing efficiency, there remains little direct evidence that has been marshalled in this respect in Sub-Saharan Africa (Naudé et al 2000:9). To test this hypothesis, a rich panel data set on manufacturing industries in South Africa is used. Efficiency and technical change scores for the manufacturing industries are calculated from an underlying production function. The evolution of technical change and industry efficiency are then examined as channels through which trade expansion could have affected manufacturing performance during the 1980-2002 period.

An examination of the evolution of technical change and industry efficiency in manufacturing helps us to see how industry responded to trade expansion, and,

[16] A quasi-experimental study employing a Ugandan data set found a significant increase in technical efficiency for firms that produce import competing products. This evidence was striking and clearly demonstrated that, subject to increased global competition from trade liberalisation, firms increased their technical efficiency (Kasekende, Abuka and Asea, 1999).

in particular, how they adjusted to remain competitive[17]. This research contributes to the development of studies regarding the behaviour and performance of industries at a disaggregated level, especially in isolating the impact of industry heterogeneity on technical efficiency. In a nutshell, this investigation applies panel data econometric techniques to estimate productivity losses due to technical inefficiency.

Chapter 2 sets out to provide empirical estimates of efficiency and technical change in South Africa's manufacturing sector. The rest of the chapter contains these results, beginning with the discussion of the literature relevant to efficiency estimation in Section 2.2. The empirical specification is presented in Section 2.3. The data investigated is discussed in Section 2.4. The results are provided in Section 2.5, which is followed by concluding comments in Section 2.6.

2.2 MEASURING EFFICIENCY AND TECHNICAL CHANGE

2.2.1 Importance of decomposing total factor productivity

One advantage of frontier production functions is that they offer the promise of decomposing productivity change into movements of the production surface (usually deemed to be "true" technological change) and movements toward or away from the surface (changes in efficiency,[18] with which a given technology is

[17] Under liberalisation firms should eliminate waste, reduce managerial slack and achieve a better cost control to remain competitive (Ferrantino et al, 1995). Labour laws may not allow this to happen.

[18] It is argued that liberalisation of the trade regime influences efficiency through various channels (Tybout and Westbrook, 1995). Liberalisation allows firms to achieve economies of scale by taking advantage of market expansion, it enables firms to absorb technologies and knowledge through participation in foreign markets, it pressures firms to reduce x-inefficiency in order to cope with competition from abroad and it forces firms to refrain from rent seeking behaviour. The finding of significant improvements in technical efficiency in manufacturing during the

applied). The presumption is that, over time, the production function will shift upward, associating larger quantities of output with smaller quantities of inputs, demonstrating the existence of technological progress. However, some panel estimates have shown that production surfaces may move in the opposite direction, as well, indicating what might be called "technological regress" (Piesse and Thirtle, 2000:490).

A number of studies employ national income accounting data to track productivity and efficiency change (De Wet, 1998 and Du Toit , 1999). However, the use of aggregate-level data tends to ignore industry specific characteristics that are fundamental from a productivity point of view (Mahedevan and Kim, 2003:670). Again, adopting the conventional growth accounting approach could yield estimates of total factor productivity without distinguishing the two components of productivity.

Moreover, the production process is not simply an engineering relationship between a set of inputs and observed output; hence, even a well defined function cannot describe production accurately, because variation in inputs does not necessarily result in a corresponding change in output (Han et al, 2002:402). Observed output is a result of a series of economic decisions, which influence the method of application of inputs; thus, variables associated with institutions will play an important part in a firm's output. Given these reasons, some firms are likely to produce not on but inside their optimum production possibility frontiers, with an actual gap between optimal and realized methods of production arising from the effects of organizational factors. Studies that measure productivity as a whole, and are unable to decompose it into measures of efficiency and technical change, will show output to be chiefly accounted for

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period of trade expansion in South Africa would suggest that welfare may have improved as a result.

by input growth. Little is left over to be attributed to technical change (Mahadevan and Kalirajan, 2000:829).

The objective should be to decompose output growth into growth due to inputs, changes in the output gap and technical change. Improvements in efficiency measure how the output gap between optimal and realized production methods evolves over time. This effect can be substantial, and may outweigh gains from technical change itself. It is important to know how far one is off the production frontier at any point in time, and how quickly one can reach the frontier. Technical change on the other hand measures the movement of the production frontier over time. It reflects the success of explicit policies to facilitate the acquisition of foreign technology and can be interpreted as providing a measure of innovation (Han et al, 2001:404).

The recognition that improvements in efficiency as well as technical change are continuous processes implies that it is possible for high rates of technical change to coexist with deteriorating efficiency. It is also possible for relatively low rates of technical change to coexist with improving efficiency. Most importantly, different policy implications result from different sources of variation in productivity. Mahadevan and Kalirajan (2000:829) stress that the decomposition of productivity is a useful exercise in distinguishing adoption of new technology by efficient industries from the diffusion of technology. The coexistence of a low rate of technical change and a low rate of efficiency may reflect failures to achieve technological diffusion. Moreover, since the measure of technological mastery is highly correlated with the level of human capital development, it assumes a particular significance in an emerging economy's development process (Han et al 2003:405). Technical change shows the movement of the firm's actual output to its maximum possible output given technology. Improvements in efficiency result in increased output if given inputs and technology are used efficiently due to accumulation of knowledge in the learning-by-doing process, improvements in the instructions of combining inputs, diffusion of new technology and knowledge and improved managerial practice. Efficiency and technical change are analytically very different and it is important to distinguish between them for policy making (Mahedevan 2001:593).

2.2.2 The stochastic frontier production function

Stochastic frontier production functions have facilitated the measurement of firm level technical efficiency. Two measurement approaches are available. One of the approaches is deterministic, in the sense that all deviations from the frontier are attributed to inefficiency and the maximum output attainable in this case is represented as a scalar. The other approach is stochastic and represents a considerable improvement over the deterministic variant; in this case, the maximum output is a random variable or a distribution of outcomes making it possible to discriminate between random errors and differences in inefficiency (Griffin and Steel, 2004).

Stochastic frontiers have been used in the study of firm efficiency and productivity since they were first independently proposed by Aigner, et al (1977) and Meeusen and van den Broek (1977). A production frontier represents the maximum amount of output that can be produced from a given level of inputs. Since firms typically fall below the maximum that is possible, the deviation of actual from maximum output becomes the measure of inefficiency and is the focus of interest in most empirical work. However, the distribution to be used for the inefficiency error has been a source of contention (Griffin and Steel, 2004:2).

One problem with cross sectional data in inefficiency measurement is that technical inefficiency cannot be separated from firm specific effects that are not related to inefficiency (Battese and Coelli, 1995; Battese et al, 2000). Panel data avoids this problem,[19] and, indeed, the availability of panel data allows writing the stochastic frontier production function in the form:

$$Y_{it} = f(X_{it}, \beta) + \varepsilon_{it} \qquad (1)$$

where Y_{it} is the output or value added for the i[th] industry in year t, X_{it} is a vector of input variables and β is a vector of unknown parameters to be estimated and $f(.)$ denotes either a Cobb-Douglas or translog production function. Green (2000:395) indicates that in the stochastic model, it is the disturbance, which is the central focus of analysis rather than the catch-all for the unknown factors omitted from the regression.

This model, therefore, combines two stochastic elements in the error term, i.e., $\varepsilon_{it} = v_{it} - \mu_{it}$. The conventional symmetric error term v_{it} is assumed to be independent and identically distributed as $N(0, \sigma^2{}_v)$ and captures variation in output that results from factors that are beyond the control of the industry such as labour market conflicts, measurement pathologies in the dependent variable and excluded explanatory variables. The remainder component of the error term is the disturbance μ_{it}, which captures industry-specific technical inefficiency in production.

Different cases have been assumed for the distribution of the technical inefficiency effects. The first basic model specified that they are i.i.d random variables, which implies that there are no particular advantages in obtaining observations on a given industry versus obtaining observations on more industries at particular time periods. The second basic model assumed that

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[19] While implementing efficiency measurement using panel data, it is important to distinguish technical inefficiency from firm and time specific effects. These effects are normally separate from exogenous technical progress. In a panel data context, it is possible to decompose the error into firm specific effects, time specific effects, the white noise and technical inefficiency (Kumbhakar, 1991).

technical inefficiency effects are time invariant. Battese and Coelli (1988) extended this model so that the technical inefficiencies had a generalised truncated-normal distribution as proposed by Stevenson (1980). Battese, Coelli and Colby (1989) further extended this model to allow use of unbalanced panel data. However, the assumption that technical inefficiency effects are time invariant becomes more difficult to justify especially as T becomes larger[20]. Although Kumbhakar (1990) proposed a stochastic frontier model for panel data, in which technical inefficiency effects vary systematically with time in a time varying specification, this model has not be widely applied. In response, Battese and Coelli (1992) suggested an alternative to Kumbhakar (1990) model in which the technical inefficiencies are an exponential function of time involving only one unknown parameter. One advantage of the time varying inefficiency model is that technical inefficiency changes over time can be distinguished from technical change.

2.2.2.1 Measuring technical efficiency

In Coelli (1996:8), technical efficiency of an individual firm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditional on the level of inputs used by the firm. Technical efficiency of firm i at time t in the context of a stochastic frontier production function equals the ratio of observed output to estimated frontier output:

$$TE_{it} = \frac{Y_{it}}{\exp\left(f\left(X_{it};\alpha\right)\right)} = \exp(-\mu_{it}) \qquad (2)$$

Since μ_{it} is by definition a non-negative random variable, the technical efficiencies will lie between zero and unity, where unity indicates the firm is technically efficient.

[20] This is because managers learn from there previous experience in the production process and so their technical inefficiency effects would change in some persistent pattern over time (Coelli, Rao and Battese, 1998).

Battese and Coelli (1992) show that it is possible to estimate a stochastic frontier production function for panel data, which has firm effects that are assumed to be distributed as truncated normal random variables, which are also permitted to evolve systematically over time. Given the availability of panel data, a choice has to be made between time invariant or time varying efficiencies. The preferred model should be selected on the basis of statistical criteria.

2.2.2.2 Measuring technical change

A critical issue in panel data modelling is the specification of technical change,[21] because the specification reveals the time path of efficiency and whether inefficiency is transitory or permanent. According to Heshmati and Nafer (1998:183), technical change has traditionally been described as a single time trend. With the advent of the flexible functional form, technical change can be generalized by the introduction of quadratic terms in the time trend with inputs in production functions. This generalised index allows the rate of technical change to be both variable and non-neutral. The general index approach of Baltagi and Griffin (1988) can model pure technical change, because no *a priori* structure is imposed on its behaviour. A time dummy allows the time effects to switch from positive to negative and back to positive. In this case, an estimable Cobb-Douglas production function would be of the form:

$$\ln Y_{it} = \alpha_0 + \alpha_k \ln(K_{it}) + \alpha_l \ln(N_{it}) + \alpha_m \ln(M_{it}) + \sum_t \lambda_t D_t + (\nu_{it} - \mu_{it}) \qquad (3)$$

In this specification, D_t is a dummy variable having a value of one for the t^{th} time period and zero otherwise and λ_t are parameters to be estimated. The dummy variable D_t is introduced to model pure technical change in line with the general

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[21] Stochastic frontier literature for panel models, has two main groups: (i) those that assume technical efficiency to be time invariant (Pitt and Lee, 1981, Schmidt and Sickles, 1984, Battese and Coelli, 1988, and (ii) those that assume technical efficiency is time varying (Cornwell et al, 1990, Kumbhakar, 1990, Battese and Coelli, 1992, Lee and Schmidt, 1993).

index approach of Baltagi and Griffin (1988). The change in λ_t between successive periods becomes a measure of the rate of technical change[22], which can be summarised as:

$$TC_{t,t+1} = \lambda_{t+1} - \lambda_t \qquad (4)$$

The implication is that for the hypothesis of no technical change, $\lambda_t = k \quad \forall t$ in model (4).

2.2.2.3 Panel data production frontier models

Panel data contains more information than does a single cross section, it therefore enables some strong distributional assumptions used in cross-sectional data to be relaxed and while estimates of technical efficiency with more desirable statistical properties are obtained. There are three difficulties with cross-sectional stochastic production frontier models summarised in Kumbhakar and Lovell (2000:95).

First, maximum likelihood estimation of the stochastic production frontier and the subsequent separation of technical inefficiency from statistical noise requires strong distributional assumptions on each error component. Panel data on the other hand enables us to adapt conventional panel estimation techniques to the technical efficiency measurement problem without invoking the strong distributional assumptions. Second, maximum likelihood estimation also requires the assumption that the technical inefficiency error component be independent of the regressors. However, not all panel data estimation techniques require the assumption of independence of the technical efficiency error

[22] The assumption that technical efficiency is constant through time is a strong one if the operating environment is competitive and the panel is long (Kumbhakar and Lovell 2000). Although the assumption of time invariance of technical efficiency is justified by the fact that only about half of the panel period can be justified as actually competitive, it is possible to vary this assumption.

component from the regressors. Finally, technical efficiency of industries in the cross section cannot be consistently estimated since the variance of the conditional mean or mode for each individual industry does not go to zero as the size of the cross section increases. Panel data helps to avoid this drawback because adding more observations on each industry generates information not provided by adding more industries to cross section. Technical efficiency of each industry can be consistently estimated as $T \to +\infty$.

2.3 ECONOMETRIC SPECIFICATION

Estimation of stochastic frontier production functions is preferred, because it facilitates derivation of measures of efficiency and technical change. In addition, it deals with the weakness in the non-frontier methodology assumption that all industries are fully realising their capacity in the production process and are thus efficient (Mahadevan, 2001:588). This assumption can ignore possible gains from technical change because the total factor productivity residual is taken to be synonymous with disembodied technological progress. The two components are analytically very different and it is important to distinguish between them for policy making as shown in Obwona (1994:133) and Piesse and Thirtle (2000:478). In a panel context, the stochastic form of the translog functional form, using a general index formulation for time, can be stated in equation (5) as:

$$\ln(Y_{it}) = \alpha_0 + \alpha_k \ln(K_{it}) + \alpha_l \ln(N_{it}) + \alpha_m \ln(M_{it}) + \alpha_{kl} \ln(K_{it})\ln(N_{it}) + \alpha_{km} \ln(K_{it})\ln(M_{it})$$
$$+ \alpha_{lm} \ln(N_{it})\ln(M_{it}) + \left(\frac{1}{2}\right)\left\{\alpha_{kk}(\ln K_{it})^2 + \alpha_{ll}(\ln N_{it})^2 + \alpha_{mm}\ln(M)^2\right\}$$
$$+ \sum_t \lambda_t D_t + (\nu_{it} - \mu_{it}) \qquad (5)$$

where; $i = 1,........28$ defines the number of industries and $t = 1,.......23$ denotes the number of years 1980 to 2002. The variable Y is output or value added measured in 1995 prices and N is the number of employees (workers employed). Capital,

K, and intermediate material inputs consumed, M, are also measured at 1995 prices. The variable μ_{it} is the combined effect of the non-price and organizational factors that constrain firms from achieving their maximum possible output from the given set of inputs and technology at a given time and the remainder, v_{it} is the statistical random disturbance term.

The production function for the manufacturing sector is estimated from pooled cross sectional data from 28 manufacturing industries over 1980-2002. The explicit specification of the production function allows us to use statistical methods and inference to evaluate the reliability of the results. The proposed methodology allows for variation due to industry effects. Since the methodology allows for inter-industry differences within the sectors, it avoids omitted variable bias in estimating the underlying parameters. Time dummies are used to allow industry technical progress to vary across time[23].

2.4 THE DATA AND SAMPLE CHARACTERISTICS

The data used in this study covers the entire South African manufacturing sector over the period 1980-2002. There are 28 individual industries grouped under the three digit ISIC categorisation. The data set includes output, value added, labour employed and capital stock. The Sources of data are Statistics South Africa www.statssa.gov.za, South African Reserve Bank www.reservebank.co.za, and Trade and Industry Policy Strategies Secretariat www.tips.org.za.

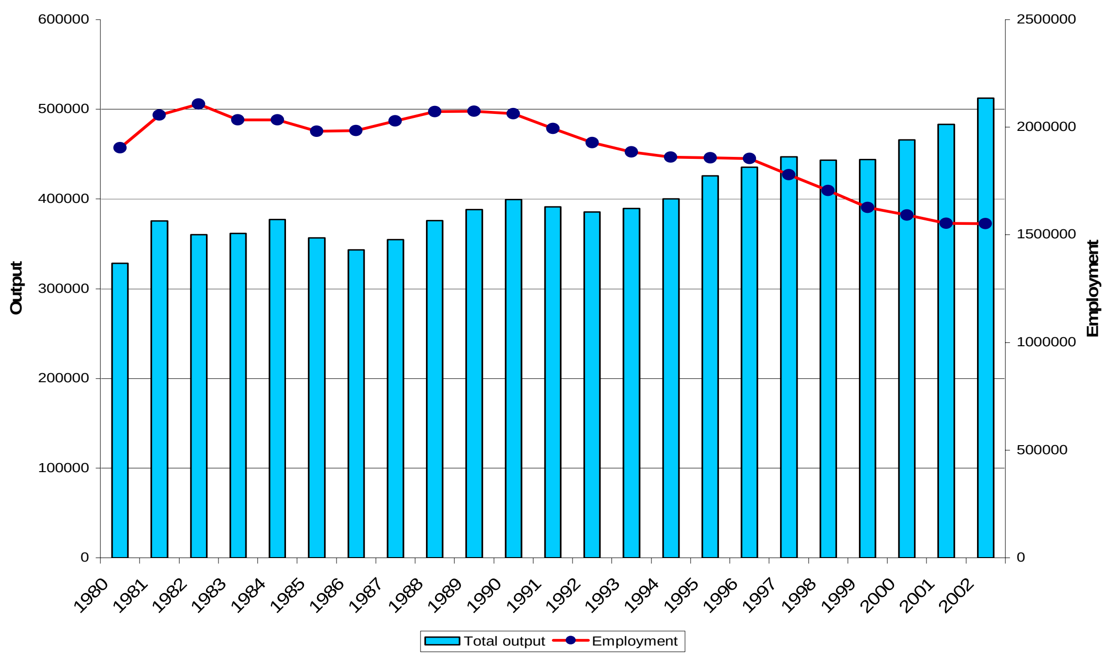
Output Y is the value of aggregate output produced on an annual basis. Value added V is defined as the difference between the value of output and the cost of materials and supplies, fuels, electricity and water, the value of contract and

[23] It is also possible to use industry dummies to allow for variation among industries within a particular year.

maintenance services done by external sources, and the cost of goods purchased for resale without transformation. Capital stock data on the industry is denoted K. Labour is denoted as N and is defined as the number of employees in an industry, while intermediate raw materials consumed are denoted by M. All variables expressed in value terms are given in constant 1995 prices.

Figure 5 shows the evolution of output and employment in South African manufacturing over the period under investigation. As indicated in the earlier analysis, the figure shows that from 1994 to 2002 there was a decline in employment and an increase in the level of output. This development can only be rationalised by a corresponding increase in labour productivity in the manufacturing sector. The increase in labour productivity is a manifestation of continuing efforts to improve the skill complement of South African workers.

Figure 5: Evolution of employment and output in manufacturing, 1980-2002



Note: Employment is defined in terms of number of employees
Source: www.statssa.gov.za, and www.tips.org.za.

2.5 ECONOMETRIC RESULTS

2.5.1 Univariate data analysis

2.5.1.1 Summary statistics

The empirical analysis is based on the entire South African manufacturing data base, which is composed of 28 sectors over a period (1980-2002) of 23 years. Table 7, below, shows the existence of substantial variability in the manufacturing sectors with regard to output, value added, capital stock and material input use.

Table 7: Summary statistics for inputs and outputs

Variable	Definition	Mean	SD	Minimum	Maximum
Y	Output	11608.3	10168.7	928.7	58197.1
V	Value added	3708.1	2672.9	276.7	11988.7
N	Number of employees	51947.5	43618.6	2091.8	207068.1
K	Capital	5653.3	8786.9	96.5	56357.3
M	Materials	7806.0	7947.9	356.8	45683.3

Note: Variables in 1995 prices and in millions of rand. Number of observations is 644.

Source: www.statssa.gov.za, and www.tips.org.za.

2.5.1.2 Correlation analysis

As part of exploratory data analysis, the nature of correlation between variables in the production function is investigated. Both parametric and non-parametric tests of hypothesis for correlation analysis are computed. Table 8 displays the results of the non-parametric covariance matrix for value added and total output and inputs. The results show that output and value added have strong positive correlations with the inputs.

Table 8: Correlation between inputs and output measures

Correlation between value added, capital, materials and labour				
Value added	Value added	Capital	Materials	Labour
Value Added	1.0000			
Capital	0.8010	1.0000		
Materials	0.8245	0.8110	1.0000	
Labour	0.6657	0.5075	0.6950	1.0000
Correlation between output, capital, materials and labour				
Output	Output	Capital	Materials	Labour
Output	1.0000			
Capital	0.8219	1.0000		
Materials	0.9206	0.8110	1.0000	
Labour	0.7120	0.5075	0.6950	1.0000

Note: The number of observations is 644
Source: Author's own computations, www.statssa.gov.za, and www.tips.org.za.

Table 9, on the other hand, displays two non-parametric test results. The tests include the Spearman and Kendall rank correlation coefficients. These two tests indicate correlation coefficients along with tests of the hypothesis that the variables are independent. The results show that output and value added have strong positive correlation with inputs, and the correlation computed is statistically significant. The significance level for the calculated correlation coefficients is indicated below the respective coefficients shown in Table 9.

Table 9: Non parametric tests for production function variables

Value added and inputs			
Value Added	Capital	Labour	Materials
Spearman's rho	0.7880	0.6288	0.8406
Prob > |t|	0.000	0.000	0.000
Kendal's tau-a	0.5902	0.4537	0.7075
Prob > |z|	0.000	0.000	0.000
Total output and inputs			
Output	Capital	Labour	Materials
Spearman's rho	0.8234	0.6827	0.9204
Prob > |t|	0.000	0.000	0.000
Kendal's tau-a	0.6241	0.4928	0.8166
Prob > |z|	0.000	0.000	0.000

Note: The number of observations is 644, p-values are defined as Prob > |t| and Prob > |z| for the Spearman's and Kendall's test respectively.
Source: Authors computations, www.statssa.gov.za, and www.tips.org.za.

2.5.1.3 Intuition behind panel unit root tests[24]

Evidence that has been gathered from testing non-stationary panels is that many test statistics and estimates of interest have normal limiting distributions[25]. This finding is in contrast to the non stationary time series literature where the limiting distributions are complicated functionals of Weiner processes (Baltagi, 2001:234). Application of panel data can help avoid the problem of spurious regression (Phillips and Moon, 1999 and Kao, 1999)[26]. Unlike the single time series spurious regression literature, panel data[27] spurious regression estimates give consistent estimates of the true value of the parameter as both N and T tend to ∞. This arises from the fact that panel estimators average across individuals and the information in the independent cross section data in panels generates a stronger overall signal than the pure time series case. In addition to other documented payoffs (Baltagi 2001:5-7), panel data techniques help us to combine the advantages of cross-section and time series by treating cross-sections as repeated draws from the same distribution, which is important, because some panel statistics converge in distribution to normally distributed random variables.

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[24] Just as in the case of time series, unit root tests are not used as an end themselves but to further specify regression equations.

[25] Certain panel statistics (estimators) converge in distribution to normally distributed random variables. In our panel there are more degrees of freedom. We dealing not just with 23 years of data but with 644 observations (23 years *28 industries).

[26] The overall conclusions on unit root tests can be examined by looking at Monte Carlo studies on size and power. Choi (2000) argues that the size of IPS tests and Fisher are reasonably close to 0.05 desired with small N, with large N Fisher test shows more distortion. Considering size adjusted power, Fisher seems to be a more powerful test. The performance of both tests worsens when a linear time trend is introduced. Karlsson and Loethgren (2000) examined the Levin and Lin and the IPS and concluded that for large T the tests have good power. However, one needs to watch inference conclusions. Large T gives the panel unit root tests high power and there is the potential risk of concluding that the whole panel is stationary even when there is only a small proportion of stationary series in the panel. The problem is reversed for small T.

[27] The debate has been whether panel data can solve some of the shortcomings found in time series analysis namely low power of time series tests, nonstandard limiting distributions of time series and the spurious regression problem in which the t-statistics diverge in miss-specified regressions of two I(1) variables. The overall answer is that panel data can help but at the cost of introducing a new issue, how homogeneous is the panel?

The importance of testing for unit roots in time series arises from the fact that a regression equation with integrated variables is likely to yield spurious results, unless there is cointegration in the relationship. In the case of panel data, Phillips and Moon (1999) have shown that, under quite weak regularity conditions, the pooled time and cross-section data improve the degrees of freedom required for estimating long run relations that may exist in cointegrated variables. Unit root tests are classified on the basis of whether there are restrictions on the autoregressive processes across cross-sections. The tests either assume a common unit root process (Levin, Lin and Chu (2002), Breitung (2000) and Hadri (2000)) or an individual root process (Im, Pesaran, and Smith (2003) and the Fisher ADF or Fisher PP shown in Maddala and Wu (1999)[28] and Choi (2001)). Levin, Lin and Chu (2002) assume existence of a common unit root process across cross-sections and employ a null hypothesis of a unit root. The basic ADF specification considered is:

$$\Delta y_{it} = \alpha_i y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X'_{it}\delta + \varepsilon_{i,t} \qquad (6)$$

Where it is assumed $\alpha = \rho - 1$ is the lag order for the difference terms, ρ_i varies across cross-sections. The null and alternative hypotheses are respectively:

$$H_0 : \alpha_i = 0 \text{ and } H_1 : \alpha_i < 0 \qquad (7)$$

Levin, Lin and Chu (2002) show that, under the null, a modified t-statistic for the resulting $\hat{\alpha}$ is asymptotically normally distributed:

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[28] This test is constructed with the idea of improving on the Levin and Lin and IPS tests. The IPS test assumes T is constant for all cross sections while both Levin and Lin and IPS have critical values that depend on the lag order employed. The Maddala and Wu (1999) test does not require balanced panel, it can accommodate different unit root tests and can be adapted for less restrictive assumptions about cross-correlations based on bootstrap techniques. The Maddala and Wu (1999) test is a Fisher (1932) based test which combines information on unit root test p-values. It has the advantage of being an exact test while the IPS test is based fundamentally on the ADF test.

$$t_{\alpha_i^*} = \frac{t_{\alpha i} - \left(N\tilde{T}\right)S_N{}^{\hat{\sigma}-2} se(\hat{\alpha})\mu_{m\bar{T}^*}}{\sigma_{m\bar{T}^*}} \rightarrow N(0,1) \tag{8}$$

Where t_{α_i} is the standard t-statistic, $\hat{\alpha}_i = 0$, $\hat{\sigma}^2$ is the estimated variance error term, $se(\hat{\alpha}_i)$ is the standard error of $\hat{\alpha}_i$, and $\tilde{T} = T - \left(\sum_i p/N\right) - 1$. The two terms $\mu_{m\bar{T}^*}$ and $\sigma_{m\bar{T}^*}$ are adjustments for the mean and standard deviation, respectively. The Breitung (2000) method differs from the Levin, Lin and Chu (2002) approach in the construction of standardized proxies. Breitung shows that his resulting estimator for α_i^* is asymptotically distributed as a standard normal. Hadri's (2000) panel unit root test is similar to the Kwaitkowsky, Phillips, Schmidt, Shinn (KPSS) unit root test and has a null hypothesis of no unit root in any series in the panel. The test is based on the residuals from individual OLS regressions of y_{it} on a constant, or a constant and time trend. The test is a Lagrange multiplier application and reports two Z statistic values, one of the Z values relies on underlying homoskedasticity across i, while the other Z statistic allows for heteroskedasticity across i. Hadri (2000) shows that under mild assumptions:

$$Z = \frac{\sqrt{N}(LM - \xi)}{\zeta} \rightarrow N(0,1) \tag{9}$$

Im, Pesaran and Shin (2003), hereafter designated (IPS), and the Fisher-Dickey Fuller and Phillips Perron tests following Maddala and Wu (1999) allow for individual unit root processes so that ρ_i may vary across cross sections. These tests are characterised by combining the individual unit root tests to derive a panel-specific result. In the case of Im, Pesaran and Shin (2003) the null hypothesis is written as:

$$H_0 : \alpha_i = 0 \text{ for all } i \tag{10}$$

while the alternative hypothesis is given by:

$$H_1 : \alpha_i = 0 \text{ for } i = 1,2,......N_1 \qquad (11)$$

In general, where the lag order in equation (6) is non-zero for some cross sections, IPS (2003) show that a properly standardised $\bar{t}_{NT}$ has an asymptotic standard normal distribution:

$$W_{tNT} = \frac{\sqrt{N}\left(t_{NT^{-N^{-1}}} \sum_{i=1}^{N} E\left(t_{iT}\left(\rho_i\right)\right)\right)}{\sqrt{N^{-1}\sum_{i=1}^{N} \operatorname{var}\left(t_{iT}\left(\rho_i\right)\right)}} \rightarrow N(0,1) \qquad (12)$$

The expressions for the expected mean and variance of the ADF regression t-statistics are provided by IPS for various time periods T and for various values of lag order ρ. An alternative approach to panel unit root results proposed by Maddala and Wu (1999) and by Choi (2001) uses Fisher's (1932) results to obtain tests that combine the ρ values from individual unit root tests. Assuming π_i is the ρ-value from any individual unit root for cross-section i then, under the null of unit root for all N cross-sections, an asymptotic result is obtained such that $-2\sum_{i=1}^{N}\log(\pi_i) \rightarrow \chi^2_{2N}$ and Choi (2001) shows that:

$$Z = \frac{1}{\sqrt{N_{i=1}}} \sum_{i=1}^{N} \phi^{-1}(\pi_i) \rightarrow N(0,1) \qquad (13)$$

Where ϕ^{-1} is the inverse of the standard normal cumulative distribution function. In Table 10, below, the results of the group unit root tests from these methods on the variables used for the estimation of the production function are reported.

Table 10: Group unit root tests for production function variables

Variable/method	Value Added	Capital stock	Labour employed	Materials input
LLC Statistic	-0.24[0.40]	-13.98[0.00]	-0.77[0.22]	-0.69[0.247]
Breitung $t-statistic$	0.84[0.80]	0.55[0.71]	-1.43[0.08]	-0.11[0.46]
IPS Statistic	-0.20[0.42]	-14.47[0.00]	0.40[0.65]	1.97[0.98]
ADF-Fischer χ^2 Statistic	63.17[0.24]	290.36[0.00]	56.11[0.47]	46.25[0.82]
PP-Fischer χ^2 Statistic	49.69[0.71]	25.952[1.00]	37.12[0.98]	44.62[0.86]
Hadri $Z-statistic$	9.92[0.00]	6.86[0.00]	10.41[0.00]	10.56[0.00]
Cross sections	28	28	28	28
Integration order	I(1)	I(1)	I(1)	I(1)

Notes: Probabilities are in brackets. The probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. Variables are in logarithmic transformation
Source: Authors own computations, www.statssa.gov.za, and www.tips.org.za.

The results in Table 10, indicate that output, value added, capital stock and material inputs are integrated of order 1. These variables are stationary in the first difference specification. Therefore a test for cointegration should be performed before regression analysis can be conducted.

2.5.1.4 Testing for cointegration in the production function

The literature on testing for cointegration in panel data has tended to follow two broad directions. The first is based on a null hypothesis of no cointegration and uses residuals from static regressions to construct test statistics (Pedroni, 1995 and Kao, 1999). The second approach is based on a null of cointegration and adopts a residual based test in the spirit of McCoskey and Kao (1998). In the same vein, McCoskey and Kao (2001) generate a test that is suited to heterogeneous panels and allows for individual cointegrating vectors. The test is constructed in a similar style to the IPS test for unit root. It is based on the average of individual cointegration test statistics and is then normalised with appropriate mean and variance for standard normal limiting distribution. The moments allow for intercept and no time trend and since they are based on a asymptotic simulation the results are the same for ADF and Phillips Perron based tests. The test is constructed as:

$$\bar{Z} = \frac{\sqrt{N\left(AD\bar{F} - \mu\right)}}{\sqrt{\sigma^2}} \sim N(0,1) \tag{14}$$

Where N is the number of cross-sections, $AD\bar{F}$ is the average of the ADF or PP statistics, μ is the mean and σ^2 is the variance (or standard deviation). The means and variances based on Monte Carlo simulated moments are provided in McCoskey and Kao (2001:186). The null hypothesis H_0: is that none of the relationships is cointegrated and the alternative H_A: is that at least one of the relationships is cointegrated. The intuition behind the testing arises because cointegration provides that there should exist a long run relationship between the natural logs of value added, capital, labour and material inputs. If there exists a long run relationship between these variables, then some or all the panels in the regression in Table 11, below, should show cointegrated relations. The test results reject the null of no cointegration at the 5 percent level, suggesting that there is a long run relationship in the estimated manufacturing production function. The test results are reported in Table 11, below.

Table 11: Production function cointegration

Equation	Method	Z Statistic	Critical value (5%)	Observations	Cross-sections
$v_{it} = f\left(k_{it}, n_{it}, m_{it}\right)$	IPS Statistic	-1.876	-1.645	644	28
	PP Statistic	-1.808	-1.645	644	28

Notes: The test assumes asymptotic normality.
Source: Authors computations, www.statssa.gov.za, and www.tips.org.za.

The test results for cointegration indicate evidence of the existence of a long run relationship between value added, capital, labour input and materials. This result is expected intuitively because economic theory has provided a direct linkage between output and inputs of labour and capital used to generate it (Solow, 1957).

2.5.2 Multivariate model results: production functions

Three important estimation steps are conducted in this section. First, traditional production frontiers for efficiency measurement are estimated. Second, aware that autocorrelation and heteroscedasticity are likely to be problems in panel data, production functions that employ the Panel Corrected Prais-Winsten adjustment are estimated. Third, the results from the above two steps are used to explain the evolution of efficiency and technical change in South African manufacturing.

The frontier models based on Battese and Coelli (1992:160) contain estimators that have two components. One component, μ_{it}, is assumed to have a strictly non-negative distribution and the other component, v_{it}, is assumed to have a symmetric distribution. In the economics literature μ_{it} is the inefficiency term and v_{it} is the idiosyncratic error. Two basic traditional models are estimated for comparison purposes. One of these models takes inefficiency to be time-invariant, while the other analyses inefficiency within a time-varying decay format.

2.5.2.1 A time invariant inefficiency model

In this specification, the inefficiency term is assumed to have a truncated normal distribution that is constant over time within the panel hence $\mu_{it} = \mu_i$. However, the idiosyncratic error term is assumed to have a normal distribution with mean zero. The only panel specific effect is the random inefficiency term.

Table 12 provides estimates of the input elasticities for the time invariant inefficiency model with an underlying Cobb-Douglas function. The Cobb-Douglas functional form is attractive for its simplicity, the logarithmic transformation provides a model which is linear in the logarithms of the inputs[29]. The parameter estimates had significant t-ratios. The corresponding output elasticities with respect to capital, labour and materials are 0.43, 0.40 and 0.20 respectively.

Table 12: Time invariant inefficiency: Cobb-Douglas production function

Stochastic frontier model: Dependent Variable ln(v)							
Variable	**Parameter**	**Coef.**	**Std. Err.**	**Z**	**P>|z|**	**[95% Conf. Interval]**	
$\ln(K)$	α_k	0.4331	0.0385	11.25	0.000	0.3577	0.5085
$\ln(N)$	α_n	0.3663	0.0382	9.51	0.000	0.2908	0.4418
$\ln(M)$	α_m	0.1850	0.0335	5.53	0.000	0.1195	0.2506
Constant	α_0	0.8167	0.6423	1.27	0.204	-0.4421	2.0755
mu	μ	1.6816	0.4821	3.49	0.000	0.7368	2.6264
Group variable		Sector	Obs per group: min			23	
Time variable		Year	Obs per group: avg			23	
Log likelihood		184.0881	Obs per group: max			23	
Number of obs		644	Wald chi²			498.73	
Number of groups		28	Prob>chi²			0.0000	

Note: Coefficients on time dummies are not reported
Source: STATA Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

The translog is a flexible production function because it imposes no restrictions upon returns to scale or substitution possibilities[30]. Table 13 presents the results for the translog specification. The translog functional form accommodates multiple inputs without necessarily violating the curvature conditions, it is also

[29] This simplicity is however, associated with a number of restrictive properties. The Cobb-Douglas production function has constant input elasticities and returns to scale for all the industries in the sample.

[30] A discussion of the translog is provided in Christensen et al (1973). The drawback of the translog is that susceptible to multicollinearity and degrees of freedom problems. The solution to these problems can be attained by using systems estimators that are more difficult to compute and also have other problems associated with their estimation (Coelli et al, 1998).

flexible because it provides second order approximation to any well behaved underlying production frontier and it forms the basis for much of the empirical estimation and decomposition of production efficiency (Kumbhakar and Lovell, 2000). About 70 percent of the parameters in the translog were significant. The variance parameter, γ, for the translog model of 0.91, is higher than that in the Cobb-Douglas of 0.89. The inefficiency parameter is significant in both models, showing that inefficiency is an important component of the manufacturing production process. The corresponding average output elasticities with respect to capital, labour and materials are 0.42, 0.45 and 0.48 respectively.

Table 13: Time invariant inefficiency: Translog production function

Stochastic frontier model: Dependent Variable ln(v)							
Variable	**Parameter**	**Coef.**	**Std. Err.**	**Z**	**P>|z|**	**[95% Conf. Interval]**	
$\ln(K)$	α_k	1.6468	0.3519	4.68	0.000	0.9569	2.3367
$\ln(N)$	α_n	0.0659	0.3582	0.18	0.854	-0.6363	0.7681
$\ln(M)$	α_m	-1.1080	0.3237	-3.42	0.001	-1.7424	-0.4736
$(\frac{1}{2})\ln(K^2)$	β_{kk}	0.0166	0.0448	0.37	0.711	-0.0712	0.1043
$(\frac{1}{2})\ln(N^2)$	β_{nn}	0.2229	0.0432	5.16	0.000	0.1382	0.3076
$(\frac{1}{2})\ln(M^2)$	β_{mm}	0.2865	0.0652	4.39	0.000	0.1587	0.4145
$\ln(K)\times\ln(N)$	β_{kn}	-0.1436	0.0259	-5.55	0.000	-0.1943	-0.0929
$\ln(K)\times\ln(M)$	β_{km}	-0.0019	0.0422	-0.04	0.965	-0.0845	0.0808
$\ln(N)\times\ln(M)$	β_{nm}	-0.0981	0.0399	-2.46	0.014	-0.1763	-0.0199
Constant	α_0	2.8977	2.3023	1.26	0.208	-1.6148	7.4102
Mu	μ	1.7014	0.5057	3.36	0.001	0.7103	2.6926
Group variable			Sector	Obs per group: min			23
Time variable			Year	Obs per group: avg			23
Log likelihood			243.4149	Obs per group: max			23
Number of obs			644	Wald chi^2			745.82
Number of groups			28	Prob>chi^2			0.0000

Note: Coefficients on time dummies are not reported
Source: STATA Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

2.5.2.2 A time varying inefficiency decay model

This analysis follows the Battese-Coelli (1992) parameterisation of time effects. The inefficiency term is modelled as a truncated-normal random variable multiplied by a specific function of time:

$$\mu_{it} = \mu_i^* \exp\left[\eta^*(t-T)\right] \quad (15)$$

where T corresponds to the last time period in each panel, η is the decay parameter to be estimated, and μ_i are assumed to have $N(\mu, \sigma_\mu)$ distribution. As in the previous model, the idiosyncratic error term is assumed to have a normal distribution with mean zero. In Table 14[31], the Cobb-Douglas model capital has an elasticity of 0.48, the labour input has an elasticity of 0.35 while material inputs record an elasticity of 0.18.

Table 14: Time varying inefficiency: Cobb-Douglas production function

Stochastic frontier model: Dependent Variable ln(v)							
Variable	Parameter	Coef.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
$\ln(K)$	α_k	0.4796	0.0353	13.58	0.000	0.4104	0.5489
$\ln(N)$	α_n	0.3519	0.0372	9.47	0.000	0.2790	0.4247
$\ln(M)$	α_m	0.1822	0.0334	5.45	0.000	0.1167	0.2477
Constant	α_0	0.7640	0.5686	1.34	0.179	-0.3505	1.8785
mu	μ	1.5634	0.3475	4.50	0.000	0.8823	2.2445
eta		0.0065	0.0019	3.36	0.001	0.0027	0.0104
Group variable		Sector	Obs per group: min			23	
Time variable		Year	Obs per group: avg			23	
Log likelihood		189.1682	Obs per group: max			23	
Number of obs		644	Wald chi²			523.73	
Number of groups		28	Prob>chi²			0.0000	

Note: Coefficients on time dummies are not reported
Source: STATA Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

[31] In Appendix A.2 results using output rather than value added in the framework of Battese and Coelli are provided for comparison purposes only. They are generated using Frontier 4.1 program.

Table 15 provides translog function estimates of the input elasticities for the time varying inefficiency decay model. About 31 percent of the parameters in the translog were insignificant. Both the Cobb-Douglas and translog models have a statistically significant μ parameter showing that inefficiency is an important component of the South African manufacturing production process. The computed average elaticities for the translog model show that capital has an elasticity of 0.20, the labour input has an elasticity of 0.48 while material inputs record an elasticity of 0.47.

Table 15: Time varying inefficiency: Translog production function

Stochastic frontier model: Dependent Variable ln(v)							
Variable	**Parameter**	**Coef.**	**Std. Err.**	**Z**	**P>|z|**	**[95% Conf. Interval]**	
$\ln(K)$	α_k	1.8339	0.3572	5.13	0.000	1.1334	2.5340
$\ln(N)$	α_n	0.4601	0.3883	1.18	0.236	-0.3011	1.2212
$\ln(M)$	α_m	-1.5408	0.3512	-4.39	0.000	-2.2293	-0.8523
$(\frac{1}{2})\ln(K^2)$	β_{kk}	0.0150	0.0451	-0.33	0.739	-0.0733	0.1034
$(\frac{1}{2})\ln(N^2)$	β_{nn}	0.1906	0.0457	4.17	0.000	0.1010	0.2801
$(\frac{1}{2})\ln(M^2)$	β_{mm}	0.3131	0.0655	4.78	0.000	0.1846	0.4416
$\ln(K)\times\ln(N)$	β_{kn}	-0.1688	0.0278	-6.07	0.000	-0.2233	-0.1143
$\ln(K)\times\ln(M)$	β_{km}	0.0024	0.0421	0.06	0.955	-0.0801	0.0845
$\ln(N)\times\ln(M)$	β_{nm}	-0.0784	0.0395	-1.98	0.047	-0.1558	-0.0009
Constant	α_0	1.7322	2.232	0.78	0.437	-2.6426	6.1072
/mu	μ	1.8410	0.4536	4.06	0.000	0.9521	2.7299
/eta	η	-0.0073	0.0022	-3.28	0.001	-0.0117	-0.0029
Gamma	γ	0.9307	0.0196			0.8810	0.9606
Group variable			sector	Obs per group: min			23
Time variable			Year	Obs per group: avg			23
Log likelihood			229.76505	Obs per group: max			23
Number of obs			644	Wald chi²			685.17
Number of groups			28	Prob>chi²			0.0000

Note: Coefficients on time dummies are not reported
Source: STATA Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

2.5.3 Technical change in South African manufacturing

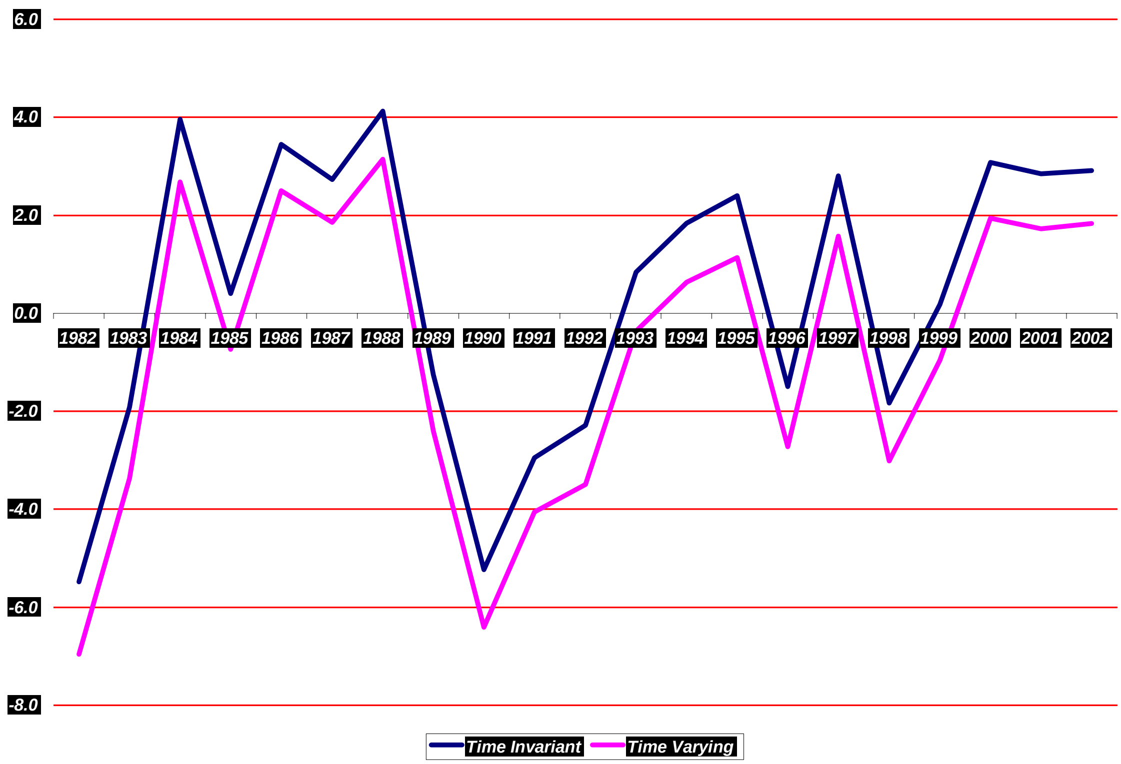
Technical change is measured as the difference between the coefficients of two time dummies associated with two consecutive periods as shown in equation (4), above. A comprehensive analysis of the results from the models reported in Tables 12 to 17 shows that the rate of technical change recorded during the period under review for the Cobb-Douglas specification ranges from a minimum of –7.0 per cent in 1982 to a maximum of 4.2 per cent in 1984. The highest overall mean growth rate recorded during the period is 0.5 per cent per annum. Over the 23 year period, 8 years of technical regress are indicated by the model results. In the translog specification, the rate of technical change in manufacturing ranges from a minimum of –4.9 per cent in 1982 to a maximum of 5.8 per cent per annum in 1984. The mean growth rate recorded during the period fell between 0.3 to 0.5 per cent per annum. Over the 23 year period, the translog records a maximum of 9 years of technical regress.

Overall, two central messages arise. First, South African manufacturing industries experienced very erratic, but slow, technical progress during the period under review. Second, the results indicate that from 1999 onwards, the pattern of technical change appears to be turning positive.

The main reasons for the rather low levels of technical change in the manufacturing sector experienced during most of the period under review appear to be related to a pattern of low innovation and modernisation in industries during the periods of technological regress. Apart from ordinary production tasks, industrial sectors need to engage in significant innovation and experimentation to achieve higher rates of technical change (Mouelhi and Goaied, 2003).

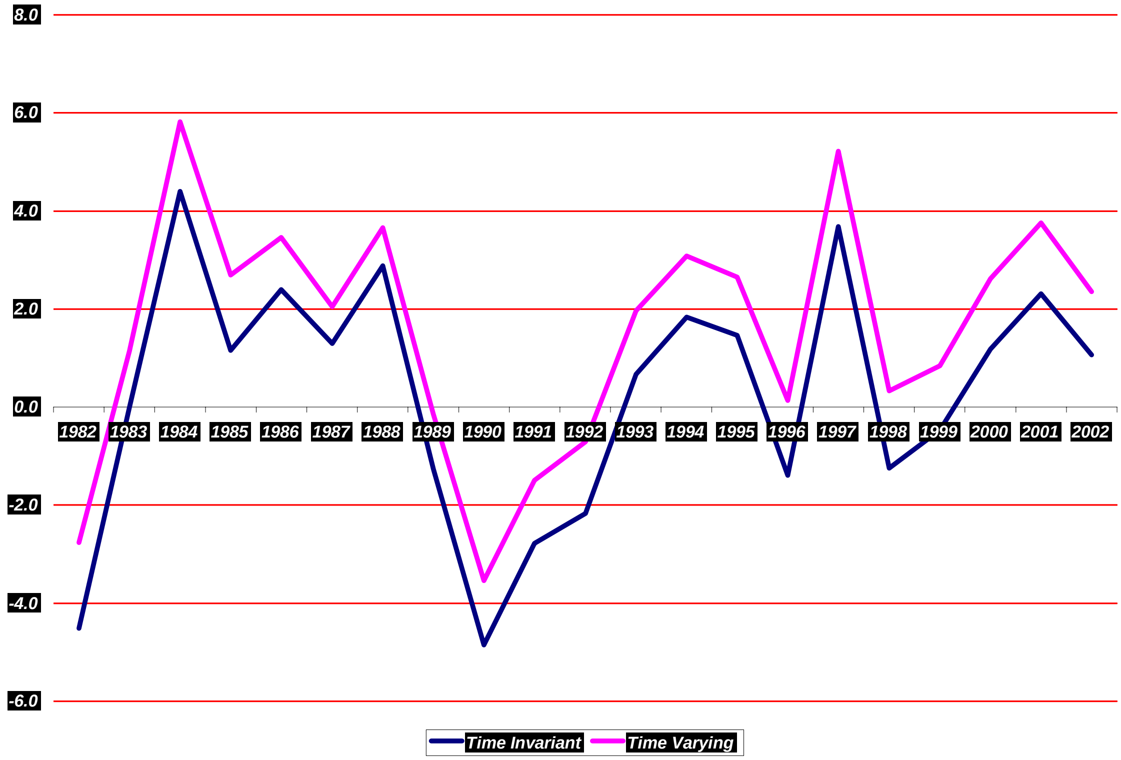
Figure 6, below, shows the evolution of technical change in South Africa. There is a marked collapse from 1989 to 1990 and a recent noticeable recovery from 1999 to 2002. This recent recovery could be related to the increased openness of the economy. Figures 6 and 7 trace the patterns of technical change using the Cobb-Douglas and Translog production functions.

Figure 6: Technical change in manufacturing: Cobb-Douglas function



Notes: Cobb-Douglas production function
Source: Author's own computation.

Figure 7: Technical change in manufacturing: Translog function



Note: Translog production function

Source: Author's own computation.

2.5.4 Technical efficiency in South African manufacturing

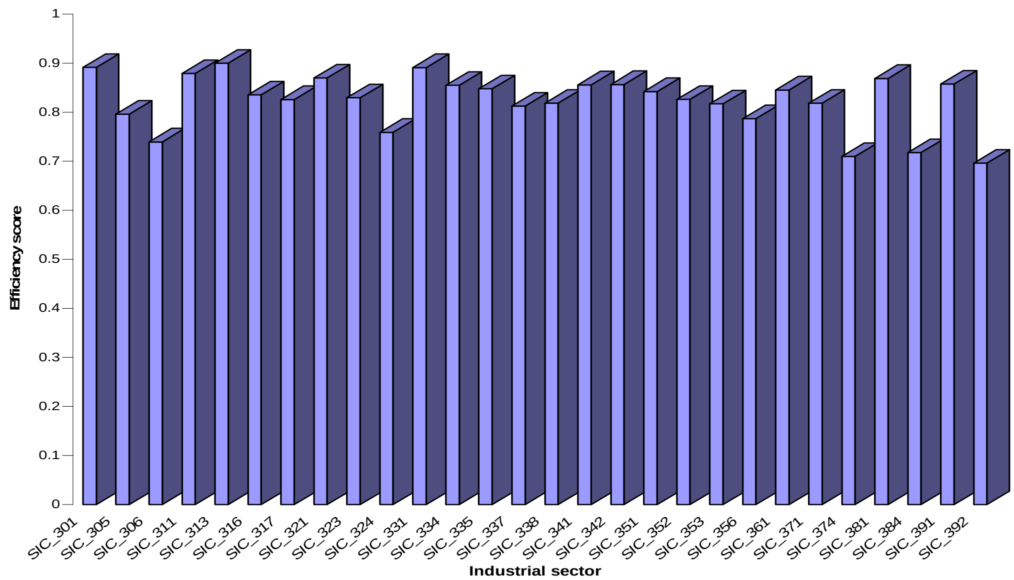
Again, a comprehensive review of the underlying efficiency estimates from the six models provides important insights. The descriptive statistics for technical efficiency measures show an average technical efficiency level of 86.8 percent. The minimum efficiency score is recorded at 84.5 per cent, while, the maximum efficiency score is recorded at 94.5 per cent. The efficiency estimates indicate that some South African manufacturing industrial sectors can improve their output level by as much as 14 per cent with the same set of inputs. Figure 8 shows the distribution of technical efficiency scores for the manufacturing sector.

A number of reasons explain deviation of actual industrial output from the estimated frontier output over this period. One explanation may be due to the sanctions that the economy was subjected to from 1985 to 1992; these could have limited competition within the economy. Another reason could be related to the fact that some sectors of South African manufacturing[32] have remained relatively protected as measured by openness indicators. Continued protection could have limited the degree of competition and exposure of these chapters to the world market.

Evidence from correlation analysis in Table 18, below, suggests an association between openness and efficiency scores. Indeed sectors (such as machinery and equipment, television, radio and communication equipment, professional and scientific equipment and other transport equipment, whose export output ratios improved or that experienced increased import pressure) recorded generally higher levels of efficiency compared to the mean level of the entire manufacturing sector.

[32] Some of the sectors that have appeared relatively protected include textiles, clothing, motor vehicles and parts, food processing and chemicals and rubber products.

Figure 8: Technical efficiency scores by sector



Source: Average sectoral efficiency scores computed by the Author.

In Table 18, simple non parametric tests of the correlation between efficiency scores and trade measures are presented. The results show that efficiency scores and exposure to trade have strong positive correlation and the correlation computed is statistically significant.

Table 16: Non parametric tests correlation tests for efficiency and trade

Efficiency score	Export exposure	Import pressure
Spearman's rho	0.1238	0.6288
Prob > |t|	0.002	0.000
Kendal's tau-a	0.0863	0.4537
Prob > |z|	0.001	0.000

Note: The number of observations is 644, p-values are defined as Prob > |t|and Prob > |z| for the Spearman's and Kendall's test respectively. Import pressure is defined as import intensity of a sector.
Source: Authors computations, www.statssa.gov.za, and www.tips.org.za.

To formally verify the results of the association and correlation experiment shown in Table 18, a simple model of the determinants of industry level efficiency is discussed in Section 2.5.6 and the results reported in Table 19. In

Section 2.5.5 below, the channels through which a liberal trade regime affects efficiency are discussed. In addition, the studies and the data that has been applied to this issue in Africa are outlined. The brief review suggests that the debate regarding the direction of causality between trade and efficiency in African manufacturing sectors is far from resolved.

2.5.5 The relationship between trade and manufacturing efficiency

Bigsten et al, (1998) outline mechanisms that trade economists think a liberal trade regime should affect efficiency in manufacturing. The first mechanism arises from the fact that in order to compete against international producers, domestic firms must adopt newer and more efficient technology or use the same technology with less x-inefficiency in order to reduce costs. The second reason arises from the difficulty of replacing imports of intermediate and capital goods by domestically produced goods. Increased availability of better as well as differentiated imported intermediates and capital goods should lead to higher output and improved efficiency for industries in developing countries. The third explanation for efficiency improvement in a liberal trade regime is that higher volumes of imports and exports increase international technical knowledge spillovers. The knowledge spilled over enables researchers from industries in developing countries to obtain insights from using these goods. Increased access to knowledge in turn leads to better improvements to the manufacturing processes. Efficiency may however not be enhanced if it was the protected sectors that previously enjoyed economies of scale. If there is a reduction in scale efficiency because industries are now competing with imports, the import pressure could lead these producers to contract or exit the domestic market (Rodrik, 1988 and 1991). Studies that have examined the issue of causality between exposure to trade and efficiency in Sub-Saharan Africa are briefly mentioned below.

2.5.5.1 Causality between trade and manufacturing efficiency

Since 1992, firm level data has been collected under the Regional Programme on Enterprise Development (RPED). The RPED initiative was coordinated by the World Bank. In the sample countries of Burundi, Cameroon, Ghana, Kenya and Zimbabwe, the initial waves of data capture covered a span of three years at different intervals in each country over the period 1991 to 1995. Using the RPED data Bigsten et al, (1999) found that exporters were more efficient than non-exporters. Most importantly, exporters also tended to increase their efficiency more rapidly than non-exporters, while new entrants into exporting had the largest subsequent gains in efficiency. Indeed one additional year of exporting was found to raise efficiency of continuous exporters by 13 percent, while the coefficient on new exporters showed that the first year of exporting raised efficiency by as much as 14 percent (Bigsten et al, 2000). The effect of exporting on efficiency[33] appeared to be larger in the African sample than in comparable studies in other regions. This finding regarding the impact of exporting on efficiency appeared to be consistent with the smaller size of domestic markets in Africa.

The important policy issue of whether more exposure to increased trade improves the efficiency of firms requires more empirical investigation. While most analysts believe that increased trade raises industry level efficiency, there

[33] Evidence has also been found of learning by exporting as well as self selection of the most efficient firms into exporting (Bigsten et al, 2000). This is contrary to the general belief that trade liberalisation and export oriented strategy increase firm level efficiency that is found in Krugman, 1987; Rodrik, 1991; Grossman and Helpman, 1994. Evidence that exporting and efficiency are associated is also reported in Harrison (1994) and Aw and Hwang (1995). In view of these controversies, the debate that exporting causes efficiency gains will only be resolved through the availability of more systematic empirical evidence (Bigsten et al 2000). This is because causality may run in the other direction suggesting that efficient firms may self select into the export market. In Ghana efficiency is unimportant for entry but of considerable importance for the exit decision (Söderbom, 2000).

remains little direct evidence that has been marshalled in this respect in Sub-Saharan Africa (Naudé et al 2000:9). Most importantly, studies examining causality between liberalisation and efficiency continue to report mixed results[34]. For example, a positive association between export status and productivity could be due to self selection of relatively more efficient plants into foreign markets. Strong evidence of learning-by-doing has been hard to come by, except in the case of the Moroccan apparel and leather industries investigated by Clerides et al, (1998). While, Kray (1997) argued that exporting caused faster growth in efficiency, Bigisten et al (2000) uncovered self selection as an important factor, suggesting that firms with higher past efficiency were more likely to become exporters. Self selection was due to the presence of high sunk costs of breaking into foreign markets, which implied that past exporters were even more likely to remain strong in the export market, providing yet more support for the learning-by-exporting hypothesis. In Section 2.5.6, a simple model to investigate the impact of trade measures and industry characteristics on efficiency is discussed.

2.5.6 Some determinants of manufacturing efficiency.

Industry level technical efficiency scores computed from the production function can be used to determine the impact of trade on industry performance. Following Kraay (1997) and Bigisten et al (2000) the level of industry efficiency as the dependent variable is interacted with measures of exposure to increased competition, and industry characteristics, such as skill competency and measures

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[34] Firm efficiency affects the decision to export because more efficient firms will find it easier to compete in export markets. One of the reasons why large firms export more is because they tend to be more efficient, but it also seems that by increasing exports, efficiency of the firm may be raised. Exporting and internationalisation are important for the survival of manufacturing firms because of the potential they provide for enhancing sales growth, increasing efficiency and improving quality (Schmitz, 1994). Evidence from South Africa that is reported in Naudé and Zake (2001) indicates that firm efficiency is important for success in exports, a 10 percent increase in efficiency will increase the probability of exporting by 19 percent and the intensity of exports by 12 percent.

of technology transfer (Biggs & Raturi, 1997: 28). The basic specification is stated as follows:

$$te_{it} = \beta_0 + (\beta_1)'trade_{it} + (\beta_2)'ind_{it} + \varepsilon_{it} \qquad (16)$$

Where te_{it} is the efficiency score of industry i at time t and $trade_{it}$ is an indicator of trade impact such as the import penetration ratio of industry i at time t. The variable ind_{it} captures industry level characteristics such as the level of skill intensity and expenditure on machinery and equipment[35]. The impact of the business cycle is captured either by the evolution of the terms of trade or by the level of capacity utilisation in an industry. The remainder term is the familiar error component. The regression results for this simple model are provided in Table 17 below.

Table 17: Determinants of efficiency

Feasible generalised least squares : Dependent variable efficiency scores						
Variable	Coefficient.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
Import penetration	0.54894	.2479252	2.21	0.027	0.0630	1.03486
Skill intensity	0.80218	.1985005	4.04	0.000	0.4131	1.19123
Machinery expenditure	0.13119	.0662571	1.98	0.048	0.0013	0.26106
Terms of trade	0.67563	.3381428	2.00	0.046	0.0129	1.33838
Import penetration ratio × skill intensity	-0.16026	.0683204	-2.35	0.019	-0.2942	-0.02636
Constant	-8.13002	1.89911	-4.28	0.000	-11.852	-4.40783
Panels	Homoskedastic		Correlation			0
Group variable	Sector		Number of groups			28
Time variable	Year		Estimated coefficients			6
Number of observations	644		Time periods			23
Estimated covariances	1		Wald chi2(5)			70.35
Log likelihood	-406.7566		Prob > chi2			0.000

Note: import penetration is the ratio of imports to domestic demand, skill intensity is the ratio of skilled employees to the total number of employees in the industry, machinery expenditure is expenditure of industries on machinery and equipment and the terms of trade index takes base year of 1995.
Source: STATA estimation results by the author

The measure of exposure to trade in this regression is import penetration. The results show that a 1 percent increase in the import penetration ratio will raise the level of manufacturing efficiency by 0.55 per cent. The significance of this

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35 The variable definitions are provided in Appendix A2.

variable indicates that trade brings industries into contact with international best practice, fostering learning and efficiency growth, possibly as a result of exposure to information on product characteristics and improved technology. It may also be due to the fact that sectors with higher import shares could have attracted a disproportionately higher level of foreign participation, which could help explain the higher levels of efficiency recorded. Sectors closed from international competition and oriented to the domestic market may have missed opportunities for upgrading, quality improvements, cost reductions and productivity improvements that follow from increased competition.

The measure of skill intensity in industry is also significant at the conventional levels. The skill elasticity is 0.88 suggesting that a 1 per cent improvement in skill intensity boosts overall manufacturing efficiency by 0.88 per cent. This indicates that skill improvements for the labour force are important for industry efficiency gains[36], because the mix of goods produced and the factor proportions used to manufacture them depend on the skill competencies of local technicians. Skill competency is important for the labour force to produce at its full potential and to avoid factor and time waste. With more trade, South African employees in the manufacturing sector will find it relatively easier to obtain the know-how necessary for further technological upgrading, as well as efficiency growth. Indeed Hunt and Tybout (1998) report that a large majority of industries with productivity gains under liberalisation experienced an increase in their skill labour intensity of production. Increased skill intensity implies an improved underlying product mix or an increase in industry technological sophistication as a result of increased foreign competition.

[36] According to Miller and Upadhay (2000) too little openness does not allow a country to leverage its stock of human capital. Human capital investment without liberalisation of the external sector may lead to less efficiency and under utilisation of the skilled human resource.

A measure of technology infusion into industry is in form of new machinery and equipment expenditure by industries. An increase in machinery and equipment expenditure by 1 per cent will improve manufacturing sector efficiency by 0.13 per cent. This variable is also significant, suggesting that since a substantial amount of machinery, equipment and intermediate inputs into the South African manufacturing sector are imported, it implies that significant improvement in industry efficiency will continue to depend on the level of openness of the national trade policy. More importantly, efficiency scores are also likely to be related to how the skilled labour force adjusts to these imported inputs. Indeed Schor (2004) reports that industries in Brazil in which increased competition occurred, new access to inputs that embody better foreign technology also contributed to productivity gains after trade liberalisation.

A frequently suggested issue is the sensitivity of measured efficiency scores to the business cycle. Industry efficiency scores could be higher during booms and lower during recessions. To deal with this problem, terms of trade are added to the base line model as another independent variable. The estimated coefficient on this variable is positive and strongly significant, suggesting that the levels of efficiency in particular industry in a given year do not necessarily indicate improvements in the application of technology. Indeed a 1 per cent improvement in the terms of trade will raise the level of industry efficiency by 0.68 per cent.

2.6 CONCLUDING REMARKS

This chapter provided estimates of technical change and efficiency within an error components framework. Use is made of time invariant models and time varying decay models. In addition, a generalised time index is also employed to introduce more flexibility to the measures of technical change. The empirical analysis is based on a balanced panel of South African manufacturing industries over the period 1980 to 2002. The models are able to account specifically for periods of technological progress as well as periods that were characterised by regress. Analysis of these periods helps to suggest some explanations for the relatively low level of technological progress experienced in manufacturing during the period of the study.

The results from the preceding investigation indicate that there is scope for some of South Africa's industrial establishments to significantly improve their output level with the same set of inputs. The results suggest that greater exposure of industrial sectors to trade helped reduce negative deviations from the frontier output over the study period. Sectors with limited exposure to trade during the period of sanctions could have missed opportunities for efficiency gains. There is also evidence that more open sectors recorded generally better efficiency levels than the mean level of the entire manufacturing sector. Sectors closed from international competition and oriented to the domestic market may have missed opportunities for upgrading, quality improvements, cost reductions and productivity improvements that follow from increased competition. More importantly, since efficiency scores are likely to be related to how the labour force adjusts to imported inputs, skill improvements for the labour force will remain fundamental, because the mix of goods manufactured and the factor proportions used to produce them will increasingly depend on the skill competencies of local technicians. Skills allow the labour force to produce at its full potential and to avoid waste of inputs as well as time.

In the next chapter, attention is focused on modelling the determinants of total factor productivity and emphasis is placed on the channels through which trade affects manufacturing productivity. Indeed, since openness affects efficiency, there is a further need to answer two questions. The first regards the sign and magnitudes of the interaction between trade and productivity, which is investigated in Chapter 3. The second relates to how efficiency affects labour use in manufacturing; this aspect is the subject of Chapter 4. It should be noted that a potential direction for future investigation could involve the computation of a malmquist measure of productivity change, comparing the results obtained with those generated in this chapter (Coelli et al, 1998).

CHAPTER 3

TRADE AND TOTAL FACTOR PRODUCTIVTY IN MANUFACTURING

3.1 INTRODUCTION

While some literature on trade policy and market structure provides several mechanisms through which trade expansion may boost industry productivity[37], a significant amount of theoretical literature still delivers disparate predictions regarding the impact of trade on productivity (Pavcnick, 2002:2). Hence, empirical evidence is still vital to inform the debate. In this chapter, therefore, a fundamental issue regarding the mechanisms through which increased trade affects industrial productivity is addressed using the South African panel data set to provide a comprehensive picture of the macroeconomic and structural determinants of manufacturing productivity. This data set combines the advantages of macroeconomic time series and microeconomic cross-sections. South Africa provides a good environment in which to investigate these issues, because trade policy over the last 25 years has exhibited significant variation; there has also been explicit heterogeneity across industrial sectors in response to trade expansion (Fedderke, 2001 Fedderke and Vaze, 2001, TIPS, 2001, Roberts, 2000, Gunnar and Subramanian, 2000).

To obtain a measure of total factor productivity in manufacturing, a production function is estimated in which industry productivity is modelled as an

[37] The first route is via imports; as imports expand, the ensuing competitive pressure results in higher productivity if domestic firms eliminate x-inefficiency or slack and use inputs more efficiently (Fernandez, 2003:3). The second mechanism in which trade may boost plant productivity is by allowing for increased access to imported intermediate inputs of higher quality and broader variety (Iscan, 1997:1). The third channel is that increased trade may influence the incentives to invest in technological innovation (Gunnar and Subramanian, 2000:4).

unobservable industry specific effect. This approach generates sector specific as well as time-varying productivity measures. The investigation searches for the channels through which measures of trade orientation interact with industrial characteristics and the macroeconomic environment to determine productivity. Previous estimates in the literature focussed only on measuring the impact of a single variable on productivity, namely trade policy (Fernandez, 2002:20). A more useful approach is to investigate the channels through which trade affects productivity. Since the analysis is confined to an identical country panel it is possible to consider many variables that might determine productivity, simultaneously.

This chapter provides empirical estimates of the determinants of total factor productivity in South Africa's manufacturing sector. It, therefore, begins with the discussion of the literature relevant to analysis of the productivity and trade linkage in Section 3.2. Section 3.3 looks at issues involved in measuring total factor productivity. The empirical specification is presented in Section 3.4. The data investigated is discussed in Section 3.5. The results, provided in Section 3.6 are followed by concluding comments in Section 3.7.

3.2 TRADE AND MANUFACTURING PRODUCTIVITY

If there are benefits to a country's manufacturing sector arising from trade, these benefits should come from two sources. The first source is greater efficiency in production through increased competition and specialisation. The second source is the opportunities that arise to exploit economies of scale in a larger market. Access to a larger market should encourage larger production runs in industries, thus reducing average costs. Trade expansion should, therefore, permit firms to increase in size and engage in more plant specialisation. In an environment of increased trade, consumers demand for variety will be satisfied through imports.

Access to the world market also means that more products can be produced profitably, which should generate gains from increased product diversity and improve consumer welfare (Petersson, 2002:241).

Proponents of trade liberalisation aim to promote productivity gains by exposing industries to fiercer international competition and facilitating access to the international market. They argue that establishments that face foreign competition are forced to adapt. In particular, plants are constrained to produce closer to the production frontier and that the frontier will move out faster. Most importantly, evidence indicates that manufacturing concerns exposed to trade pay higher wages, operate at a higher scale, produce with more capital and achieve higher productivity levels (Van Biesebroeck, 2003). Manufacturing total factor productivity seems to be directly associated with the production of tradable goods, which implies that the benefits from foreign activities are likely to be higher in two areas. First, benefits arise in places where the domestic market is small and foreign sales are a prerequisite to fully exploit scale economies. Second, benefits accrue where production technology lags best practice, providing ample scope for productivity improvements through imitation and adoption of foreign technology. The literature suggests a number of mechanisms or channels through which trade liberalisation affects manufacturing productivity (Fernandez, 2003:3, Van Biesbroek, 2003 Pavcnik, 2000:2, and Muendler, 2002:2). These channels include: the foreign input push, competitive push, competitive elimination, technological innovation and economies of scale. The channels are discussed in sub-sections that follow below.

3.2.1 Foreign input push

Easier access to equipment and intermediates may allow a foreign input push at the firm level, because high quality equipment and intermediate goods allow industries to adopt new production methods. The use of these inputs raises efficiency, because the efficiency of foreign equipment and intermediate inputs is higher than the efficiency of domestic inputs (Fernandez, 2003). In the same vein, studies of competitive effects of increased import penetration such as Krishna and Mitra (1998) and Tybout and Westbrook (1995) demonstrate that increased competition from imports, in fact, lowers the price-cost margin.

Increased foreign competition leads to the closure of less productive factories or induces firms to shift their industrial focus (Van Biesbroek, 2003). However, foreign inputs may be only a minor component of the productivity change in some countries. Rather, it is foreign pressure that forces plants to raise productivity, because the shutdown probability of inefficient firms rises with competition from abroad. If productivity is negatively affected by trade protection, gains in productivity should associate positively with increased imports of intermediate inputs and investments in machinery at the plant level (Muendler, 2002:36). Grossman and Helpman (1991) argue that access to higher quality or broader variety of foreign intermediate inputs through trade boosts plant productivity, which explains why firms engaged in export activities benefit from exposure to technology embodied in imported final goods. Such firms obtain, from imported capital goods, previously unavailable technologies to boost productivity. This increase in knowledge, in turn, leads to better technical efficiency. Therefore, differences in firm level efficiency will tend to be greater in industries protected from international competition, due to limited access to foreign technology, expertise or problems acquiring imported intermediate and capital goods, because of protectionism (Muendler, 2002).

3.2.2 Competitive push and the elimination of X-inefficiency

Firms are said to respond strongly to increased competitive pressure and raise their efficiency. The turnover and the exit of the less productive firms contribute positively to productivity change. Since the removal of import barriers increases competition on the product market side, foreign imports constitute a competitive push on individual firms. Theory suggests that managers remove agency problems and innovate processes under fierce competition (Pavcnik, 2000:37). In particular, the elimination of X-inefficiency or slack occurs as imports expand. The ensuing competitive pressure results in higher productivity as firms use inputs more efficiently (Fernandez, 2003:3; Fernandez, 2002:4). Trade liberalisation, in essence, induces competitive pressure, which forces firms to raise their efficiency.

By reducing protection, trade liberalisation lowers domestic prices, forcing high cost producers to exit the market. To compete against international producers, domestic firms must adopt newer and more efficient technology or use the same technology with less x-inefficiency in order to reduce costs (Tybout et al, 1991), which could result in a reallocation of output from less efficient to more efficient producers. These gains, however, result only if irreversibility of investment in capital equipment does not stop the exit of less productive plants (Pavcnik, 2000).

3.2.3 Competitive elimination

Competition in the product market may also induce more exits and cause a competitive elimination of inefficient producers (Muendler, 2002:28). Increased competitive pressure makes the least efficient firms shut down and enables the surviving, competitive plants to increase market share. The increase in market share is what raises productivity. In Chile, aggregate productivity improvements in a number of industries were found to stem from reshuffling resources from less to more efficient firms as a result of trade expansion. (Pavcnik, 2000:3). When trade barriers are removed, competitive elimination of the least efficient firms is said to strike more fiercely. Estimates from turnover probabilities confirm that the likelihood of survival drops markedly when trade barriers fall and that low efficiency firms go out of business more frequently (Muendler, 2002:4).

Pavcnik (2000:6) finds that productivity improvements in Chile were indeed related to trade liberalisation and that competition forced plants in formerly shielded sectors to restructure. Most importantly, exiting plants were, on average, less productive than plants which continued to produce. Plant exit contributes to the reshuffling of resources within the economy and reallocation of market shares as well as resources from less to more efficient producers, which acts as an important channel for productivity improvements. However, even if it is granted that trade enhances productivity, competitive elimination may not occur without costs. These costs result from the exit of firms, often resulting in large relocations and displacements of labour and capital. Fears related to the costs of labour displacement and plant bankruptcies may deter governments from exposing their domestic firms to foreign competition.

3.2.4 Higher incentives for technological innovation

Trade can spur innovation by enhancing industrial learning, since it facilitates international exchange of technical information and can improve the efficiency of the global research efforts in different countries. One of the links between international trade and productivity is through technical knowledge spillovers (Grossman and Helpman, 1991). International trade boosts research by transmitting information, increasing competition and entrepreneurial effort, while expanding the size of the market for innovative firms. Trade encourages modern technology, increases demand for skilled labour and promotes learning-by-doing. Trade expansion may contribute to the exchange of ideas, adoption of technological knowledge and faster productivity growth.

As indicated in the preceding paragraph, trade increases a firm's incentive to engage in productivity-enhancing technological effort. In contrast, however, Rodrik (1991) finds that lower protection or higher import competition reduces a firm's investment in productivity enhancing technological upgrades. Deraniyagala and Fine (2001:2) also argue that the magnitude of gains could be fairly low. If trade reduces the domestic market shares of unshielded domestic producers without expanding their international sales, their incentives to invest in improved technology will decrease as protection ceases. This effect reduces the benefits of tariff reductions that are supposed to lower the relative prices of imported capital goods and ease access to foreign technology for domestic firms (Pavcnik, 2000:37). It is also argued that liberalisation facilitates procurement of technology; however, it is questionable whether domestic plants actually acquire better technology, because acquisition is dependent on the flexibility of the domestic labour force. Muendler (2002:1) finds that foreign technology adoption may be relatively unimportant, because the efficiency difference between foreign and domestic inputs has only a minor impact on productivity in some cases. The explanation for this result lies in the fact that foreign technology adoption takes time due to delays in learning, difficulties with factor complementarities and differences in production arrangements.

3.2.5 Economies of scale

Even in the context of economies of scale, the theoretical trade literature offers conflicting predictions about the evolution of plant productivity following a liberalisation episode. This conflict is especially apparent in cases where imperfect competition is present. On one hand, trade liberalisation exposes domestic producers to foreign competition, reduces their market power and may force them to expand output and move down the average cost curve, resulting in the exploitation of economies of scale. On the other hand, however, gains from economies of scale in developing countries may be unlikely, because increasing returns to scale are usually associated with import competing industries, in which output is likely to contract due to intensified foreign competition (Pavcnik, 2000:2).

3.3 APPROACHES TO THE STUDY OF TRADE AND PRODUCTIVITY

Three main methods have been applied to study the relationship between trade and productivity in the literature. These approaches include the macro-level, industry-level and micro-level. These three methods are discussed in sub-sections that follow, below.

3.3.1 The macro- level approach

The macro-level approach undertakes cross-country comparisons using growth regressions associating output growth with an aggregate measure of trade openness. The findings from these studies suggest that open economies tend to grow faster (Sachs and Warner, 1995). The difficulties plaguing measures of outward policy orientation across countries and over time are outlined in (Rodrik and Rodriquez, 2001). In particular, aggregate measures of openness fail to capture the differential incentives provided by trade protection to different industries. These studies also suffer from endogeneity bias, and a number of specification problems. The results of these studies are sensitive to the sample of countries used, as well as the time periods analysed, while the conclusions depend on whether the study employed cross-section or panel data (Harrison, 1996). The difficulties attendant to interpretation of multi-country studies on the trade growth nexus calls for attention to be focused on individual country experiences.

The concern regarding cross-country regressions is that the number of variables similarly affecting all countries is limited. In addition, many of these variables are likely to suffer from endogeneity or may be prone to mis-specification. Furthermore, many country specific variables relevant to productivity could be correlated with other regressors or may, in fact, be unobservable. Such variables include country policies or historical factors. To the extent that these do not vary over time, fixed effect estimates[38] could, in principle, be used to deal with the problem, but this is limited by the fact that cross-country time series data that are comparable are still relatively rare, especially in African countries, which has led scholars to exhibit considerable scepticism with regard to results from cross-country regressions. It is, therefore, important to assess the extent to which results from cross-country analysis hold up to more rigorous scrutiny than is possible within individual countries, where data at a lower level of aggregation would be desirable, allowing for a much more precise definition of the variables of interest (Deininger, 2003).

3.3.2 The industry-level approach

The industry-level approach attempts to circumvent the problems that plague cross country macro level studies by considering cross-industry regressions, in the spirit of the Solow residual regressions of total factor productivity growth on trade policy variables (Kim, 2000, and Lee, 1995) or on regressions of demand growth due to export expansion and import substitution (Nishimizu and

[38] It is suggested that this methodology could face potential problems if some of the variables that are hypothesised to cause productivity changes are time invariant, or may be changing only very slowly over time and may. If these factors change only very marginally then they cannot be easily distinguished from country level fixed effects.

Robinson, 1984). The main weakness affecting these studies is that a single productivity measure could ignore cross-plant heterogeneity, which is a stylised fact in many countries and may be useful in investigating the impact of trade on productivity. Industry level studies have also been criticised by Muendler (2002) for the inability to unmask the underlying microeconomic process, as seen in Kim (2000).

3.3.3 The micro-level approach

Microeconomic studies use longitudinal data to trace the effects of trade exposure on firms or plants in selected countries using regressions derived from two main sources. The first source is derived from firm output growth generated in a Solow framework on an indicator variable for the period of trade reform (Krishna and Mitra, 1998). The second is based on plant TFP measures affected by trade policy orientation in the industry (Pavcnik, 2000 and Fernandez 2003). These two approaches are able to identify the effect of trade reform in Chile and Colombia, respectively, although not without criticism. It is argued that the indicator variable for the trade reform period cannot isolate the corresponding productivity gains, because it also captures contemporaneous macroeconomic shocks (Fernandez, 2002). Most importantly, this indicator could ignore the variation in productivity across industries.

Section 3.3 reviewed the approaches mainly used to study the effect of trade on productivity. In Section 3.4, the study turns to the measurement of total factor productivity in manufacturing.

3.4 MEASURING TOTAL FACTOR PRODUCTIVITY

The production function approach is the most popular method used to capture productivity and the link between growth and foreign trade variables, protection measures, industry specific characteristics and macroeconomic shocks. Two types of functions are employed. The first is an aggregate value added function, while the second is a gross output function. The analysis usually starts by assuming industry $i's$ technology at time t can be described by a production function of the form:

$$y_{it} = \beta_0 + \beta_n n_{it} + \beta_m m_{it} + \beta_k k_{it} + \varepsilon_{it}, \varepsilon_{it} = w_{it} + u_{it} \quad (17)$$

Gross output is given by y_{it}, n_{it} is labour, m_{it} are intermediate raw material inputs, k_{it} is the capital used in industry i while, ε_{it} is the industry-specific efficiency that is composed of two terms: w_{it} assumed to be known by the plant, but not by the researcher, and u_{it}, which is the unexpected productivity shock not known to either the plant or the researcher. All these variables are also measured over each time period, t.

The industry productivity measure relies on the difference between an industry's actual output and predicted output. It is important to obtain consistent estimates of the coefficients in the production function. It is known that a plant's private knowledge of its productivity (w_{it}) affects its decisions about its choice of hiring labour, purchasing materials and investing in new capital, yet this process is unobserved by the econometrician. This information asymmetry introduces simultaneity bias[39] (Fernandez 2003:5, Pavcnik, 2000:8 and Olley and Pakes, 1996).

[39] To analyse the simultaneity problem we need a dynamic model of firm behaviour that allows for firm specific efficiency differences that exhibit idiosyncratic changes over time (Olley and Pakes, 1996)

Simultaneity bias arises because an industry's private knowledge of its productivity affects its choice of inputs. More productive industries are more likely to hire more workers and invest in capital due to profitability, OLS estimation of a production function may lead to estimates of the input coefficients that are higher than their true values. The use of ordinary least squares for production function estimation assumes that regressors, such as labour, are treated as exogenous variables, yet input choices could indeed be endogenous. Since input choices and productivity are correlated, OLS estimates suffer from simultaneity bias (Fernandez 2003:5). Four main mechanisms have been employed to control the simultaneity problem.

The first approach is to impose a normal distribution on the unobserved heterogeneity and assume that the industry-specific efficiency is uncorrelated with the industry's choice of inputs and use maximum likelihood estimation (Tybout et al, 1991). The second mechanism is to assume that the unobserved industry specific efficiency w_{it} is time-invariant, so it can be denoted by w_i, and estimate a fixed effects model of the form:

$$y_{it} = \beta_0 + \beta_n n_{it} + \beta_m m_{it} + \beta_k k_{it} + w_i + u_{it} \qquad (18)$$

The fixed effects model only partially solves the simultaneity problem, because it only removes the effects of the time-invariant plant productivity component (Pavcnik, 2000:8). However, during times of large structural adjustments, such as trade liberalisation, the assumption of unchanging productivity is not tenable and fixed effects methodology could generate biased estimates of the input coefficients. Moreover, if one is interested in how industry efficiency evolves over time in response to a change in the trade regime then the assumption that plant productivity is constant over time does not help in tackling the problem.

The third mechanism uses an industry specific and time-varying efficiency measure that can be captured as a quadratic function of time (Liu and Tybout (1996). In this case, the production function is specified as:

$$y_{it} = \beta_0 + \beta_n n_{it} + \beta_m m_{it} + \beta_k k_{it} + w_{it} + u_{it} ; w_{it} = \alpha_{1i} + \alpha_{2i} t + \alpha_{3i} t^2 \qquad (19)$$

In this framework, the production function is first estimated by fixed effects to obtain the input coefficient vector β. The residuals are then calculated by subtracting the actual from the predicted values of output, and, for each industry i, this residual measure is regressed on a constant, time and time squared. A productivity measure is then constructed using estimates of the coefficients from the second regression. This approach improves on the fixed effects methodology and requires a parametric specification of productivity, but is punitive, since many degrees of freedom are lost in the estimation process.

While the traditional approach is anchored by the use of instrumental variables to control simultaneity, an alternative approach was suggested by Olley and Pakes (1996) and modified by Levinsohn and Petrin (2001). This approach has found numerous applications, most notably by Pavcnik (2000:10), Fernandez (2003:12) and Driemeier, et al (2002:38). In the Olley-Pakes framework, labour and materials are assumed to be freely variable, while capital is the state variable assumed to be affected by the distribution of the productivity shock. The observed firm decision, in this case, will be a function of the firm's productivity. Inverting such a function allows for the anticipated, but unobserved, productivity shock to be controlled with the observed variables. Investment is used to model the anticipated productivity shock[40]. In this case, the inputs are divided into freely variable n_i and m_i, while k_i is the state variable. The productivity shock w_{it} is also a state variable impacting the decision rules of

[40] The weakness with using investment is that the methodology requires that non-zero investment by firms should not arise. In view of this requirement, Levinsohn and Petrin (2001) employ intermediate input demand functions. The demand for electricity as an intermediate input is preferred, because electricity cannot be stored. Most importantly, energy use closely tracks the productivity term over time.

industries, while μ_{it} has no impact on firm decisions; μ_{it} is also assumed to be i.i.d. Under perfect competition, input and output prices are common across firms, making it possible to assume invertibility and write investment as a function of the two state variables.

$$i_{it} = i(w_{it}, k_{it}) \tag{20}$$

which can be inverted to yield:

$$w_{it} = i(i_{it}, k_{it}) \tag{21}$$

Equation (17), under the monotonicity assumption, can then be written as:

$$y_{it} = \beta_n n_{it} + \beta_m m_{it} + \phi_{it}(i_{it}, k_{it}) + u_{it} \tag{22}$$

where

$$\phi_{it}(i_{it}, k_{it}) = \beta_0 + \beta_k k_{it} + w_{it}(i_{it}, k_{it}) \tag{23}$$

Different measures of logarithmic productivity can be generated using two estimation methods, depending on whether a TFP measure or a no-shock productivity measure is considered. From equation (17) our TFP measure is given as[41]:

$$w_{it} \hat{+} \mu_{it} = y_{it} - \beta_n n_{it} - \beta_m m_{it} - \beta_k k_{it} = tfp_{it} \tag{24}$$

The derivation of the productivity measure that excludes the component of the shock to output that is uncorrelated with inputs follows Olley and Pakes (1996). One approach considered in Olley and Pakes (1996) is to employ a polynomial in i_{it} and k_{it} in the regression of output on the variable inputs to model the qualified variation in productivity[42].

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[41] The TFP measure is essentially the "Solow" residual.

[42] A polynomial in investment and capital can be employed to help provide industry-specific and time-varying productivity. This measure does not need a specific functional form, yet it provides a tractable solution to the simultaneity problem (Driemeier, et al (2002:38).

3.5 ECONOMETRIC SPECIFICATION

The estimation proceeds in two steps. First, time-varying and industry specific measures of total factor productivity are obtained. Second, the channels through which manufacturing productivity interacts with foreign trade variables, protection measures, industry specific characteristics and the macroeconomic environment are modelled in a regression framework. This two step approach essentially relies on measures that exhibit significant variation across industries over time. This approach is superior to previous attempts that relied on a single change in the trade regime. The model also accounts for the potential endogeneity of trade policy by considering lagged trade measures as well as controlling for industry-specific characteristics (Fernandez, 2002; Tybout and Westbrook, 1995).

Total factor productivity determinants can be investigated within a panel data context (Doornik and Hendry (2001)). A panel based model for estimating determinants of total factor productivity can be represented as:

$$tfp_{it} = x_{it}^{'}\gamma + \lambda_t + \mu_i + \nu_{it}\,,\; t = 1.....,T, i,....,N. \qquad (25)$$

where the variables λ and μ are time and individual specific effects and x_{it} is a vector of explanatory variables. Two critical issues arise regarding the specification of the error component of the underlying model (Baltagi, 2000). The error variable for the disturbances can be designated as a one-way component. In this case, the error is composed mainly of the unobservable individual-specific effect and the remainder stochastic disturbance term. An alternative specification utilizes a two-way error component model for the disturbances, which basically composes the error term in three parts: the unobservable individual effect, the unobservable time effect and the remainder stochastic disturbance term. In this model, the time effect is individual-invariant and accounts for time-specific effects not included in the regression.

In the light of the above discussion, an error components model for the determinants of total factor productivity for the manufacturing sector can then be specified as:

$$tfp_{it} = \beta_0 + (\beta_1)' TP_{it} + (\beta_2)' X_{it} + (\beta_3)' M_{it} + \varepsilon_{it} \qquad (26)$$

Where TP is a trade policy measure, X consists of industry-level characteristics and M captures the role of macroeconomic factors, while the two way error component ε_{it} is given as:

$$\varepsilon_{it} = \mu_i + \lambda_t + \nu_{it} \qquad (27)$$

where i denotes the standard industrial classification for the 28 sectors from 301 to 392 and t is the time period from 1980 to 2002. The symbol μ_i denotes a product-specific effect, while λ_t denotes a time-specific effect and ν_{it} is the remainder assumed to be a white noise stochastic error term.

3.6 THE DATA AND VARIABLES

Productivity growth analysis is based on an industry-level panel data set of South African manufacturing firms provided by South African Statistics Authority (STATSSA), Trade and Industrial Policy Strategies Secretariat (TIPS) and the South African Reserve Bank. For each industry, data is available on production and sales revenues, input use (labour categories and raw materials), investment, exports and imports at the three digit ISIC industry code. The capital stock is measured at constant 1995 prices. The gross mark-up of an industry is the net operating surplus of that industry as a percentage of total intermediate inputs plus labour remuneration less all net indirect taxes. Intermediate imports are imports of goods and services produced elsewhere in the world, but used as inputs in the production process in industries. The export-output ratio is total exports divided by the gross total output value of domestic industries. Skill intensity is the ratio of skilled employment to total employment. Industry level machinery and equipment expenditure is measured in constant 1995 prices. Market size is the domestic sales value of industries to total industrial output. Table 18 shows sector sizes in terms of market size. The large sectors are food, motor vehicle parts and accessories and basic iron and steel.

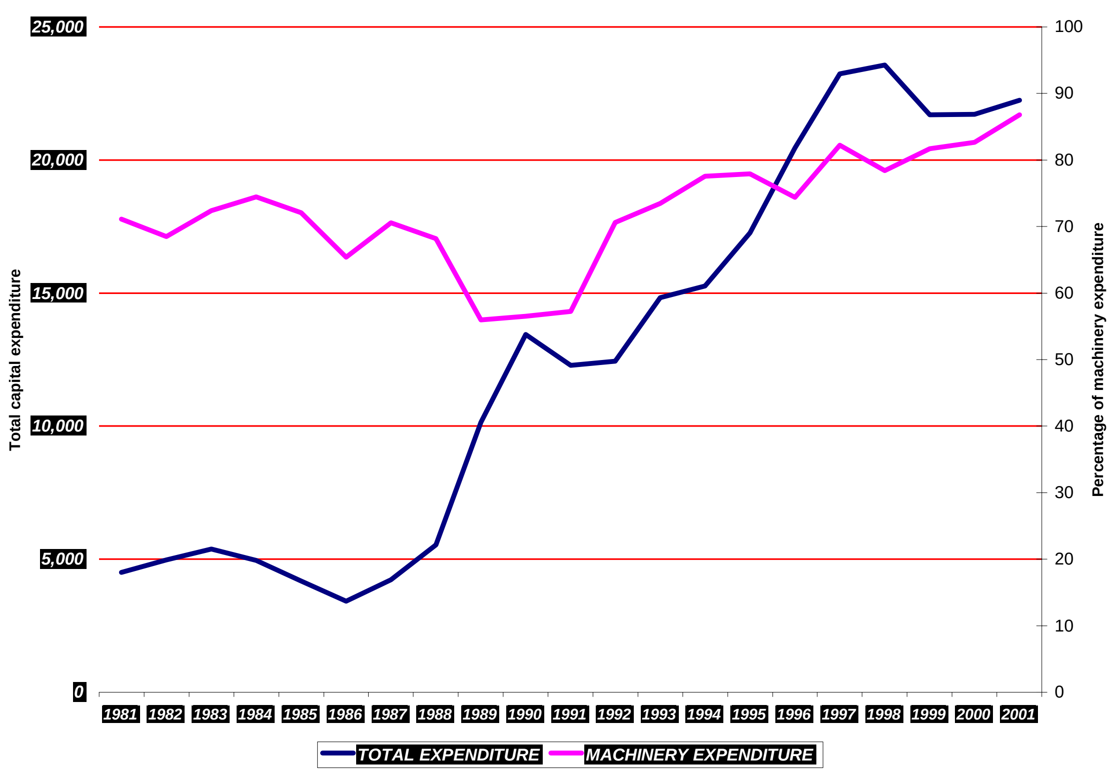
Table 18: Proportion of industry sales to total manufacturing sales

CODE	SECTOR	1995	2000	2001	2002	2003
301	Food (301-304)	13.97	13.32	13.44	13.48	13.56
305	Beverages (305)	4.94	4.55	4.72	4.39	4.89
306	Tobacco (306)	2.09	1.69	1.83	1.82	1.89
311	Textiles (311-312)	2.89	2.27	2.19	2.19	2.03
313	Wearing apparel (313-315)	3.19	2.35	2.17	2.02	2.12
316	Leather & leather products (316)	0.58	0.60	0.56	0.54	0.50
317	Footwear (317)	0.86	0.50	0.39	0.36	0.35
321	Wood & wood products (321-322)	1.92	2.02	2.02	2.07	2.20
323	Paper & paper products (323)	5.18	2.80	2.61	2.57	2.37
324	Printing, publishing & recorded media (324-326)	3.02	2.61	2.45	2.27	2.48
331	Coke & refined petroleum products (331-333)	4.70	6.93	7.31	7.40	6.06
334	Basic chemicals (334)	4.23	4.83	5.02	5.09	4.80
335	Other chemicals & man-made fibres (335-336)	6.06	5.88	5.88	5.78	5.94
337	Rubber products (337)	1.18	1.04	1.06	1.09	1.10
338	Plastic products (338)	2.75	2.42	2.44	2.47	2.60
341	Glass & glass products (341)	0.71	0.51	0.57	0.54	0.55
342	Non-metallic minerals (342)	2.57	2.47	2.43	2.36	2.45
351	Basic iron & steel (351)	6.96	7.48	7.09	7.92	8.53
352	Basic non-ferrous metals (352)	2.28	3.47	3.58	3.54	3.09
353	Metal products excluding machinery (353-355)	6.44	5.52	5.51	5.58	5.74
356	Machinery & equipment (356-359)	5.21	4.39	4.35	4.40	4.67
361	Electrical machinery (361-366)	3.17	2.94	2.78	2.76	2.82
371	Television & communication equipment (371-373)	0.96	1.04	0.72	0.73	0.85
374	Professional & scientific equipment (374-376)	0.40	0.31	0.33	0.33	0.34
381	Motor vehicles, parts & accessories (381-383)	11.12	12.04	12.94	13.06	12.75
384	Other transport equipment (384-387)	0.61	1.40	1.24	1.18	1.21
391	Furniture (391)	1.49	1.40	1.24	1.18	1.21
392	Other industries (392)	0.55	3.24	3.13	2.89	2.89
	TOTAL	100	100	100	100	100

Note: Data covers the entire manufacturing sector
Source: Quantec Research, Trade and Industry Policy Strategies, www.tips.org.za

Tariffs are the sum of customs payments divided by the value of imports. The real effective exchange rate of the Rand $(RER)$with base year 1995 is identified as series KBP5036J in the Reserve Bank Quarterly Bulletin Time Series. Inflation is defined as the change in the consumer price index published by Statistics South Africa (STATSSA). Another interesting variable is machinery and equipment expenditure in the manufacturing sector. Evidence in Figure 9 shows a steady increase in this variable as a proportion of total capital expenditure especially in the most recent past.

Figure 9: Manufacturing machinery and equipment expenditure, 1980-2001.



Note: Data is for the entire manufacturing sector.

Source: Regression output, www.statssa.gov.za

Table 19 contains the descriptive statistics of the key variables used in the estimation process. It shows a degree of heterogeneity in some of the key variables. For example, the mean export share is 13.4 per cent, covering a range marginally in excess of 0.2 per cent up to a maximum of 67 per cent. Import penetration also exhibits heterogeneity with a mean penetration rate of 20.4 per cent, a minimum of 0.5 per cent and a maximum of 89 per cent. Industry Capacity utilisation is relatively more stable. The mean capacity utilisation rate is 82 per cent, the maximum recorded is 97 per cent with a standard deviation of 6.2.

Table 19: Descriptive statistics for productivity variables

Variable	Definition	Mean	Standard Deviation	Minimum	Maximum
EX	Export share	13.40	13.79	0.23	66.95
MZ	Import penetration	20.35	17.47	0.53	89.07
GM	Gross mark up	18.54	20.63	0.69	202.77
IM	Intermediate imports	11.24	7.44	0.83	83.05
MS	Market share	3.57	3.19	0.31	14.71
TARIFF	Customs duties paid	6.84	6.48	0.06	42.96
RAD	Machinery expenditure	70.31	16.99	9.13	98.57
RER	Real exchange rate	97.13	15.01	59.8	129.3
SKILL	Skill intensity	36.23	12.85	9.58	76.14
TOT	Terms of trade	101.28	6.27	93.56	121.83
CPI	Consumer price index	73.83	45.41	14.90	157.80
CAP	Capacity utilisation	82.03	6.16	62.3	97.33
Memorandum Items					
I	Number of Industries				28
T	Number of Periods				23
N	Number of observations				644

Note: For each industry, intermediate imports are generated as a ratio of intermediate imports to total output, the tariff variable is derived as the ratio of customs duties paid to imports, research and development is captured by the ratio of total machinery expenditure to total gross fixed investment.
Source: Regression output, www.statssa.gov.za, www.tips.org.za and www.reservebank.co.za.

3.7 ECONOMETRIC RESULTS

3.7.2 Estimating TFP determinants using static panel data estimators

Two results are presented in this section. In Table 20, findings from applying the maximum likelihood procedure are provided; while in Table 21 results from estimating total factor productivity determinants using fixed effects within regression are reported.

The expectation is that increased export shares should associate positively with total factor productivity. Import penetration ratios are expected to affect productivity positively if industries lower costs and become more efficient when import competition increases (Fernandez, 2003). However, if imports are endogenous with respect to domestic industries' productivity, a negative correlation may arise. A negative correlation arises because some import competing industrial chapters attract imports by being relatively less productive. The reduction in tariffs is also expected to impact positively on industrial productivity growth.

Furthermore, an increase in intermediate imports, increased skill intensity and growth in investment in machinery and equipment should impact positively on productivity. However, an appreciation in the real exchange rate or an increase in inflation should associate negatively with industry productivity performance. An increase in capacity utilisation should be positively related to manufacturing productivity[43].

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[43] TFP growth is likely to be sensitive to the business cycle because capital and labour inputs are difficult to adjust in the short-run, output fluctuations will be related to fluctuations in import and export shares. To deal with this simultaneity problem capacity utilisation is used as a dependent variable (Gunnar and Subramanian, 2000).

In the light of the expectations indicated above, Table 20 presents the results of the random effects maximum likelihood regression. The results show that the export output ratio had a positive and statistically significant relationship with total factor productivity. A one per cent increase in the export output ratio would increase total factor productivity by 0.78 per cent. Miller and Uphadhay (2000) reach a similar conclusion, namely, more openness associates with high total factor productivity using an aggregate sample that included African countries. Gunnar and Subramanian (2000) employing aggregate time series South African manufacturing data finds that a 10 percentage point increase in openness associated with an increase in total factor productivity by 5 per cent in the long run.

The increase in import penetration had a significant negative association with the level of total factor productivity, suggesting that imports may be endogenous with respect to productivity in some domestic industries. A one per cent increase in the import penetration ratio would decrease total factor productivity by 0.63 per cent. It seems imports are being attracted to manufacturing sectors with relatively less productive industries. In contrast Bjurek and Durevall (1998) using Zimbabwean manufacturing industry data report that an increase by one percentage point in imports raised total factor productivity by 0.2 percentage points.

Increases in market size had a negative impact on total factor productivity, indicating that productivity gains were higher for smaller industrial sectors. A one per cent increase in the market share would decrease total factor productivity by 0.26 per cent. Trade liberalisation seems to bring a decline in inefficiency rents that benefit small industrial sectors.

Investment in equipment and machinery is used to proxy technology acquisition, since South African industries do not engage in substantial research and development activity, the bulk of research and development is likely to be embodied in capital equipment, as expected this variable had a positive and significant association with productivity. A one per cent increase in the machinery and equipment expenditure would increase total factor productivity by 0.48 per cent. A similar finding is reported in Gunnar and Subramanian (2000) where a 10 percentage point increase in the share of machinery and equipment investment was associated with an increase in total factor productivity by 3 per cent. The use of intermediate imports also represents an interaction between South African firms and the outside world. An increased use of intermediates had a positive and significant impact on productivity. A one percent increase in the intermediates would increase total factor productivity by 1.12 per cent.

The tariff variable[44] was significant but wrongly signed, suggesting that a one per cent increase in the tariffs would increase total factor productivity by 0.07 per cent. This is counter to the findings of Gunnar and Subramanian (2000) in which it was indicated that annual growth rate in total factor productivity was nearly 3 percentage points higher in sectors where tariffs were reduced by 10 per cent compared with sectors where tariffs were unchanged. In the same thrust, Brazilian data suggests that the effect of nominal tariffs can be identified after controlling for endogeneity of nominal tariffs. The estimated coefficient for tariffs in the productivity equation was negative, even when a measure of tariffs on inputs was added to the productivity equation; the associated coefficient on tariffs on inputs remained negative. The key message is that there is a huge degree of heterogeneity of responses to trade liberalisation and that the effect of

[44] This results suggests the need to employ the effective industry nominal tariff rates themselves in empirical work. Fernandez (2003) reports a negative association between tariff rates and productivity. Productivity gains were associated with tariff declines. This again emphasises the need to employ tariff rates.

tariff reductions depends heavily on the observed and unobserved characteristics of the industries (Schor, 2004).

Capacity utilisation had an insignificant impact on productivity performance. Current levels of inflation and the real exchange rate had an insignificant impact on productivity. However, a real exchange rate depreciation should increase the demand for and profitability of traded industries out put. Therefore, real exchange rate changes that stimulate exports and limit imports associate with higher total factor productivity. In Zimbabwe, Bjurek and Durevall (1998) report that increases in inflation reduced manufacturing total factor productivity, explaining the empirical regularity between higher inflation and lower economic growth (Miller and Uphadhay, 2000).

The model in Table 21 also allows for interactions between variables in the estimation process. A number of interactions were found to be important for productivity. The first important block of interactions dealt with openness as measured by the export-output ratio. In this block the interaction between export output ratio and market shares had a positive and significant impact on productivity. Within this block, the interaction between export output ratio and the real exchange rate has a negative and significant impact on total factor productivity. The other interaction in this group is between export-output ratios and inflation, this interaction had a negative and significant association with manufacturing productivity performance.

The second vital block of interactions dealt with openness as measured by import penetration. The interaction between import penetration and market share impacted negatively on productivity. Within this block, interactions between the real exchange rate and inflation with import penetration had positive and significant effects on productivity. The interaction with the tariff measure impacted negatively on industrial productivity performance.

The third category concerns the interplay between machinery and equipment with other measures. In this group, it is only the relationship with the real exchange rate variable that had a negative and significant impact on manufacturing productivity. The fourth class of interactions captures the fundamental role of the rapport between other variables and intermediates on productivity. The significant associations in this case are between intermediates and market share as well as between intermediates and the real exchange rate. The latter had a negative effect while the former has a positive impact on productivity.

The final group of interactions deals with trade measures and levels of skill intensity in industrial sectors, the two associations are significant. It is however, the interaction between import penetration and skill intensity that is found to connect positively and in a statistically significant way with productivity performance. This latter finding may be related to that in Miller and Uphadhay (2000) and indicates the fundamental role of trade in encouraging the use of skilled labour. To check the robustness of the results in Table 20, the determinants of total factor productivity in manufacturing are examined in Table 21 in a fixed effects regression framework.

Table 20: Estimating TFP determinants by maximum likelihood regression

Random effects ML regression: Dependent Variable TFP						
Variable	Coefficient.	Std. Err.	Z	P>|z|	[95% Interval]	Conf.
Export output ratio	0.7751	0.1887	4.11	0.000	0.4052	1.1451
Import penetration ratio	-0.6257	0.2105	-2.97	0.003	-1.0384	-0.2132
Market size	-0.2639	0.0941	-2.80	0.005	-0.4485	-0.0794
Machinery expenditure	0.4659	0.1938	2.40	0.016	0.0859	0.0846
Intermediate imports	1.1152	0.2014	5.53	0.000	0.7203	1.5101
Tariff	0.0697	0.0169	4.13	0.000	0.0366	0.1028
Capacity utilisation	0.1677	0.1065	1.57	0.115	-0.0410	0.3764
Rand real exchange rate	-0.0579	0.2179	-0.27	0.790	-0.4851	0.3691
Inflation	-0.8011	1.0747	-0.75	0.456	-2.9075	1.3052
Export output ratio × market share	0.0579	0.0114	5.08	0.000	0.0355	0.0802
Export output ratio × real exchange rate	-0.1254	0.0363	-3.45	0.001	-0.1967	-0.0542
Export output ratio × inflation	-0.7002	0.1725	-4.06	0.000	-1.0384	-0.3620
Import penetration ratio × market share	-0.0122	0.0154	-0.79	0.428	-0.0423	0.0179
Import penetration ratio × real exchange rate	0.0937	0.0438	2.14	0.032	0.0078	0.1795
Import penetration ratio × tariff	-0.0267	0.0065	-4.09	0.000	-0.0396	-0.0139
Import penetration ratio × inflation	0.0403	0.1939	2.08	0.038	0.0232	0.7832
Machinery expenditure × market share	-0.0134	0.0128	-1.05	0.295	-0.0385	0.0117
Machinery expenditure × real exchange rate	-0.1126	0.0431	-2.61	0.009	-0.1972	-0.0281
Machinery expenditure × inflation	0.0276	0.1969	0.14	0.889	-0.3585	0.4137
Intermediate imports × market share	0.0449	0.0146	3.08	0.002	0.0163	0.0735
Intermediate imports × real exchange rate	-0.2331	0.0451	-5.17	0.000	-0.3215	-0.1447
Intermediate imports × inflation	-0.1791	0.1816	-0.99	0.324	-0.5349	0.1767
Export output ratio × skill intensity	-0.0616	0.0225	-2.74	0.006	-0.1056	-0.0175
Import penetration ratio × skill intensity	0.0458	0.0216	2.13	0.034	0.0036	0.0881
Constant	-0.1462	1.0658	-0.14	0.891	-2.2351	1.942
/sigma_u	0.0708	0.0149	4.74	0.000	0.0415	0.1001
/sigma_e	0.1228	0.0037	32.78	0.000	0.1155	0.1301
Rho=	0.2496	0.0816			0.1190	0.4317
Group variable	sector	Number of obs			589	
Time variable	year	Number of groups			28	
Log Likelihood	370.538	LR chi2 (24)			243.44	
Random effects	gaussian	Chibar2(01)			23.71	
Prob>chi²	0.0000	Prob>=chibar2			0.000	

Source: Estimation results by the author

Note: Detailed variable definitions are provided in Appendix A.3.

As in Table 20, the results in Table 21 show that the export output ratio had a positive and statistically significant relationship with manufacturing total factor productivity, while the increase in import penetration had a significant negative association with productivity performance. Increases in market size impacted negatively on the evolution of manufacturing productivity. A rise in investment in equipment and machinery by industries generated a robust improvement in manufacturing productivity. An increased application of intermediate imports also had a positive and significant impact on total factor productivity. Again the tariff variable was significant but wrongly signed. Capacity utilisation had a positive but insignificant impact on the evolution of manufacturing productivity, while inflation and the real exchange rate had negative but insignificant impacts on the pattern of industrial productivity.

The results for the interactions were also broadly similar. The interaction between export-output ratio and market shares had positive impact on industrial productivity. The interaction between export output ratios and real exchange rate as well as that between the export output ratio and inflation had negative and significant associations with manufacturing productivity. The interaction between import penetration and tariffs showed a negative and significant association with productivity performance. Machinery and the real exchange rate interaction had a negative impact on productivity, while the interaction between real exchange rate and intermediates associated negatively with productivity. Again, the effect of import penetration and skill intensity is found to be positive and significant, a similar result to that reported in Table 20.

Table 21: Estimating TFP determinants by fixed effects within regression

Random effects within regression: Dependent Variable TFP						
Variable	Coefficient.	Std. Err.	Z	P>|z|	[95% Interval]	Conf.
Export output ratio	0.8556	0.2122	4.03	0.000	0.4388	1.2725
Import penetration ratio	-0.8196	0.2245	-3.35	0.001	-1.3001	-0.3391
Market size	-0.3385	0.1162	-2.91	0.004	-0.5668	-0.1103
Machinery expenditure	0.4572	0.1997	2.29	0.022	0.0648	0.0849
Intermediate imports	1.1171	0.2107	5.55	0.000	0.7566	1.5846
Tariff	0.0839	0.0201	4.17	0.000	0.0444	0.1236
Capacity utilisation	0.1471	0.1211	1.21	0.225	-0.0908	0.3851
Rand real exchange rate	-0.0683	0.2223	-0.31	0.759	-0.5059	0.3693
Inflation	-2.0253	1.1266	-1.80	0.073	-4.2382	0.1876
Export output ratio × market share	0.0584	0.0135	4.32	0.000	0.0318	0.0849
Export output ratio × real exchange rate	-0.1245	0.0380	-3.28	0.001	-0.1991	-0.0498
Export output ratio × inflation	-0.6709	0.1848	-3.63	0.000	-1.0341	-0.3077
Import penetration ratio × market share	-0.0109	0.0231	-0.47	0.638	-0.0562	0.0344
Import penetration ratio × real exchange rate	0.0946	0.0448	2.11	0.035	0.0066	0.1825
Import penetration ratio × tariff	-0.0308	0.0078	-3.90	0.000	-0.0463	-0.0153
Import penetration ratio × inflation	0.4226	0.2019	2.09	0.037	0.0259	0.8192
Machinery expenditure × market share	0.0013	0.0154	0.09	0.932	-0.0289	0.0316
Machinery expenditure × real exchange rate	-0.1210	0.0442	-2.74	0.006	-0.2078	-0.0342
Machinery expenditure × inflation	0.1453	0.2057	0.71	0.480	-0.2587	0.5494
Intermediate imports × market share	0.0415	0.0178	2.33	0.020	0.0066	0.0765
Intermediate imports × real exchange rate	-0.2450	0.0469	-5.22	0.000	-0.3372	-0.1528
Intermediate imports × inflation	-0.2021	0.1898	-1.07	0.287	-0.5749	0.1706
Export output ratio × skill intensity	-0.0929	0.0295	-3.15	0.002	-0.1501	-0.0350
Import penetration ratio × skill intensity	0.1010	0.0375	2.69	0.007	0.0272	0.1747
Constant	0.3042	1.0967	0.28	0.782	-1.8502	2.4587
/sigma_u	0.1177					
/sigma_e	0.1243					
Rho=	0.4729	(fraction of variance due to u_i)				
Group variable		sector	Number of groups			28
Time variable		year	Number of groups			28
R-sq within		0.3910	Corr(u_i,xb)			-0.7424
Number of obs		589	Test that all u_i=0			F(27,537)=4.58
F(24,537)		14.36	Prob>F			0.000

Source: Estimation results by the author
Note: Detailed variable definitions are provided in Appendix A.3.

3.8 CONCLUDING REMARKS

Increased trade affected productivity performance in South African industries. The results in Tables 20 and 21 show an important association between openness measures and productivity. Increased competition in foreign markets through export exposure benefits industry productivity. The benefits to productivity arise due to pressures for reduction in inefficiency and to lower costs from the exposure to more advanced technologies. The results also show a negative impact of import penetration on industry productivity. The estimated coefficient shows evidence that some import competing industrial chapters are relatively less productive, yielding a negative relationship between import penetration and productivity.

The increased import of cheaper intermediate inputs is an important mechanism for industry level productivity gains. The data set has information on imported intermediate inputs and industries did differ in the degree to which production relied on imported inputs. The effect of intermediate imports on productivity is positive and statistically significant.

The results also cast some light on the issue of productivity and technology acquisition. Data on machinery and equipment purchases at the industry level is employed to estimate this effect. Machinery and equipment investment is indeed crucial for productivity gains in the light of trade expansion. The results show that machinery investment had positive effects on productivity.

The analysis also models the impact of interactions on productivity. The key findings are that the interaction between export-output ratio and market shares impacted on productivity in a positive and significant manner. The interaction between export output ratios and the real exchange rate had a negative impact on manufacturing productivity. The effect of the interaction between export-output ratio and inflation on productivity was negative. When import penetration and tariffs are interacted, there is a negative association with productivity. The machinery and the real exchange rate interaction impacts negatively on total factor productivity. The interaction between imported intermediates and market share impacted positively on productivity, while that with the real exchange rate and inflation impacted negatively on manufacturing productivity.

In conclusion, the analysis in Chapter 3 indicates important directions for policy. Most significantly, the results suggest positive payoffs for industrial productivity of an appropriately managed liberalisation of the external sector. Liberalisation of the external sector is good for competition and learning. Learning is available through increased access to world class intermediate inputs and technology. The findings also indicate that some macroeconomic variables interact with trade policy measures to affect industrial performance. In terms of future research directions, it would be interesting to examine the issue of productivity at a much lower classification level than the three digit categorisation. Such research should employ plant level rich data sets that were generated by the manufacturing censuses of 1991, 1993 and 1996 to examine issues related to trade, industry concentration and efficiency in South Africa as has been implemented in Ivory Coast (Harrison, 1994).

After examining the issue of trade and productivity in Chapter 3, the impact of trade on derived labour demand is investigated in Chapter 4. While this issue is of critical significance, relatively few studies in Africa have examined this problem. Using South African trade and industrial data sets, an attempt is made to shed some light on these issues.

CHAPTER 4

TRADE AND LABOUR DEMAND IN MANUFACTURING

4.1 INTRODUCTION

There are relatively few studies analysing the effect of trade-induced shifts in the composition of employment in developing countries, in general, and in their manufacturing industries, in particular. Yet, growth in trade and increased foreign competition exact important effects on the economy. Trade may affect the efficiency with which firms use factors of production, such as labour, as well as the distribution of output within a sector between more and less efficient firms. The backdrop, however, is that the net effect of trade liberalisation on employment in manufacturing is not agreed *a priori*[45] (Wacziarg and Wallack, 2004:3).

Since employment issues are of critical importance in South Africa's manufacturing sector, the direct investigation of the impact of international competition on labour demand is required to meet needs in both academic and policy circles. Some effort in this direction is found in Gunnar and Subramanian, (2000), Petersson (2002) and Moolman (2003), among others. These studies succeed in revealing some important informative regularities; however, most other previous attempts ignored the role of trade or used highly aggregate data for analysis. In this study, a break with these past methodological tendencies is made. In addition, by relying on micro level data, the hope is that the substantial variability among industries that is resident within the three digit sectors will be

[45] A discussion of the plusses and minuses is provided in Section 4.2 of the study.

exploited. The contribution of this investigation, therefore, lies in using longitudinal South African manufacturing industries data to generate more tractable and robust results. This approach allows for the control of industry specific factors at the disaggregated level, in order to uncover the impact of competition on labour demand. Most importantly, the analysis employs data on imports by origin concorded to the industrial chapters, representing one of the first attempts to emphasise the issue of concordance in the analysis of the effects of trade on labour demand in South Africa. The issue of concordance is not trivial as it is important to tie imports directly to the industries in which the impact of trade on employment is being investigated.

This chapter provides empirical estimates of the impact of trade on derived labour demand in South Africa. Initially, it discusses literature relevant to labour demand and trade analysis in Section 4.2. The empirical specification is presented in Section 4.3. The data investigated is discussed in Section 4.4. The results are provided in Section 4.5, which is followed by concluding comments in Section 4.6.

4.2 TRADE AND LABOUR DEMAND

Opponents of free trade argue that lower production costs and fewer regulations in foreign countries allow foreign firms to out-compete domestic producers. In this vein, trade liberalisation has substantially aggravated the employment situation, because higher imports have caused job losses in South Africa (ILO, 1999). In other words, trade expansion leads to less domestic output and fewer domestic jobs. Proponents of free trade, on the other hand, argue that free trade expands export markets resulting in greater demand for products, greater domestic production and more jobs. The interest groups that are for and against liberalisation appear to agree that it leads to labour displacements of some form. Davidson, Martin and Matusz (1999:272) suggest that such arguments are misguided and appear to propose that debate should instead focus on the impact of trade on factor markets. It is, for example, argued that trade expansion leads to an increase in labour demand elasticities and as a result places labour markets under increased pressure. Rising labour demand elasticities matter because higher elasticities can trigger more volatile responses of wages and employment to any exogenous shocks to labour demand (Krishna, Mitra and Chinoy 2001:392, Slaughter, 2001:29).

In the classical model, movements of labour and capital across sectors allows countries to reap the benefits of trade openness. In this paradigm, trade gains obtain from the reallocation of resources towards sectors offering comparative advantage. In the Ricardian model, comparative advantage is a result of relative technological differences across countries, while in the Heckscher-Ohlin vintage, it is due to varying relative factor endowments (Wacziarg and Wallack, 2004:4). In a simple Heckscher-Ohlin-Samuelson (H-O-S) model of comparative advantage, trade leads to a reallocation of resources and to production specialisation in those sectors that intensively use the country's most abundant factor. For developing countries, the model predicts output shifts towards low-skill labour intensive goods, increased demand for unskilled workers and an upward shift in their wage, relative to other factors. For the developed countries, there should be a widening gap between unskilled and skilled relative wages.

The Heckscher-Ohlin-Samuelson framework provides a clear prediction regarding the effect of trade on employment across sectors. Trade liberalisation contracts the import substitute sector, reducing jobs in that sector, while the export sector expands along with employment in that sector. Trade redistributes employment from the import substitute sector to the export sector. Empirical evidence appears to contradict this prediction in many developing countries (Bussolo, Mizala and Romaguera, 2002:640). It is recognised that the HOS framework needs to be adjusted in the context of intra-industry trade (IIT), because a large part of trade is between countries with similar factor endowments trading in products that are vertically or horizontally differentiated. The analysis then needs to adjust for expansions and contractions that occur within industries. More fundamentally, it is argued that technical change affects IIT sectors more than the non-IIT sectors, because more product and process innovation occurs here. The sensitivity of IIT industries may, therefore, be greater in the sense that the adjustment to trade occurs more rapidly (Greenaway, Hine and Wright, 1999:488).

New trade theory also posits sectoral labour shifts as a result of increased trade. For example, models with increasing returns to scale suggest that trade liberalisation may lead to agglomeration of production (Krugman, 1995). Grossman and Helpman (1991) indicate that trade policy openness facilitates transmission of technology. Labour reallocation, for example, occurs with a reduction in trading frictions, especially when technological transmission affects sectors differently. Another class of models suggest that the effects of liberalisation need not involve labour movements, because economic integration allows countries to exploit increasing returns to research and development activities, yielding dynamic productivity benefits that need not stem from changes in specialisation patterns. In a nutshell, gains from trade are possible in the absence of intersectoral factor movements (Wacziarg and Wallack, 2004:2,3).

Experience in industrialised countries has seen a large fall in employment amongst the unskilled workers, while that for skilled labour has risen. Wage levels for skilled workers have increased in relation to those of unskilled workers, a development consistent with the Stolper-Samuelson theorem

(Deardorff, 1994). This development is explained by the shift towards skill-biased technological growth and expansion in international competition. It should be pointed out that examinations of the impact of trade on labour markets in the context of the Heckscher-Ohlin theory has focused primarily on developed country contexts (Krugman, 2000, Milner and Wright, 1998, Leamer, 1998 and Sachs and Shatz, 1994).

While the Stolper-Samuelson and Heckscher-Ohlin theories hold in the long run equilibrium, real world processes seldom reflect pure equilibrium states. Any empirical application of these theories must therefore take into consideration the dynamic adjustment to equilibrium that is an important aspect of the impact of trade on derived labour demand (Pesaran and Smith, 1995). In addition, theory implicitly presumes that the impact of trade liberalisation is uniform across industries. There are many reasons as to why the impact of trade liberalisation may actually differ across manufacturing sectors. Some of these reasons include differences in the degree of liberalisation across sectors, differences in the types of non tariff barriers across industries and differences in the level of organisation of labour across the manufacturing sector. These factors affect the extent to which the impact of trade liberalisation as predicted the Heckscher-Ohlin theory may hold in real life (Fedderke et al 2003). In view of this discussion, Section 4.2.1 looks at the approaches that have been employed to unravel the impact of trade on derived labour demand in manufacturing.

4.2.1 Approaches to the study of effects of trade on employment

At the empirical level, three main approaches have been used to evaluate the impact of trade on employment in manufacturing (Sakurai, 2003:2 and Greenaway, Hine and Wright, 1999:489). These approaches include, the factor content approach, the growth accounting approach and an eclectic regression framework based on static or dynamic labour demand equations. Each of these approaches is discussed below, in turn.

4.2.1.1 The factor content approach

In the factor content trade approach, trade in goods is interpreted as trade in factor content, which is embedded in the traded goods. This approach provides a link between changes in factor content trade as changes in relative factor prices (Deardoff and Staiger, 1988). In the factor content variant, estimates are made of the labour required to produce a given amount of exports or the amount of labour being displaced by a given amount of imports.

Most of the earlier evidence based on factor content trade finds that trade induced variations in labour demand by skill are not sufficient to account for the actual movements in relative wages. Even work comparing relative product price changes to relative wage changes concludes that the role of trade is negligible. Sapir and Schumacher (1985) argue that since imports and exports of European Union and other OECD countries have similar labour contents, an expansion in trade would have minor effects on employment, although trade between the European Union and developing countries would lead to a loss of jobs. Other investigations following this line, such as Wood (1994), have been criticised for assuming, in their analysis, that similar technologies of production are used both in the north and south. Cortes and Jean (2000) and Krugman (1995) also conclude that the labour market impact of trade with developing economies has been modest. Sakurai (2003:2) calculates the factor content of trade embodied in Japanese exports and imports in order to estimate the effect of trade on employment and the wages of skilled and unskilled labour. He finds a negative effect of increased trade on the Japanese manufacturing labour market, but the magnitude of the effect was not very large.

One of the limitations of the factor content analysis is that it is based on the assumption of competitive labour markets. The impacts of state regulations, unions, collective bargaining and institutional rigidities are ignored. However, in the era of increased globalisation, the patterns of economic growth and employment will depend upon domestic labour market conditions. Empirical evidence indicates that labour market regulations do interact with expanded trade (Bussolo, Mizala and Romaguera, 2002:664). Krishna, Mitra and Chinoy (2001:393) also suggest that the linkage between greater trade openness and labour demand may be empirically quite weak. This could be explained by the fact that most analyses ignore the impact of a variety of frictions affecting firm labour demand decisions. In particular, the inflexibility of industrial labour may be due to regulations affecting minimum wages or contractual wage agreements. Even state regulations, union collective bargaining or other institutional rigidities, can make labour market adjustment induced by trade policy behave rather differently.

Milas (1999: 149) alludes to the view that employment and wage inflexibility are also caused by large firing and hiring costs, the threat of strikes and the role of unemployment benefits. In short, the labour market does not behave according to the perfectly competitive paradigm (Bussolo, Mizala and Romaguera, 2002:640). Market rigidities, in practice, tend to extend the duration of unemployment when certain skills become obsolete. Shortages of labour with relevant skills may also hamper export expansion in some sectors (Petersson, 2002:241).

4.2.1.2 The growth accounting approach

In the growth accounting variant, sources of employment are decomposed into domestic demand, trade and productivity elements. It is also generally found that trade factors have played only a minor role in job losses and productivity growth has been the main factor displacing labour in the short run. However, Gregory and Greenhalgh (1997) recover, using this approach, a positive gain in employment from trade changes, especially for financial services and primary and extractive sectors, but a loss for the manufacturing sector in the United Kingdom.

The problem with the growth accounting approach is that components of employment change, namely domestic demand, trade and productivity are assumed to be independent (Greenaway et al, 1999). These components may, however, not be independent. For example, if imports stimulate faster productivity growth then it is possible that secondary effects due to trade are not being picked up by this method. In addition, trade induced productivity growth might be stimulated via various channels. For example, evidence is available that growth in trade is linked to growth in labour productivity (Cortes and Jean, 2000). Caves and Krepps (1993) also show the existence of pro-competitive impacts of trade on technical efficiency. In the same vein, Bussolo, Mizala and Romaguera, (2002:240) and Borgas and Ramey (1994) emphasise the effect of domestic labour market conditions and point to a role for reduced rents and unionised labour employment. Feenstra and Hanson (1996) show that trade expansion may result in relocation abroad of most labour intensive stages of the production processes. In addition, in an environment of increased competition from imports, firms adopt defensive changes in output prices and techniques of production (Neven and Wyploz, 1996).

Leamer (1994) argues that the growth accounting approach is flawed in a fundamental way; trade is not capable of explaining changes in aggregate employment, since employment in the tradable sector is derived as a residual, after adjusting for factor supplies and factor demands by the non-tradable sector as well as adjusting for technology. The growing globalisation of the world economy is, according to Leamer, the critical issue. Attempts to apportion relative importance to either trade or technology are, therefore, likely to be irrelevant.

The growth accounting variant also does not adequately explain the impact of increased trade on labour demand in manufacturing in the light of intra-industry trade. An increase in intra-industry trade or the exchange of essentially similar products creates relatively low-trade induced adjustment costs and can facilitate further trade liberalisation (Greenaway and Milner, 1986). Intra-industry trade brings smaller adjustment costs than a concentration of production to a few sectors in line with comparative advantage. Wage flexibility and the ability to reallocate labour within, compared to between, sectors determines whether adjustment would be smoother due to intra-industry, as opposed to inter-industry trade. Labour requirements are more similar under intra-industry trade, which involves the exchange of goods with similar production techniques, than between industries, because less retraining will be required and labour can transfer with ease (Petersson, 2002). The result is that there will be smaller effects on the distribution of incomes between labour, varyingly skilled, and capital. Under intra-industry trade, the distribution of manufacturing employment across regions and countries is likely to be similar. Deepening integration with advanced countries, such as those in the European Union, should, therefore, expand intra-industry trade in a few sectors, producing differentiated and skill-intensive products. This kind of specialisation may suggest a continuation of weak trade-induced employment creation in South African manufacturing (Petersson, 2002).

4.2.1.3 Labour demand in a regression framework

The regression approach essentially employs regression techniques that are implemented within the context of either static or dynamic[46] labour demand equations. Greenaway, Hine and Wright (1999:491) using the dynamic variant, find that, when trade is introduced, increases in trade volumes, both in terms of exports and imports, cause reductions in the level of derived labour demand. Disaggregating imports by origin provides supportive evidence for a positive relationship between openness and increased labour efficiency in the firm. Increased import penetration induces the elimination of x-inefficiency and the take up of new technology.

Gunnar and Sabramanian (2000:29), using a static analysis with South African data, show that employment tends to fall less in the sectors where tariffs are reduced more aggressively. Their result questions the argument that trade expansion could aggravate the unemployment problem, as firms might reduce the workforce to remain competitive. Correlation analysis conducted in a static framework by Petersson (2002:258) also appears to suggest that employment changes were positively correlated with increased exports and imports. This was specifically more so with imports than exports, suggesting that increased imports do not crowd out domestic jobs, but seem to accompany booming sectors.

In most of the Turkish industries considered by Krishna, Mitra and Chinoy, (2001), the hypothesis of no relationship between trade openness and labour

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[46] The bulk of the regression approaches have used the dynamic models of labour demand to account for labour market adjustment as well as quantify the possible employment losses that may result from more efficient use of labour.

demand elasticities could not be rejected, a finding that was robust to changes in specification. Results from Japan also provide conflicting conclusions on the impact of increased trade on employment in firms; for example, Sakurai (2003:19) suggests that the effect of increased trade on the Japanese manufacturing labour market was not very large. However, studies that link Japan to other countries in a cross-industry framework, or those based on surveys of firms, found that increasing trade, especially increasing imports from developing countries, had some negative impact on the employment and the wage levels of Japanese manufacturing labour (Higuchi and Genda, 1999). Furthermore, Tomiura (2003:120) using a longitudinal data set of manufacturing industries[47] and controlling for industry specific factors, finds a significant impact of import price changes on Japanese employment. In this study, a substantial share of the decline in average employment was accounted for by intensified import competition; furthermore, employment sensitivity increased with import share.

Empirical evidence of the effects of trade liberalisation on labour demand remains mixed. Levinsohn, (1999: 322) opens this debate by indicating that both job creation and destruction are possible, because jobs can be simultaneously created or destroyed in both expanding and contracting industries. Roberts and Tybout (1996) find that industry exit and entry do not increase with import competition, once demand shocks are controlled for. Papageorgiou et al (1991) uncover few relationships between trade liberalisation and transitional shifts in employment in nineteen liberalisation episodes that they examine over various periods ranging from 1960 to 1979 in developing countries. For example, in Brazil, Singapore and Peru they found no relationship between a sector's imports

[47] A criticism has been levelled against using industry level data because this means focusing on net employment changes. If the effect of trade liberalisation is to reallocate jobs within an industry leaving the net employment about the same, industry-level data will be unable to detect this reallocation. One may then erroneously conclude that trade had little to no impact on jobs. See Levinsohn (1999).

and employment change. In the Philippines, evidence indicated that import liberalisation could be linked to a fall in employment in only one of the decontrolled sectors. It was only in Chile that the impact of liberalisation on manufacturing employment varied by sector, with export sectors expanding and import competing sectors contracting, though net employment increased. Such variations in results have been explained as resulting from restrictive labour markets. Indeed, it has been posited that sluggish labour market response to trade liberalisation is due to imperfect competition. Currie and Harrison (1997) document the case of Morocco, where many firms adjusted to trade reform by reducing profit margins and raising productivity rather than laying off workers. In other countries, trade reform could generate a limited impact on employment, because the patterns of labour market regulations made it difficult to fire workers.

4.3 ECONOMETRIC SPECIFICATION

4.3.1 The analytical framework

Empirical evidence shows that evaluating the impact of trade on employment by relying either on the factor content, or the growth accounting approaches, generates limited evidence, if any, of the direct effects of trade on employment. Available evidence also suggests that the impact of trade on derived labour demand can be modelled in a context that permits the use of concorded, but disaggregated, data on trade-intensity. More specifically, the impact of trade can be discerned using a data set that allows categorisation of imports by country or region of origin. This approach facilitates a recovery of the effect of trade on technical efficiency in manufacturing. A simple model that incorporates a profit maximising firm in the context of a Cobb-Douglas production function of the form:

$$y_{it} = A^{\theta} k_{it}^{\alpha} . n_{it}^{\beta} \tag{28}$$

is built, where y denotes the firm's real output level, k and n denote homogenous inputs of capital and labour, respectively. In equation (28) variables α and β represent coefficients of factor shares and θ provides for factors altering the efficiency of the production process.

A profit maximising firm employs labour and capital at levels in which the marginal revenue product of labour is equated to the wage w and the marginal revenue product of capital equals its user cost r (Sapsford and Tzannatos, 1993: 150, and Hamermesh, 1986: 431). Ignoring capital, a firm's output is given by expression (29), below:

$$y_{it} = A^{\theta} \left(\frac{\alpha n_{it}}{\beta} \frac{w_i}{r} \right)^{\alpha} n_{it}^{\beta} \tag{29}$$

Taking logs to linearise the above expression yields a firm's derived labour demand:

$$\ln_{it}^{*} = \sigma_0 + \sigma_1 \ln\left(\frac{w}{r} \right) + \sigma_2 \ln(y_{it}) \tag{30}$$

where $\sigma_0 = -\left(\frac{\theta \ln A + \alpha \ln \alpha - \alpha \ln \beta}{\alpha + \beta} \right), \sigma_1 = \frac{-\alpha}{(\alpha + \beta)}$ and $\sigma_2 = \frac{1}{(\alpha + \beta)}$

The negative sign on σ_1 implies that an increase in the price of labour relative to the price of capital results in a decrease in the firm's labour demand. Technical efficiency, as well as the rate of technology adoption, is assumed to increase over time. As the labour force increasingly familiarises with installed technical equipment its efficiency will improve. In this framework, increases in x-efficiency will be correlated with trade expansion because it is assumed that more technology becomes available with increased trade. The estimating equation in Sub-section 4.3.2 has to account for the of impact of trade on technical change. In line with Greenaway et al (1999: 491) parameter A, in the production function, varies with time in the following way:

$$A_{it} = e^{\delta_0 T_i} (mz)_{it}^{\delta_1} (ex)_{it}^{\delta_2}, \text{ where } \delta_0, \delta_1, \delta_2 \rangle 0 \tag{31}$$

where T is the time trend, import penetration (mz) is equal to imports (z) divided by domestic demand[48] (d), and export share (ex) is measured as the ratio of exports (x) to output (y). Since trade expansion implies increased competition from imports in the domestic market or greater exposure of exports to the international market, it implies that there will be induced efficiency effects in the use of the labour input. In this framework, a general formulation, in which an industry's labour demand is affected by trade shares, can be given as:

$$\ln n_{it} = \sigma_0^* - \phi_0 T - \phi_1 \ln mz_{it} - \phi_2 \ln ex_{it} + \sigma_1 \ln\left(\frac{w}{r}\right) + \sigma_2 \ln y_{it} \tag{32}$$

with $\sigma_0^* = -\frac{(\alpha \ln \alpha - \alpha \ln \beta)}{(\alpha + \beta)}$; $\phi_0 = \phi\delta_0$; $\phi_1 = \phi\delta_1$; $\phi_2 = \phi\delta_2$; $\phi = \frac{\theta}{(\alpha + \beta)}$.

Labour demand is inherently dynamic in nature and panel data has the advantage of allowing for the dynamics of labour adjustment. A dynamic specification is preferred, because labour demand fluctuations can also be influenced by a number of factors such as seasonality, the business cycle, plant level idiosyncratic shocks as well as adjustment costs associated with hiring, training and firing. The factors causing labour demand fluctuations affect adjustment costs, which drives a wedge between the wages paid to labour and the marginal product. The existence of these costs implies that a firm's demand for labour depends not only on current exogenous factors but also on the initial level of employment and the expectations about the future level of such factors, making the employment decision rule a dynamic problem (Dutta, 2004: 236). To properly capture the impact of adjustment costs, it is important to relate current to past levels of employment in industries.

[48] Domestic demand is defined as value of output of domestic industries plus value of imports.

One method of recognising adjustment costs is to distinguish between desired and actual levels of employment, $\ln n_t^*$ and $\ln n_t$ respectively. Because of the existence of adjustment costs, only some fraction of the adjustment required to bring existing employment up to the desired level will be achieved during a single period. In a partial adjustment model, only some fraction, say λ, of the desired employment change is achieved during the current time period. This dynamic adjustment mechanism can be stated as:

$$\ln n_t - \ln n_{t-1} = \pi\left(\ln n_t^* - \ln n_{t-1}\right) \qquad (33)$$

where $0 \le \pi \le 1$. Substituting (33) into (32) and rearranging, an expression for the determinants of actual employment is generated as:

$$\ln n_{it} = \sigma_0^* - \phi_0 T - \phi_1 \ln mz_{it} - \phi_2 \ln ex_{it} + \sigma_1 \ln\left(\frac{w}{r}\right) + \sigma_2 \ln y_{it} + \sigma_3 \ln n_{it-1} \qquad (34)$$

where $\sigma_3 = (1 - \pi)$

Large values of π imply rapid adjustment, while low values imply slow adjustment. The adjustment costs associated with the employment decision rule makes it possible for the level of employment to deviate from its steady state when adjustment to equilibrium is occurring. Again, if the employment measure is an aggregation across workers with differing adjustment costs, an additional lag structure may be necessary to allow for the effects of labour heterogeneity[49] (Nickell, 1986). Dutta (2004: 235) and Alonso, (2004:477) show that industries display significant rigidities in labour adjustment and the degree of adjustment differs between industries as well as between types of labour, which is reflected in divergent persistence profiles. Furthermore, justification for a longer lag structure may be necessary if serially correlated technology shocks are present. Lags may also be justified in the labour demand function, once bargaining

[49] Some empirical studies explicitly recognise the heterogeneity of labour types and account for this by specifying and estimating separate labour demand equations for different categories of workers. This may be important because theoretical arguments highlight the differential degree of quasi-fixedness of different types of labour as in Alonso, (2004)

considerations are taken into account to capture sequences of bargaining or expectations formation about future wages on output levels (Hamermesh, 1993).

4.3.2 The estimating equation

The employment equation needs to capture the impact of adjustment in derived labour demand. The adjustment dynamics are normally characterised by the presence of a lagged dependent variable among the regressors (Baltagi, 2001:129; Ahn et al, 2000).

$$\ln n_{it} = \delta \ln n_{i,t-1} + x_{it}\beta + \mu_{it} \qquad (35)$$

where X_{it} consists of forcing variables which affect the efficiency of production, these include variables such as the extent of foreign competition, the degree of market power, the level of import or export penetration for an industry and the level of competing imports by place of origin. Assuming a two-way error component model,

$$\mu_{it} = \eta_i + \lambda_t + \nu_{it}, \qquad (36)$$

where λ_t is the time effect common to all industries, η_i is the permanent but unobservable, industry specific effect and ν_{it} is the remainder of the error term.

Dynamic panel data regressions of the form represented in (35), above, are characterised by two sources of persistence over time. The first is autocorrelation, due to the presence of a lagged dependent variable among the regressors. The second is the individual effects that characterise the heterogeneity among individuals. Inclusion of a lagged dependent variable makes the OLS estimator biased and inconsistent in estimating the coefficient of the dependent variable. Even the fixed effects estimator based on the within transformation will still be biased and inconsistent for a typical panel where N is large and T is fixed. The random effects GLS estimator is also biased in a dynamic panel data model.

While, the instrumental variable (IV) estimation method is consistent, it does not necessarily generate efficient estimates of model parameters. Ahn and Schmidt (1995), show that the IV estimator does not make use of all the available moment conditions and does not take into account the differenced structure of the residual disturbances.

Arrellano and Bond (1991) proposed a generalised method of moments (GMM) procedure to tackle the above problem. This procedure requires additional instruments that can be obtained by utilising the orthogonality conditions that exist between lagged values of the dependent variable and the disturbances. The generalised method of moments in Arellano and Bond (1991:288) employs differences, rather than levels, for instruments dated $t-2$ and earlier, as in equation (37) below.

$$\ln n_{it} = \alpha_1 \ln n_{i(t-1)} + \alpha_2 \ln n_{i(t-2)} + \beta\ (L) X_{it} + \lambda_t + \eta_t + \nu_{it} \qquad (37)$$

The remainder of the variables are as earlier defined, X is the vector that contains explanatory variables and $\beta(L)$ is a vector of polynomials in the lag operator. Allowance for a distributed lag structure for the independent variables may be necessary, because it is difficult to impose a common evolution for employment following changes in the explanatory variable. This allowance, in essence, provides for the lack of clarity regarding the source of the dynamics in the employment equation. In a dynamic setting, a baseline differenced employment equation is recommended, so that the industry specific effects are transformed out.

4.3.2.1 The moment conditions

The Arrellano and Bond (1991) generalised method of moments (GMM) procedure is more efficient than the Anderson and Hsiao (1982) estimator. The rationale for the procedure is that if the orthogonality conditions that exist between lagged values of n_{it} and the disturbances v_{it} are utilised, additional instruments can be obtained in a dynamic panel model. Assuming x'_{it} is a vector of explanatory variables and the labour demand equation is represented as:

$$n_{it} = \delta n_{i,t-1} + x'_{it}\beta + \mu_{it} \qquad \mu_{it} = \eta_i + v_{it} \tag{38}$$

To get a consistent estimate of δ it implies the following moment conditions

$$E(\Delta v_{it} n_{it-s}) = 0 \qquad s \geq 2 \tag{39}$$

Where Δ is the first difference operator. These conditions imply that values of the dependent variable lagged two or more periods can be used as valid instruments in the first difference equations. Condition 39 may be expressed as $E(Z'_i \Delta v_i) = 0$ where $\Delta v_i = (\Delta v_{i3}, \ldots\ldots, \Delta v_{iT_i})'$ is a vector and Z_i is a matrix of instruments.

$$Z_i = \begin{bmatrix} n_{i1} & & & 0 \\ & n_{i1}, n_{i2} & & \\ & & \ddots & \\ 0 & & & n_{i1}, \ldots, n_{i,T-2} \end{bmatrix} \tag{40}$$

Arrellano and Bond (1991) suggest that it is possible to exploit the exogeneity assumption regarding some or all of the explanatory variables (x_{it}) outside the dependent variable. For example, if the (x_{it}) are predetermined such that $E(x_{it} v_{is}) \neq 0$ for $s \prec t$ and zero otherwise, then only $\left(x_{i1}', x_{i2}', \ldots\ldots, x_{is-1}'\right)$ are valid instruments in the differenced equation for period s. If (x_{it}) are strictly exogenous such that $E(x_{it} v_{is}) = 0$ for t, s, then it is possible for all the $\left(x_{i1}', x_{i2}', \ldots\ldots, x_{iT}'\right)$ to be used as valid instruments for all the equations. This suggests that it is possible for explanatory variables to include a combination of both predetermined and strictly exogenous variables. This estimator can be further utilised by replacing Δv with the differenced residuals obtained in the one step consistent estimator to obtain a two step Arrellano and Bond (1991) GMM estimator (Baltagi, 2001:132). In essence, the Arrellano and Bond (1991) approach uses lags of endogenous variables as instruments and is efficient, because it expands the instrument set as the panel progresses and the number of potential lags increases[50]. The resulting estimated equation would be unbiased, while consistent estimates of the regression coefficients will be generated, so long as the difference equation is free of higher order serial correlation. It is recommended that if the validity of the instrument set employed is to be relied upon, a check for serial correlation between the instruments and the residuals from the model should be implemented using the Sargan test[51].

4.4 DATA AND DESCRIPTIVE STATISTICS

A data set of South African manufacturing industries from 1988 to 2002 is available at the three digit level of disaggregation making it possible to implement dynamic labour demand equations. For this sample period of concorded data, a longitudinal data set of 420 observations (28 industries in 15 years) at the three-digit level is used. This detailed data set is important for an appreciation of the response of South African employment to international exposure and competition. The analysis incorporates imports by origin at the three digit SIC level to determine the originating region from which, the stronger efficiency effects emanated.

[50] It should be pointed out that this GMM estimator that exploits only the orthogonality conditions valid for first differenced equations can be limited. It does not allow for the identification of time invariant variable effects and it also doesn't take into consideration the orthogonality conditions valid for equations in levels.

[51] Sargan (1964) tests for the absence of second order serial correlation in the first differenced residuals. The results of this test should be reported see Doornik et al (2001).

The data set that is employed is specifically assembled using a diversity of sources to allow for the construction of an integrated database of industrial, labour and trade statistics. The panel consists of 28 manufacturing industrial sectors corresponding to the three digit ISIC level of aggregation, from 1988 to 2002. The data contains information on inputs, output, industry characteristics and a number of policy variables.

The key variables are N which is the total number of employees in each industry; W is the average real wage in each industry; Y is real output in each industry; import penetration MZ is equal to imports divided by domestic demand, and export share EX is measured as the ratio of exports to output. For the origin of imports, the analysis concentrates on five regions: America, Europe, Asia, Oceania and Africa. Table 22 shows the summary statistics for the variables used in the employment analysis. Imports from Europe are the most important, followed by those from Asia and the Americas. Some industries are very open to imports, recording a maximum export to output ratio of 96.5 per cent. The average market share in the industrial sector is 3.6 per cent, while largest sector represents 15.9 per cent of domestic sales.

Table 22: Summary statistics for employment variables

Variable	Definition	Obs	Mean	SD	Minimum	Maximum
N	Number of Employees	644	51948.0	43619.0	2092.0	207068.0
Y	Output	644	11608.3	10168.7	928.7	58197.1
W	Real wage	644	49246.3	24431.2	16359.6	178821.2
K	Capital	644	5653.3	8786.9	96.5	56357.3
Ex	Export output ratio	644	14.5	14.9	0.2	76.5
Mz	Imports penetration ratio	644	21.2	18.4	0.4	96.5
Ms	Market share	644	3.6	3.2	0.2	15.9
africa_mz	Imports from Africa	420	59.0	85.4	0.0	741.5
america_mz	Imports from America	420	593.9	1030.3	2.7	7503.3
Asia_mz	Imports from Asia	420	898.1	1613.5	0.0	12600.0
europe_mz	Imports from Europe	420	1745.9	3311.9	5.7	26700.0
oceania_mz	Imports from Oceania	411	82.0	280.3	0.0	3154.2

Notes: Variables measured in millions of Rand.
Source: www.reservebank.co.za, www.statsa.gov.za, www.tips.org.za, http.trade@easydata.co.za,

As part of the exploratory data analysis, an investigation of the correlation between variables in our employment function is implemented. This is to gain some initial view regarding the types of associations that may obtain between the variables of interest. Both parametric and non-parametric tests of hypothesis are computed. Table 23, shows the results of the non-parametric covariance matrix for labour, output, real wages, capital input, export pressure, import penetration and market share. The results show that employment, output, capital input and market share are positively correlated, while employment, real wages, export pressure and import penetration have a negative association.

Table 23: Correlation between employment and determinants

Employment	Employment	Total output	Real wages	Capital stock	Export pressure	Import pressure	Market share
Employment	1.0000						
Output	0.7120	1.0000					
Real wages	-0.4038	0.1876	1.0000				
Capital stock	0.5075	0.8219	0.2206	1.0000			
Export pressure	-0.1129	0.0533	0.1060	0.1406	1.0000		
Import penetration	-0.1355	0.0346	0.1536	0.2255	0.5365	1.0000	
Market share	0.6901	0.9207	0.0725	0.8046	0.0273	0.0400	1.0000

Note: Computed by the author
Source: : www.reservebank.co.za, www.statsa.gov.za, www.tips.org.za, http.trade@easydata.co.za

Table 23 presents the non-parametric test results. The results show that employment and output, capital stock and market share have strong and significant positive correlation while employment and export pressure as well as import penetration have a significant negative association. This is an early indicator, although not necessarily a confirmation, of the efficiency effects on labour that arise due to increases in trade volumes. The test results in Table 24, are relevant, in the sense that they confirm whether the computed correlation between variables is actually statistically significant at the conventional levels.

Table 24: Non parametric tests for employment and its determinants

Employment	Total output	Real wages	Capital stock	Export pressure	Import pressure	Market share
Spearman's rho	0.6827	-0.3771	0.4975	-0.1674	-0.2016	0.6984
Prob > |t|	0.000	0.000	0.000	0.000	0.000	0.000
Kendal's tau-a	0.4928	-0.2577	0.3344	-0.1106	-0.1358	0.4985
Prob > |z|	0.000	0.000	0.000	0.000	0.000	0.000

Note: Spearmans and Kendall's statistics computed using stata software
Source : www.statsa.gov.za, www.tips.org.za, http.easydata.co.za

4.5 ECONOMETRIC RESULTS

The results are presented in two parts. The first part describes the estimated equations while the second presents the interpretation attached to the results.

4.5.2 Labour demand equation results

The results of the estimation exercise are presented in Tables 25, and 26 below. The first table reports the baseline regression. In the baseline specification, derived labour demand is a function of real output, real wages and market size. This model is augmented by the impact of trade volumes and some interactions between trade and wage effects. However, because the literature suggests that there are some reasons to believe *a priori* that origin of imports may matter, this effect is also investigated. The main trading regions are divided into the Americas, Europe, Asia, the rest of Africa and Oceania. The impact of region of origin on derived labour demand is investigated in Table 26.

In Table 25, three baseline regressions for derived labour demand in South African manufacturing are reported. In column 2 of this Table, where the results from regression 1 are presented, output and wages have the expected impacts. An increase in output leads to a rise in the level of derived labour demand, in both the short-run and in the long-run, while increases in wages, on the other hand, have the expected negative effect on labour demand in the short-run. Industrial sectors with a large share of the domestic market had a significant impact on employment determination. The positive coefficient on lagged employment in the models suggests some persistence in both the wage and output effects. The baseline specification performs well in the conventional statistical sense, with no reported second order serial correlation, suggesting that a valid instrument set consisting of lags of output, wages, and market share has been employed and the residuals are not correlated.

Column 3 of Table 25 reports the second regression's results. Here, import and export penetration ratios are introduced into the underlying baseline equation. The first thing to note is that not much change occurs to the performance of the basic model most of the variables are broadly similar in magnitude, yet the specification remains largely robust. An increase in output leads to a rise in the level of derived labour demand, while increases in wages, on the other hand, have a negative effect on labour demand. Turning to trade shares, the export share exerts a positive impact on derived labour demand that is significant at the 1 per cent level. This indicates that an increase in the demand for manufactured exports has a positive impact on derived labour demand. These results suggest that export growth appears to exert pressure for industries to hire more units of the labour input. The current import penetration ratio is negative and significant at the one per cent level as expected. These results suggest that import pressure makes industries to shed some of their employees in order to remain competitive.

The results presented in column 4 of Table 25 are the last augmentation to the baseline regression. Even in this last augmentation, an increase in output still leads to a rise in the level of derived labour demand and an increases in wages, leads to a decrease in labour demand in manufacturing. The focus here however, is on the impact of trade on the slope of the labour demand function. It has been argued that increased openness makes it easier to substitute foreign for domestic workers (Borgas and Ramey, 1994). This hypothesis is examined by interacting import and export volumes with the real wage rate. For the export share, the effect is positive but not significant; however, for import penetration the effect is negative and significant at the 1 per cent level. Since the effect of the interaction between current import penetration and real wage is significant at the conventional levels, some labour substitution in manufacturing appears to be taking place as trade openness increases.

Table 25: Baseline labour demand models for South African manufacturing

Model Number / Dependent Variable	1 $\Delta \log n$		2 $\Delta \log n$		3 $\Delta \log n$	
Variable	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Constant	-0.0292	-3.45	0.0023	0.22	-0.0319	-7.27
$\Delta \log n_{t-1}$	0.0128	2.11	0.0677	2.19	0.0005	0.04
$\Delta \log n_{t-2}$	0.0063	0.73	-0.0092	-0.35	-0.0157	-1.20
$\Delta \log y_t$	0.0942	3.91	0.2208	3.23	0.1708	3.04
$\Delta \log y_{t-1}$	0.0199	0.67	0.0143	0.32	0.0622	1.17
$\Delta \log y_{t-2}$	0.0508	3.03	-0.1205	-2.49	-0.0855	-1.75
$\Delta \log(w/r)_t$	-0.0288	-2.00	-0.1242	-2.26	-0.1044	-2.32
$\Delta \log(w/r)_{t-1}$	0.0009	0.05	-0.0446	-0.75	0.0621	1.53
$\Delta \log(w/r)_{t-2}$	0.0068	0.22	-0.0557	-0.64	-0.0415	-0.73
$\Delta \log marketshare_t$	0.0308	1.98	0.0012	0.07	0.0085	0.53
$\Delta \log marketshare_{t-1}$	-0.0534	-3.16	-0.0432	-1.85	-0.0562	-2.60
$\Delta \log marketshare_{t-2}$	0.0053	0.59	0.0112	1.08	0.0049	0.56
$\Delta \log \exp ort_t$			0.0713	3.79	0.0343	2.89
$\Delta \log \exp ort_{t-1}$			0.0070	0.38	-0.0096	-0.72
$\Delta \log \exp ort_{t-2}$			0.0151	0.92	0.0072	0.53
$\Delta \log import_t$			-0.2111	-2.62	0.0355	2.86
$\Delta \log import_{t-1}$			-0.0139	-0.38	-0.0168	-1.04
$\Delta \log import_{t-2}$			0.0479	1.93	0.0125	0.81
$\Delta \log(w/r)_t \times \Delta \log \exp ort_t$					0.0002	0.07
$\Delta \log(w/r)_{t-1} \times \Delta \log \exp ort_{t-1}$					0.0021	1.45
$\Delta \log(w/r)_{t-2} \times \Delta \log \exp ort_{t-2}$					0.0031	1.29
$\Delta \log(w/r)_t \times \Delta \log import$					-0.0058	-2.45
$\Delta \log(w/r)_{t-1} \times \Delta \log import_{t-1}$					-0.0030	-0.98
$\Delta \log(w/r)_{t-2} \times \Delta \log import_{t-2}$					-0.0045	-1.65
Wald (joint)	χ^2 (11)=42.62 [0.000]**		χ^2 (17)=93.09[0.000]**		χ^2 (23)=415.5[0.000]**	
Wald (dummy)	χ^2 (140)=2865 [0.000]**		χ^2 (140)=171.90[0.034]*		χ^2 (47) =2643[0.000]**	
Wald(time)	χ^2 (12)=63.56 [0.000]**		χ^2 (12)=174.2[0.000]**		χ^2 (20) =506.6[0.000]**	
Second order serial correlation	N(0,1)=-0.5875[0.557]		N(0,1)=-0.041[0.97]		N(0,1) =1.41[0.16]	

Note: All models estimated in differences by instrumental variables and coefficients on time dummies are not reported. Source: computed by the author: **www.statssa.gov.za**, www.tips.org.za, http.trade@easydata.co.za

In Table 26, an examination of the region specific impact of trade on derived demand for labour is investigated. The first column in the table lists disaggregated imports, into those originating from America, Europe, Asia, Africa and Oceania. In Europe, South Africa's key trading partners include UK, Germany, France, Netherlands and Italy. Trade with America as a region is dominated by the USA, Canada, Mexico, Brazil and Argentina. The main countries in Asia that trade with South Africa are Japan, China, Hong Kong, Singapore, Taiwan, Korea and Malaysia. For Oceania and Africa, the key countries involved are Australia, New Zealand and Egypt.

Results from regression 4 in column 2 of Table 26 are based on the impact of imports from the most technologically advanced of the partner regions namely Europe and America. The results indicate a significant positive impact on derived labour demand of imports from both America and Europe. In regression 5, imports from Asia are introduced. The results reported in column 3 indicate a significant positive association between imports originating from Europe and a strongly negative and significant association between manufacturing labour demand with imports from Asia. In regression 6, results of which are reported in the last column of Table 26, imports from Oceania and Africa are introduced. Findings indicate a positive impact from Oceania and a weak impact from the African region. In a nutshell, imports from Asia lead to the most noticeable loss in demand for labour in South African manufacturing.

Table 26: Import origin and manufacturing labour demand

Model Number	4		5		6	
	$\Delta \log n$		$\Delta \log n$		$\Delta \log n$	
Variable	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-0.0218	-4.09	-0.0278	-9.60	-0.0236	-6.28
$\Delta \log n_{t-1}$	0.0003	0.20	-0.0033	-0.29	0.0043	2.02
$\Delta \log n_{t-2}$	0.0040	0.50	-0.0232	-2.33	-0.0001	-0.06
$\Delta \log y_t$	0.0164	3.06	0.0926	3.85	0.0109	2.64
$\Delta \log y_{t-1}$	0.0018	0.22	0.0679	1.33	-0.0002	-0.06
$\Delta \log y_{t-2}$	0.0078	0.77	-0.0809	-1.57	-0.0028	-1.11
$\Delta \log(w/r)_t$	-0.0135	-2.37	-0.1323	-3.10	0.0069	0.98
$\Delta \log(w/r)_{t-1}$	0.0004	0.07	0.0473	1.69	-0.0089	-1.75
$\Delta \log(w/r)_{t-2}$	-0.0031	-0.93	-0.0009	-0.04	0.0035	1.02
$\Delta \log marketshare_t$	0.0407	2.22	0.0189	0.91	0.0188	0.97
$\Delta \log marketshare_{t-1}$	-0.0545	-3.57	-0.0474	-1.87	-0.0336	-1.91
$\Delta \log marketshare_{t-2}$	0.0152	1.11	0.0126	1.13	0.0008	0.07
$\Delta \log amer\_imp_t$	0.0291	2.04	0.0283	1.73	0.0086	0.62
$\Delta \log amer - imp_{t-1}$	0.0039	0.31	-0.0009	-0.07	0.0114	0.79
$\Delta \log amer\_imp_{t-2}$	-0.0159	-1.12	-0.0005	-0.29	-0.2175	-1.16
$\Delta \log euro\_imp_t$	0.0193	2.11	0.306	2.02	0.0295	2.26
$\Delta \log euro - imp_{t-1}$	0.0166	1.17	0.0207	1.12	0.0102	0.78
$\Delta \log euro\_imp_{t-2}$	-0.0142	-1.45	0.0182	1.63	0.0284	2.00
$\Delta \log asia\_imp_t$			-0.0021	-2.33	-0.0110	-1.16
$\Delta \log asia\_imp_{t-1}$			-0.0297	-2.02	-0.0429	-3.95
$\Delta \log asia\_imp_{t-2}$			-0.0347	-3.90	-0.0209	-1.73
$\Delta \log oceania\_imp_t$					0.0089	2.00
$\Delta \log oceania\_imp_{t-1}$					-0.0000	-0.02
$\Delta \log oceania\_imp_{t-2}$					-0.0085	-2.05
$\Delta \log africa\_imp_t$					0.0109	1.00
$\Delta \log africa\_imp_{t-1}$					-0.0083	-1.29
$\Delta \log africa\_imp_{t-2}$					-0.0002	-0.02
Wald (joint)	χ^2 (17)=51.4[0.000]**		χ^2 (20)=232.4[0.000]**		χ^2 (26)=748.6[0.000]**	
Wald (dummy)	χ^2 (140)=255.2[0.000]**		χ^2 (39)=7950[0.000]**		χ^2 (38)=748.6[0.000]**	
Wald (time)	χ^2 (12)=52.7[0.000]**		χ^2 (12)=280.6[0.000]**		χ^2 (12)=121.9[0.00]**	
Second order serial correlation	N(0,1)=--0.27 [0.786]		N(0,1)=-0.647 [0.51]		N(0,1)=-0.258 [0.796]	

Note: Estimates in differences by instrumental variables. The variables are as defined in table 24.
Source: computed by the author: **www.statssa.gov.za**, www.tips.org.za, http.trade@easydata.co.za

4.5.2.2 Role of product and time specific effects

As indicated in equation 38 it is possible to model the impact of the product-specific and time-specific effects. Product specific-effects are time-invariant characteristics such as the degree of market competition in different industries, information asymmetry in the industrial sector[52] and the degree of product differentiation. Other product specific characteristics are related to government influences that apply to specific industries, unobservable entrepreneurial and managerial skills in different industries and the language and business culture. These effects are captured by product specific dummies as data for these variables is unavailable.

Time-specific effects capture the effects of policy interventions and trade policy shifts. These shifts include the impact of policies such as the General Export Incentive Scheme, the impact of membership in the WTO, the effect of sanctions or the role of the government of national unity since 1994, where conditions that cut across all industrial sectors were created. Time effects can also capture significant changes in productivity due to innovation or to other noticeable effects such as the impact of the depreciation of the Rand in 2002. The impact of global crises[53]can also be classified as time specific. Again, since data on these key changes is unavailable, their effects are captured using time-specific dummies. For simplicity, it is assumed that product-specific and time-specific effects are fixed parameters to be estimated and all the remainder of the disturbances are stochastic, independent and identically distributed. An

[52] Availability of information to enable exporters or importers of commodities in South Africa and the rest of the world differs from product to product.
[53] Such as crises include the East Asian and Russian financial crisis of 1997 and 1998 respectively as well as the September 11 crisis in the US.

extension of equation 5 from Table 26 is done to provide results indicating the impact of these effects in Table 27.

Table 27: Product and time specific effects in manufacturing

Variable/Model Number	5	
Product specific effects	**Coefficient**	**t-ratio**
Food	-0.0176	-2.66
Beverages	0.0224	2.15
Tobacco	0.0021	0.40
Textiles	-0.0142	-2.58
Wearing apparel	0.0002	0.03
Leather & leather products	-0.0323	-4.41
Footwear	-0.0023	-0.41
Wood & wood products	0.0036	0.80
Paper & paper products	-0.0259	-2.37
Printing, publishing & recorded media	0.0061	1.19
Coke & refined petroleum products	0.0122	1.64
Basic chemicals	0.0039	0.56
Other chemicals & man-made fibres	0.0077	1.55
Rubber products	0.0138	2.89
Plastic products	-0.0051	-0.67
Glass & glass products	-0.0221	-2.60
Non-metallic minerals	-0.0169	-1.44
Basic iron & steel	0.0029	0.34
Basic non-ferrous metals	-0.0038	-2.57
Metal products excluding machinery	0.0057	1.26
Machinery & equipment	0.0378	1.76
Electrical machinery	-0.0221	-1.74
Television & communication equipment	0.0169	1.34
Professional & scientific equipment	0.0285	2.94
Motor vehicles, parts & accessories	-0.0143	-0.97
Other transport equipment	-0.0103	-1.53
Furniture	0.0061	0.83
Time specific effects	**Coefficient**	**t-ratio**
1992	0.0099	0.98
1993	0.0038	0.33
1994	0.0082	0.65
1995	0.0201	2.48
1996	0.0205	1.64
1997	-0.0098	-0.84
1998	0.0087	0.42
1999	0.0099	0.53
2000	-0.0121	-0.83
2001	-0.0593	-2.74
2002	0.0593	3.23

Source: computed by the author:

The results in Table 27 show that food, textiles, leather and leather products, paper and paper products, glass and glass products and basic non ferrous metals exerted negative and statistically significant product specific effects. This suggests that there are some unique characteristics in these products that tend to reduce derived labour demand in the manufacturing sector. There is need to identify these characteristics using firm level surveys targeting these industry chapters. Positive and significant product specific effects were also recorded in beverages, rubber products and the professional & scientific equipment sectors. Regarding the time specific effects, the impacts over the period under review were generally positive, with statistically significant impacts recorded in 1995 and 2002. The only negative time specific impact on manufacturing employment is recorded in 2001. This suggests that the question of the decline in employment in manufacturing over the period under review can be unravelled by looking more closely at the product specific characteristics.

4.5.2.3 Interpretation of the overall results

These results can be explained in a number of ways in terms of the existing trade theories. More intuitively, the debate on employment effects of trade lies also on the question of whether trade between South Africa and the rest of the world is of inter-industry or intra-industry type. Inter-industry trade refers to international exchange of widely dissimilar goods. Such trade between South Africa and its trading partners stems from differences in the rankings of sectoral comparative advantage. Explanations for inter-industry trade in the context of South African trade should, therefore, be consistent with the Ricardian and Heckscher-Ohlin models.

Intra-industry trade, on the other hand, is the simultaneous importing and exporting of similar products. For South African manufacturing, intra-industry exchange should produce extra gains from international trade over and above those associated with comparative advantage, because it allows firms to take advantage of larger markets. Indeed, new trade models provide simple explanations for observed intra-industry patterns by linking it to imperfect competition, consumer preferences and other features of industrial organisation.

Trade models argue that there is increased efficiency, through achievement of scale economies, and welfare gains, due to a larger choice of varieties for consumers (Petersson, 2002). In addition, moving from one industry to another owing to inter-industry adjustment is expensive, because workers' capital depreciates necessitating retraining. However, intra-industry trade makes human capital portable across firms, so that, even though some firms exit the market, adjustment costs will be smaller.

South African trade with Europe and the America's appears to be based on fairly long established trade links. An increasing share of South African trade with Europe and America is likely to be of the intra-industry type. The impact of import trade with Europe and the Americas on derived labour demand in South African manufacturing is positive.

Isemonger (2000) finds an upward trend in the overall level of intra-industry trade manifested at all levels in South African industry. In the same vein, Peterson (2002), using South African data, also finds an increase in trade following liberalisation in 1994 and that large differences in intra-industry trade existed among sectors, while trade with the European Union was dominated by differentiated and skill-intensive industries. Motor vehicles and machinery represent more than half of this expansion in trade with the European Union. The level of intra-industry trade with Europe in equipment and machinery has played an important role in the industrialisation of South Africa, because machinery and equipment producing sectors lie at the heart of production and technical change (Sichei and Harmse, 2004). Europe is also one of South Africa's most important sources of imports, particularly for capital goods and technology. Major investment in South Africa's automobile, chemical, mechanical and electrical engineering industries are from Europe. There are also strong links between Europe and South Africa regarding foreign direct investment. Inward

FDI has a positive relationship with imports, because FDI and trade complement each other (Markusen and Venables, 2000). If intra-industry trade is increasing or is dominating inter-industry trade in some sectors, then industrial and trade policies for products should be designed in a way to reap maximum trade benefits.

While trade between South Africa and Asia has been growing rapidly, it appears to have reduced demand for South African labourers in the import competing industries. While import penetration from Asia exerts a largely negative impact on derived labour demand for South African manufacturing that with Oceania exerts a positive impact. Products from Asia that are similar to those made in South African industries tend to displace South African products and labour. Indeed, the textile industry in South Africa is facing competition from textiles from Asia. The average impact of imports from Africa was largely insignificant.

4.6 CONCLUDING REMARKS

South Africa has, over the last quarter of a century, experienced the effects of globalisation and the growth in trade that comes along with it. Naturally, the impact of expanding trade volumes on manufacturing labour markets in particular, has generated a fair amount of debate. More specifically, there has been concern that the impact of trade on the country would be reflected largely in job losses, because the South African manufacturing sector was assumed to be unable to adjust or compete with those in the north and East Asia. Other arguments have posited that since the country has a low wage base, it would experience rapid expansion as firms relocated to South Africa from the rest of the world. The interest in labour adjustment in manufacturing is profound in South

Africa, because of the continued stagnation or decline in manufacturing employment (and employment, in general).

Chapter 4 investigated the impact of trade on industry level outcomes for the entire South African manufacturing industry. A dynamic labour demand equation was built incorporating imports and exports and is estimated in a panel that uses a constructed rich database. The baseline equation appears properly specified, and adequately accommodates changes in specification as well. The results show that import volumes generally caused reductions in the level of derived labour demand. The reductions in derived labour demand results from the fact that increased trade and openness serves to increase the efficiency with which labour is utilised in an industry. In a nutshell, increased import penetration serves to reduce inefficiency and encourages the use of new technology. The positive impact of export expansion on derived labour demand supports results from efficiency estimates that indicate the importance of skilled labour. Increased trade requires emphasis on skill development for the labour force, because intra-industry trade benefits can only arise in an environment in which the skill competencies of labour are improved. The results uncover some evidence of foreign labour substituting for South African workers in the manufacturing sector.

Some of the trade flows between South Africa and its trading partners is of the inter-industry type, stemming largely from differences in sectoral comparative advantage, while some of the trade flows are increasingly of an intra-industry type. Some of the products entering South Africa are produced at lower cost abroad than can obtain for similar products in South Africa; such commodities have tended to displace South African products and labour. The analysis presented here shows that trade has the potential to exact factor adjustment. It is, therefore, important to take into account possible factor adjustments in all products and in all the key spheres of policy. These spheres of policy exist at the level of industrial policy, trade policy and in bilateral and multilateral agreements. In this vein, it is important to conduct periodic analysis at industry and firm level to identify product specific factors affecting labour demand.

There are important avenues in which this analysis can be expanded given more finely graded data. For example, it would be useful to explore the relationship for different categories of labour especially given the wealth of literature on the skills gap. Investigating groupings of industries by relative factor intensity is another important area. Most importantly, it is worth pursuing issues related to the speed of adjustment and the importance of intra-industry trade, especially with data broken more frequently, covering a longer period of time. Other extensions will merit the analysis of imperfect competition in the labour market as well as investigating the impact of imports on derived labour demand at bilateral levels.

CHAPTER 5

SUMMARY AND POLICY IMPLICATIONS

5.1 INTRODUCTION

This thesis reviews the evolution of trade policy in South Africa over nearly the last quarter of a century and indicates the performance of the manufacturing sector during that period. In analysing productive efficiency, emphasis is placed on understanding total factor productivity and its components. The literature on stochastic frontiers and efficiency measurement is reviewed to provide the baseline analytical framework. The methodologies for decomposing the sources of total factor productivity into efficiency and technical change are explained. The methodologies are then applied to South African manufacturing data set to estimate efficiency and technical change. Using the results from the empirical work, the evolution of how the TFP components are related to the liberalisation episodes is explored.

The thesis also focused on the key determinants of total factor productivity with emphasis placed on the channels through which trade affects manufacturing productivity. Again, South African manufacturing data is used to investigate the suggested theoretical links. Finally, the effect of trade on derived labour demand is analysed. An interesting aspect of this part of the research is the use of a unique South African data set to investigate the postulated theoretical arguments regarding the behaviour of manufacturing. The main conclusions and implications of the research are summarised in Section 5.2, while the areas for further research are indicated in Section 5.3 below.

5.2 CONCLUSION: OVERALL POLICY IMPLICATIONS

A number of policy implications emerge from the analysis. These include and are not restricted to the following:

5.2.1 Trade and industrial productivity policies

Panel data econometric techniques are used to estimate productivity loss due to technical inefficiency and to determine the pattern of technical change in South African manufacturing industries. The results indicate scope for the average South African industrial establishments to improve their output level by as much as 14 per cent with the same set of inputs. However, openness appears to have been important for efficiency improvement in manufacturing. The estimation results also show that increased competition in foreign markets through export exposure benefits industry productivity. The benefits to productivity arise due to pressures for reduction in inefficiency and to lower costs from the exposure to more advanced technologies. Investment in equipment and machinery which represents technology embodied in capital equipment had a positive association with productivity. An increased use of intermediates also improved industrial productivity.

The results suggest that policy should focus on the improvement in the technological competencies of the labour force in terms of skill augmentation. Improvement of technical skills is required to enable local technicians to produce at full potential, avoiding waste of time and materials. Government policies should continue to allow companies to access good quality equipment at competitive world prices. Most importantly, policies should be designed to provide information and support that encourages industries to up grade their technical competencies. This support is required for the attainment of a competitive edge that is necessary to gain comparative advantage. Government support is also needed in some enterprises to carry out restructuring and industrial training in new technology, marketing as well as international promotion. An outward oriented technology policy is therefore, an important complement of this overall process.

Promotion of modern export oriented industries can be done through enhanced incentives for technological catch-up. Part of the process for catch-up requires easier access to intermediates as well as to capital goods. The evidence on industrial efficiency suggests that South African industry may need to reorganise more regionally to capture the advantages of economies of scale that are required to improve industry-wide efficiency.

Overall, policy reversal is not recommended because open trade policy has an important role to play in fostering international best practice, learning and efficiency growth. A liberal external environment has a role to play in the acquisition of improved technology and the encouragement of foreign participation. The level of openness of South African trade policy in future will continue to determine access to international finance as well as to knowledge for skills upgrading. Trade has proved to be important in productivity improvement by increasing access of the manufacturing sector to better foreign machinery and equipment.

Tariff rationalisation is therefore a key aspect of trade policy that will ensure increased competition. Tariff liberalisation needs to be continued, in particular, to reduce the high dispersion in tariff rates. It is important to simplify tariffs by reducing tariff categories and encouraging greater uniformity in their range and number. Tariff rationalisation is important for administrative purposes and to remove uneven protection that obtains in manufacturing. Removal of uneven protection will widen gains that arise from trade by encouraging manufactured exports.

5.2.2 Trade and labour market policies

The investigation of the impact of trade on industry level outcomes for the entire South African manufacturing industry shows that exports increased demand for labour in manufacturing while import volumes generally caused reductions in the level of derived labour demand. The import effect results from the fact that increased trade and openness serve to increase the efficiency with which labour is utilised in industry. In a nutshell, increased import penetration serves to reduce inefficiency and encourages the use of new technology. Commodities produced at lower cost from Asia in particular, tended to displace South African products and labour. South African trade with Europe and America appeared to absorb manufacturing labour. The findings show that trade has the potential to exact factor adjustment and needs to be taken into account in the policy sphere. In this vein, it is important to conduct periodic analysis at the industry and firm levels to identify product specific factors that affect labour demand. Policies that promote labour market flexibility are required to allow manufacturing to adjust to the changing and more competitive external environment.

In the light of the empirical evidence on efficiency and labour demand, it is important for South African industry to reorganise more regionally to capture the advantages of economies of scale. Intra-industry trade with Europe and America already provides South Africa with the global networks of production, where it supplies to the world market. In this arrangement, South Africa benefits from the use of the latest internationally available production and marketing techniques. These networks are important for accelerating the country's development by transferring technology and innovation, as well as bringing new ideas, to increase its competitive advantage. This comparative advantage should be used to expand the untapped trade potential particularly, with the rest of Africa.

5.3. AREAS FOR FURTHER RESEARCH

There are potential directions in which the investigation of trade, productivity and labour demand in South African manufacturing can be extended. In the area of technical change and efficiency, further investigation could involve the computation of a malmquist measure of productivity change. The results obtained should then be compared with those generated in this study. Future research should examine the issue of productivity at a much lower classification level than the three digit categorisation. Such research should employ plant level rich data sets that were generated by the manufacturing censuses of 1991, 1993 and 1996 to examine issues related to trade, industry concentration and efficiency in South Africa.

On the issue of trade and labour demand, important avenues exist in which analysis can be expanded given more finely graded data. For example, it would be useful to explore the relationship for different categories of labour especially given the wealth of literature on the skills gap. Grouping of industries can also be done by relative factor intensity to provide another important area for investigation. It is also worth pursuing issues related to the speed of adjustment and the importance of intra-industry trade, especially with data broken more frequently, covering a longer period of time. Other extensions that merit analysis concern issues of imperfect competition in the labour market. Finally, it would be interesting to investigate the impact of origin of imports on derived labour demand at the bilateral rather than regional level.

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APPENDIX

Appendix A1: Technical efficiency in panel frontier models

Two types of panel data production frontier models can be adopted in measuring technical efficiency. In the first, technical efficiency is allowed to vary across industries, but is assumed constant through time for each industry. However, the assumption of time invariance of technical efficiency may be weak in long panels. The second type of panel data production frontier models allows technical efficiency to vary across industries and through time for each industry. Kumbhakar and Lovell (2000:97) provide a detailed discussion regarding panel frontiers.

A1.1 Time-invariant technical efficiency

Since observations exist on I industries indexed $i = 1,....,I$ by through T time periods, indexed by $t = 1,...,T$. A Cobb-Douglas production frontier with time invariant technical efficiency can be written as:

$$\ln Y_{it} = \alpha_0 + \sum_n \alpha_n \ln X_{nit} + v_{it} - \mu_i, \qquad \text{A.1}$$

Where v_{it} represents random statistical noise and $\mu_i \geq 0$ represents technical inefficiency. The structure of the production function is assumed to be constant through time and no allowance is made for technical change. In essence, this model is similar to the cross-section production frontier except for the addition of time subscripts to output, inputs and to the statistical noise. The parameters of the model and technical efficiency can be estimated in a number of ways[54].

[54] It should be pointed out that maximum likelihood estimation of panel data estimation of a stochastic production frontier panel data with time invariant technical efficiency is structurally similar to the procedure followed in cross-sectional data.

(a). Fixed effects model

This is the simplest panel model to estimate. In order to adapt this model to the efficiency measurement the requirement that $\mu_i \geq 0$ has to be met. It is further assumed that v_{it} are $iid\left(0, \sigma_v^2\right)$ and are uncorrelated with the regressors. No distributional assumption is required for the μ_i, it can be correlated with the regressors or with v_{it}. Since μ_i are treated as fixed or non-random, they become industry specific intercept parameters to be estimated along with the α_n s. This model can be estimated by OLS in the form:

$$\ln Y_{it} = \alpha_{0i} + \sum_n \alpha_n \ln X_{nit} + v_{it}, \qquad \text{A.2}$$

Where the $\alpha_{0i} = \left(\alpha_0 - u_i\right)$ are the industry-specific intercepts. Estimation is accomplished either by suppressing α_0 and estimating I industry specific intercepts or by retaining α_0 and estimating $\left(I-1\right)$ industry-specific intercepts or by applying a within transformation, in which all data are expressed in terms of deviations from industry means and the I intercepts are recovered as means of industry residuals[55]. A normalisation is employed after estimation in which:

$$\hat{\alpha}_0 = \max_i \left\{\hat{\alpha}_{0i}\right\} \qquad \text{A.3}$$

and the resultant μ_i is derived from:

$$\hat{\mu}_i = \hat{\alpha}_0 - \hat{\alpha}_{0i} \qquad \text{A.4}$$

this ensures that all $\hat{\mu}_i \geq 0$ and the industry-specific estimates of technical efficiency are then given by:

$$TE_i = \exp\left\{-\hat{\mu}_i\right\} \qquad \text{A.5}$$

In a fixed-effects model one industry will be 100 per cent technically efficient, and the technical efficiencies of others are computed relative to the technically

[55] Each of these variants is referred to as the least squares dummy variables (LSDV).

efficient industry. The fixed effects model is simple and has nice consistency properties for the industry-specific technical efficiency. The drawback is that while the fixed effects (μ_i) are intended to capture variation across industries in time-invariant technical efficiency, they also capture the effects of all phenomena that vary across industries but are time invariant for each industry.

(b). Random effects model

In this model the μ_i are randomly distributed with constant mean and variance, are assumed to be uncorrelated with the regressors and with the v_{it}. No distributional assumptions are made regarding μ_i only that it should be non negative. The v_{it} are required as before to have zero expectation and constant variance. This modification allows for the inclusion of time-invariant regressors in the model and the model can be written as:

$$\ln Y_{it} = [\alpha_0 - E(\mu_i)] + \sum_n \alpha_n \ln X_{nit} + v_{it} - [\mu_i - E(\mu_i)]$$

$$= \alpha_0^* + \sum_n \alpha_n \ln X_{nit} + v_{it} - \mu_i^* \qquad \text{A.6}$$

where the underlying assumption that the μ_i are random rather than fixed permits some of the X_{nit} to be time invariant. This random effects model fits into the one way error components model in panel data literature and can be estimated by the standard two step generalised least squares GLS method. Once α_0^* and $\alpha_n s$ have been estimated using feasible GLS, the μ_i^* can be generated from the residuals by means of equation A.7 below:

$$\hat{\mu}_i^* = \frac{1}{T}\sum_t \left(\ln Y_{it} - \hat{\alpha}_0^* - \sum_n \hat{\alpha}_n \ln X_{nit} \right) \qquad \text{A.7}$$

Estimates of μ_i are again obtained by means of normalisation such that:

$$\hat{\mu}_i = \max_i\{\hat{\mu}_i^*\} - \hat{\mu}_i^* \qquad \text{A.8}$$

The estimates will be consistent as both T and I tend to infinity. Estimates of industry-specific technical efficiency are then obtained by substituting $\hat{u}_i$ into equation A.5. In tune with the fixed effects model, estimators for the random effects model also require that at least one industry be 100 per cent technically efficiency so that the technical efficiencies of the remaining industries are measured relative to the technically efficient industries.

A1.1 Time-varying technical efficiency

The assumption that technical efficiency is constant through time is very strong in operating environments that are competitive. Technical inefficiency cannot remain constant for long time periods. While it is desirable to relax this assumption, the relaxation however, happens only at the cost of additional parameters to be estimated. Two approaches have been followed in the estimation of the time-varying technical efficiency model. The first approach has time-varying technical efficiency modelled using fixed or random effects and the second by maximum likelihood approach or method of moments[56].

(a) Fixed effects and random effects models

Cornwell, Schmidt, and Sickles (1990) and Kumbhakar (1990) proposed a stochastic production panel data model with time-varying technical efficiency. The model is specified as:

$$\ln Y_{it} = \alpha_{0t} + \sum_n \alpha_n \ln X_{nit} + v_{it} - \mu_{it}$$

[56] If the independence and distributional assumptions are tenable, then it is possible to use maximum likelihood estimation. It is also possible to estimate parameters in equation A.9 using method of moments.

$$= \alpha_{it} + \sum_{n} \alpha_n \ln X_{nit} + v_{it} \qquad \text{A.9}$$

where α_{0t} is the production frontier intercept common to all industries in period t, $\alpha_{it} = \alpha_{0t} - \mu_{it}$ is the intercept for industry i in period t, the remainder of the variables are as previously defined. With an $I \times T$ panel it is not possible to obtain estimates of all $I \bullet T$ intercepts α_{it}, the N slope parameters α_n and σ_v^2. Cornwell, Schmidt, and Sickles (1990) addressed this problem by specifying:

$$\alpha_{it} = \Omega_{i1} + \Omega_{i2} t + \Omega_{i3} t^2 \qquad \text{A.10}$$

While this reduces the number of intercepts to be estimated, Lee and Schmidt (1993) proposed an alternative specification in which the μ_{it} in equation A.9 are specified as:

$$\mu_{it} = \alpha(t) \bullet \mu_i \qquad \text{A.11}$$

Where the function $\alpha(t)$ is specified as a set of time dummy variables α_t. This model is appropriate for short panels. Once the $\alpha_t s$ and μ_i are estimated, then

$$\mu_{it} = \sum_{i} \{\hat{\alpha}_t \hat{\mu}_i\} - (\hat{\alpha}_t \hat{\mu}_i) \text{ and } TE = \exp\{- \hat{\mu}_{it}\} \qquad \text{A.12}$$

Appendix A2: The Battese and Coelli (1992) specification

Maximum likelihood estimates of stochastic frontier production functions for panel data with time-varying or invariant efficiencies in the spirit of Battese and Coelli (1992) can be estimated. In particular, Battese and Coelli (1992) propose a stochastic frontier production function for panel data which has firm effects that are assumed to be distributed as truncated normal random variables, and are permitted to vary systematically with time. The model may be expressed as:

$$Y_{it} = x_{it}\alpha + (\nu_{it} - \mu_{it}) \quad i = 1,...., N, t = 1,..., T, \qquad \text{A13}$$

where Y_{it} is the logarithm of the output of the i-th industry in the t-th time period; x_{it} is a $k \times 1$ vector of inputs of the i-th industry in the t-th time period; α is a vector of unknown parametes; the ν_{it} are random variables which are assumed to be *iid* $N(0, \sigma\nu^2)$, and independent of the $\mu_{it} = (\mu_i \exp(-\eta(t-T)))$, where the μ_i are non-negative random variables that are assumed to account for technical inefficiency in production and are assumed to be *iid* as truncations at zero of the $N(\mu, \sigma\mu^2)$ distribution; η is a parameter to be estimated; and the panel of data need not be complete.

Coelli (1996) utilises the parameterization of Battese and Corra (1977) to replace $\sigma\nu^2$ and $\sigma\mu^2$ with $\sigma^2 = \sigma\nu^2 + \sigma^2\mu^2$ and $\gamma = \frac{\sigma\mu^2}{(\sigma\nu^2 + \sigma\mu^2)}$ in the context ofe maximum likelihood estimation. The parameter, γ, lies between 0 and 1 and this range is searched to provide a good starting value for use in an iterative maximization process. The log-likelihood function of this model is presented in Battese and Coelli (1992).

The imposition of restrictions upon model A.13 can provide a number of the special cases of this particular model which have appeared in the literature such as Battese, Coelli and Colby (1989), Battese and Coelli (1988), Pitt and Lee (1981), Aigner, Lovell and Schmidt (1977) as well as Stevenson (1980. Predictions of individual industry technical efficiencies from stochastic production frontiers can be derived in which the measures of technical efficiency relative to the production frontier (A13) are defined as:

$$EFF_i = E(Y_i^* \mid \mu_i, X_i / E(Y_i^* \mid \mu_i = 0, X_i) \qquad \text{A14}$$

where Y_i^* is the production of the i-th industry, which will be equal to $\exp(Y_i)$ when the dependent variable is in logs. The EFF_i will take a value between zero and one. The results of implementing the Battese and Coelli (1992) specification produces estimates in Table A2.1 and A2.2 below and efficiency estimates are found in Table A2.3 and Table A2.4. These results employ output rather than value added for the Cobb-Douglas and translog functions respectively.

Table A2.1: Maximum Likelihood Estimates: Cobb-Douglas production function

Stochastic frontier model: Dependent Variable ln(y)				
Variable	**Parameter**	**Coefficient**	**Standard error**	**t-ratio**
$\ln(K)$	α_k	0.1466	0.0355	4.12
$\ln(N)$	α_n	0.2162	0.0280	7.71
$\ln(M)$	α_m	0.4507	0.0225	20.04
t	α_t	0.0120	0.0020	6.17
Constant	α_0	1.9121	0.1409	13.57
Sigma-squared	σ^2	0.2873	0.0464	6.19
Gamma	γ	0.9501	0.0093	102.60
mu	μ	-0.1026	0.1889	-0.54
eta	η	-0.1643	0.0035	-4.68
Log likelihood function	366.1463			
LR test of one sided error	1076.8774			
Maximum no. of iterations	100			
No. of cross sections	28			
No. of time periods	23			
Total no. of observations	644			

Note: Error components specification using output rather than value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Table A2.2: Maximum Likelihood Estimates: Translog production function

Stochastic frontier model: Dependent Variable ln(y)				
Variable	**Parameter**	**Coefficient**	**Standard error**	**t-ratio**
$\ln(K)$	α_k	0.5805	0.2297	2.53
$\ln(N)$	α_n	0.3995	0.2366	1.69
$\ln(M)$	α_m	-0.2552	0.2059	-1.24
t	α_t	0.0345	0.0089	3.84
$\ln(K)\times\ln(N)$	β_{kn}	0.0457	0.0237	1.93
$\ln(K)\times\ln(M)$	β_{km}	-0.1254	0.0304	-4.12
$\ln(K)\times(t)$	β_{kt}	0.0058	0.0012	4.94
$\ln(N)\times\ln(M)$	β_{nm}	-0.2273	0.0260	-8.73
$\ln(N)\times(t)$	β_{nt}	-0.0008	0.0011	-0.74
$\ln(M)\times(t)$	β_{mt}	-0.0070	0.0017	-4.05
$(\frac{1}{2})\ln(K^2)$	β_{kk}	0.0054	0.0327	0.17
$(\frac{1}{2})\ln(N^2)$	β_{nn}	0.1341	0.0319	4.21
$(\frac{1}{2})\ln(M^2)$	β_{mm}	0.4995	0.0450	11.09
$(\frac{1}{2})\ln(t^2)$	β_{tt}	-0.0003	0.0002	-1.25
Constant	α_0	1.6830	1.1193	1.41
Sigma-squared	σ^2	0.3078	0.0400	7.69
Gamma	γ	0.9627	0.0039	248.07
mu	μ	-0.0109	0.4107	-2.65
eta	η	-0.0163	0.0025	-6.47
Log likelihood function	479.2915			
LR test of one sided error	1099.3067			
Maximum no. of iterations	100			
No. of cross sections	28			
No. of time periods	23			
Total no. of observations	644			

Note: Error components specification using output instead of value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Table A2.3 : Cobb Douglas function technical efficiency Estimates

Industry	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
S_301	0.939	0.938	0.937	0.936	0.935	0.934	0.932	0.931	0.930	0.929	0.928	0.927	0.926	0.925	0.923	0.922	0.921	0.920	0.918	0.917	0.916	0.915	0.913
S_305	0.807	0.804	0.801	0.798	0.795	0.792	0.789	0.786	0.783	0.779	0.776	0.773	0.770	0.766	0.763	0.760	0.756	0.753	0.749	0.746	0.742	0.738	0.735
S_306	0.983	0.983	0.983	0.982	0.982	0.982	0.982	0.981	0.981	0.981	0.980	0.980	0.980	0.979	0.979	0.979	0.978	0.978	0.978	0.977	0.977	0.977	0.976
S_311	0.640	0.635	0.630	0.625	0.621	0.616	0.611	0.606	0.601	0.596	0.591	0.585	0.580	0.575	0.570	0.565	0.559	0.554	0.549	0.543	0.538	0.532	0.527
S_313	0.653	0.649	0.644	0.639	0.634	0.630	0.625	0.620	0.615	0.610	0.605	0.600	0.595	0.590	0.585	0.580	0.575	0.569	0.564	0.559	0.553	0.548	0.543
S_316	0.562	0.557	0.552	0.546	0.541	0.535	0.530	0.524	0.519	0.513	0.507	0.502	0.496	0.490	0.485	0.479	0.473	0.467	0.461	0.455	0.450	0.444	0.438
S_317	0.579	0.574	0.569	0.564	0.558	0.553	0.548	0.542	0.537	0.531	0.526	0.520	0.514	0.509	0.503	0.498	0.492	0.486	0.480	0.474	0.469	0.463	0.457
S_321	0.639	0.634	0.629	0.624	0.620	0.615	0.610	0.605	0.600	0.595	0.590	0.584	0.579	0.574	0.569	0.564	0.558	0.553	0.547	0.542	0.537	0.531	0.525
S_323	0.822	0.819	0.816	0.813	0.811	0.808	0.805	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.778	0.774	0.771	0.768	0.764	0.761	0.758	0.754
S_324	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.778	0.774	0.771	0.768	0.764	0.761	0.758	0.754	0.751	0.747	0.743	0.740	0.736	0.732	0.729	0.725
S_331	0.689	0.685	0.681	0.677	0.672	0.668	0.663	0.659	0.654	0.650	0.645	0.640	0.636	0.631	0.626	0.621	0.616	0.612	0.607	0.602	0.597	0.591	0.586
S_334	0.814	0.812	0.809	0.806	0.803	0.800	0.797	0.794	0.791	0.788	0.785	0.782	0.779	0.776	0.772	0.769	0.766	0.762	0.759	0.756	0.752	0.749	0.745
S_335	0.848	0.845	0.843	0.841	0.838	0.836	0.833	0.831	0.828	0.826	0.823	0.820	0.818	0.815	0.812	0.809	0.807	0.804	0.801	0.798	0.795	0.792	0.789
S_337	0.623	0.618	0.613	0.608	0.603	0.598	0.593	0.588	0.583	0.578	0.573	0.567	0.562	0.557	0.551	0.546	0.540	0.535	0.529	0.524	0.518	0.513	0.507
S_338	0.720	0.716	0.712	0.708	0.704	0.700	0.696	0.692	0.687	0.683	0.679	0.674	0.670	0.666	0.661	0.657	0.652	0.647	0.643	0.638	0.633	0.629	0.624
S_341	0.560	0.555	0.550	0.544	0.539	0.533	0.528	0.522	0.517	0.511	0.505	0.500	0.494	0.488	0.483	0.477	0.471	0.465	0.459	0.453	0.447	0.442	0.436
S_342	0.598	0.593	0.588	0.583	0.578	0.572	0.567	0.562	0.556	0.551	0.546	0.540	0.535	0.529	0.524	0.518	0.512	0.507	0.501	0.495	0.490	0.484	0.478
S_351	0.811	0.808	0.806	0.803	0.800	0.797	0.794	0.791	0.788	0.785	0.781	0.778	0.775	0.772	0.769	0.765	0.762	0.758	0.755	0.751	0.748	0.744	0.741
S_352	0.839	0.837	0.834	0.832	0.829	0.827	0.824	0.821	0.819	0.816	0.813	0.810	0.808	0.805	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.777
S_353	0.860	0.858	0.856	0.854	0.851	0.849	0.847	0.844	0.842	0.840	0.837	0.835	0.832	0.830	0.827	0.825	0.822	0.819	0.817	0.814	0.811	0.808	0.806
S_356	0.922	0.921	0.919	0.918	0.917	0.916	0.914	0.913	0.912	0.910	0.909	0.907	0.906	0.904	0.903	0.901	0.900	0.898	0.897	0.895	0.893	0.892	0.890
S_361	0.813	0.811	0.808	0.805	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.781	0.778	0.774	0.771	0.768	0.765	0.761	0.758	0.754	0.751	0.747	0.744
S_371	0.767	0.763	0.760	0.756	0.753	0.749	0.746	0.742	0.738	0.735	0.731	0.727	0.723	0.720	0.716	0.712	0.708	0.704	0.700	0.695	0.691	0.687	0.683
S_374	0.696	0.692	0.688	0.684	0.680	0.675	0.671	0.666	0.662	0.657	0.653	0.648	0.644	0.639	0.634	0.630	0.625	0.620	0.615	0.610	0.605	0.600	0.595
S_381	0.976	0.975	0.975	0.974	0.974	0.974	0.973	0.973	0.972	0.972	0.971	0.971	0.970	0.970	0.970	0.969	0.969	0.968	0.967	0.967	0.966	0.966	0.965
S_384	0.905	0.903	0.902	0.900	0.899	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.884	0.882	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866
S_391	0.702	0.698	0.694	0.690	0.686	0.681	0.677	0.673	0.668	0.664	0.659	0.655	0.650	0.646	0.641	0.636	0.632	0.627	0.622	0.617	0.612	0.607	0.602
S_392	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean effic. in year	0.770	0.767	0.764	0.761	0.758	0.754	0.751	0.748	0.744	0.741	0.737	0.734	0.730	0.727	0.723	0.720	0.716	0.713	0.709	0.705	0.701	0.698	0.694

Note: Error components specification using output instead of value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Table A2.4 : Translog Production function technical efficiency estimates

Industry	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
S_301	0.900	0.898	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.883	0.882	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.860
S_305	0.881	0.879	0.877	0.875	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.859	0.857	0.855	0.853	0.851	0.848	0.846	0.844	0.842	0.839	0.837	0.834
S_306	0.983	0.982	0.982	0.982	0.981	0.981	0.981	0.981	0.980	0.980	0.980	0.979	0.979	0.979	0.978	0.978	0.978	0.977	0.977	0.976	0.976	0.976	0.975
S_311	0.737	0.733	0.729	0.726	0.722	0.718	0.714	0.710	0.706	0.702	0.698	0.694	0.690	0.686	0.681	0.677	0.673	0.668	0.664	0.660	0.655	0.651	0.646
S_313	0.722	0.718	0.714	0.710	0.706	0.702	0.698	0.694	0.690	0.685	0.681	0.677	0.673	0.668	0.664	0.659	0.655	0.650	0.646	0.641	0.637	0.632	0.627
S_316	0.739	0.735	0.732	0.728	0.724	0.720	0.717	0.713	0.709	0.705	0.701	0.697	0.692	0.688	0.684	0.680	0.676	0.671	0.667	0.662	0.658	0.654	0.649
S_317	0.706	0.702	0.698	0.694	0.690	0.685	0.681	0.677	0.672	0.668	0.664	0.659	0.655	0.650	0.646	0.641	0.636	0.632	0.627	0.622	0.617	0.612	0.608
S_321	0.735	0.731	0.728	0.724	0.720	0.716	0.712	0.708	0.704	0.700	0.696	0.692	0.688	0.684	0.680	0.675	0.671	0.666	0.662	0.658	0.653	0.649	0.644
S_323	0.897	0.895	0.894	0.892	0.890	0.889	0.887	0.885	0.883	0.882	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.860	0.858	0.856
S_324	0.937	0.936	0.935	0.934	0.933	0.931	0.930	0.929	0.928	0.927	0.926	0.925	0.924	0.922	0.921	0.920	0.919	0.917	0.916	0.915	0.913	0.912	0.911
S_331	0.869	0.867	0.865	0.863	0.861	0.859	0.857	0.855	0.852	0.850	0.848	0.846	0.843	0.841	0.839	0.836	0.834	0.831	0.829	0.826	0.824	0.821	0.818
S_334	0.964	0.964	0.963	0.962	0.962	0.961	0.961	0.960	0.959	0.959	0.958	0.957	0.957	0.956	0.955	0.955	0.954	0.953	0.952	0.952	0.951	0.950	0.949
S_335	0.970	0.970	0.969	0.969	0.968	0.968	0.967	0.967	0.966	0.966	0.965	0.965	0.964	0.964	0.963	0.962	0.962	0.961	0.961	0.960	0.959	0.959	0.958
S_337	0.757	0.753	0.750	0.746	0.743	0.739	0.735	0.732	0.728	0.724	0.720	0.717	0.713	0.709	0.705	0.701	0.697	0.692	0.688	0.684	0.680	0.676	0.671
S_338	0.835	0.832	0.830	0.827	0.825	0.822	0.819	0.817	0.814	0.811	0.808	0.806	0.803	0.800	0.797	0.794	0.791	0.788	0.785	0.782	0.779	0.775	0.772
S_341	0.678	0.674	0.670	0.665	0.661	0.657	0.652	0.647	0.643	0.638	0.633	0.629	0.624	0.619	0.614	0.609	0.605	0.600	0.595	0.589	0.584	0.579	0.574
S_342	0.709	0.705	0.701	0.697	0.692	0.688	0.684	0.680	0.676	0.671	0.667	0.662	0.658	0.653	0.649	0.644	0.640	0.635	0.630	0.626	0.621	0.616	0.611
S_351	0.947	0.947	0.946	0.945	0.944	0.943	0.942	0.941	0.940	0.939	0.938	0.937	0.936	0.935	0.934	0.933	0.932	0.931	0.930	0.929	0.928	0.927	0.926
S_352	0.982	0.981	0.981	0.981	0.980	0.980	0.980	0.979	0.979	0.979	0.978	0.978	0.978	0.977	0.977	0.977	0.976	0.976	0.975	0.975	0.975	0.974	0.974
S_353	0.929	0.928	0.927	0.926	0.924	0.923	0.922	0.921	0.919	0.918	0.917	0.916	0.914	0.913	0.912	0.910	0.909	0.907	0.906	0.905	0.903	0.902	0.900
S_356	0.972	0.971	0.971	0.971	0.970	0.970	0.969	0.969	0.968	0.968	0.967	0.967	0.966	0.965	0.965	0.964	0.964	0.963	0.963	0.962	0.961	0.961	0.960
S_361	0.918	0.916	0.915	0.914	0.912	0.911	0.910	0.908	0.907	0.905	0.904	0.902	0.901	0.899	0.898	0.896	0.895	0.893	0.891	0.890	0.888	0.886	0.884
S_371	0.931	0.930	0.929	0.928	0.927	0.926	0.924	0.923	0.922	0.921	0.920	0.918	0.917	0.916	0.914	0.913	0.912	0.910	0.909	0.908	0.906	0.905	0.903
S_374	0.887	0.885	0.883	0.881	0.880	0.878	0.876	0.874	0.872	0.870	0.868	0.866	0.864	0.862	0.860	0.858	0.856	0.853	0.851	0.849	0.847	0.844	0.842
S_381	0.834	0.831	0.829	0.826	0.823	0.821	0.818	0.815	0.813	0.810	0.807	0.804	0.802	0.799	0.796	0.793	0.790	0.787	0.784	0.780	0.777	0.774	0.771
S_384	0.988	0.987	0.987	0.987	0.987	0.986	0.986	0.986	0.986	0.986	0.985	0.985	0.985	0.985	0.984	0.984	0.984	0.984	0.983	0.983	0.983	0.982	0.982
S_391	0.788	0.785	0.782	0.779	0.776	0.773	0.769	0.766	0.763	0.759	0.756	0.753	0.749	0.746	0.742	0.738	0.735	0.731	0.727	0.723	0.720	0.716	0.712
S_392	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mean effic. in year	0.864	0.862	0.860	0.858	0.856	0.854	0.852	0.850	0.848	0.845	0.843	0.841	0.839	0.837	0.834	0.832	0.830	0.827	0.825	0.822	0.820	0.817	0.815

Note: Error components specification using output instead of value added.
Source: FRONTIER 41 Regression output from data obtained from www.tips.org.za, www.statssa.gov.za and www.resbank.co.za

Appendix A3: Variable definitions

Variable	Definition
Africa_mz	Value of imports from the African region in millions of Rand
America_mz	Value of imports from the American region in millions of Rand
Asia_mz	Value of imports from the Asian region in millions of Rand
CAP	The percentage utilisation of production capacity. Therefore 100 percent would refer to full capacity utilisation.
CPI	Consumer price index 1995=100
DD	Domestic demand is equal to total output plus imports minus exports. The import-domestic demand ratio is an indication of how much of the domestic demand is satisfied by imports.
EX	The export-output ratio is a measure of how much of South Africa's industrial output is exported. The export-output ratio is equal to total exports (X) divided by total output (Q) of an industry times one hundred: Export-output ratio = (X / Q)*100.
Europe_mz	Value of imports from the European region in millions of Rand
Fixed capital productivity	Fixed capital productivity is a measure of output per unit of fixed capital input. Fixed capital productivity is equal to total output (Q) divided by the fixed capital input (C), i.e. the capital stock: Fixed capital productivity = Q / C = output per unit of fixed capital input.
GM	The gross mark-up of an industry is the net operating surplus of that industry as a percentage of total intermediate inputs plus labour remuneration for that industry. It excludes all net indirect taxes.
Gross domestic fixed investment	Gross domestic fixed investment consists of buildings and construction works, transport equipment, machinery and other equipment and transfer costs
IM	Intermediate imports refer to the imports of goods and services produced elsewhere in the world, but used in the industry of the country under consideration and consumed in the production process. Intermediate imports exclude the importation of production factors.
K	Fixed capital stock consists of buildings and construction works, transport equipment, machinery and other equipment and transfer costs.
Labour productivity	Labour productivity is the ratio between output (Q) and the labour input (LI) used to produce that output: Labour productivity = Q / LI = output per unit of labour input. Labour productivity can be expressed as output per worker (by dividing total output by total number of workers employed.
M	Value of materials input in millions of Rand.
MS	Proportion of industry sales to total manufacturing sector sales
MZ	The import-domestic demand ratio or import penetration is equal to total imports (Z) divided by total domestic demand (DD) times one hundred: Import-domestic demand ratio = (Z / DD)*100.
MZ1	Import leakage is a measure of how much is imported to satisfy local demand. Import leakage is equal to total imports (Z) divided by total imports added total output (Q) times one hundred: Import leakage = [Z / (Z + Q)]*100.
N	Employment figures indicate the number of paid employees and include casual and seasonal workers. Employment consists of three main categories, namely highly skilled, skilled and semi-and unskilled labour.
oceania_mz	Value of imports from the Oceania region in millions of Rand
RAD	Expenditure by industries on machinery and equipment in

Variable	Definition
	millions of Rand.
RAD1	Ratio of expenditure by industries on machinery and equipment to total gross domestic investment
RER	Rand real exchange rate 1995=100
SKILL	Ratio of skilled employees to total number of employees
TARIFF	Ratio of customs duties paid by industry to total imports
TE	Technical efficiency scores
TOT	Terms of trade index 1995=100
V	Value added= Value added at basic prices + Net indirect taxes on products (by government).
Y	Final output of goods by industry used or consumed by individuals, households and firms and not processed further or resold

Notes: Where necessary nominal variables are deflated with an appropriate price index to obtain real series.

Source:http://ts.easydata.co.za;http://www.tips.org.za;http://www.resbank.co.za; http://www.statssa.gov.za