Testing creative destruction in an opening economy

The case of the South African manufacturing industries[1]

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Abstract

This paper analyses the relationship between trade liberalization and economic growth using a Schumpeterian framework of technological innovation and applies it to sector-level South African data. The framework examines direct and indirect effects of trade liberalization on productivity growth. Indirect impacts operate through a differential impact of trade liberalization on firms conditional on their distance from the international technological frontier. Results confirm positive direct impacts of trade liberalization. Results confirm also that the greatest positive impact of trade liberalization will be on sectors that are close to the international technological frontier and that experienced a low level of product market competition before liberalization.

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1. Introduction

What policy intervention does a small, less developed economy far from the international technological frontier use in order to promote growth? One intervention that has frequently been posed in the literature is trade liberalization.

Empirical results on the impact of openness and economic growth have steadily accumulated in the literature. Aghion and Howitt (2009) report three core results coming from the growth and trade literature. First, openness has a direct positive and significant effect on growth. Second, the positive effect on growth of trade liberalization is higher for smaller countries, because of a *market size effect* or a *scale effect* whereby the larger the domestic economy relative to the world economy, the less innovation or learning-by-doing domestic producers gain by opening up to trade.[2] Third, growth is less enhanced by openness in more advanced countries; this is interpreted as a *knowledge spillover effect* whereby trade induces knowledge flows across countries, such that more advanced countries stand to gain proportionately less from such knowledge spill-overs.[3]

But there is an additional effect of trade on growth highlighted in Aghion and Howitt (2009) which is not captured in the literature, namely that trade liberalization tends to enhance product market competition, by allowing foreign producers to compete with domestic producers. This in turn should enhance domestic productivity for at least two reasons: first, by forcing the most unproductive firms out of the domestic market; second, by forcing domestic firms to innovate to escape competition from their new foreign counterparts. This framework is complementary to Melitz (2003) which emphasizes the increase in productivity following trade liberalization due to a better allocation of factors of production. While AH do not identify the specific mechanism which induces an aggregate increase in productivity, either by reallocating resources to the most productive firms as in Melitz, or by technological and skill upgrading, as in Bustos (2011), they suggest that the positive effect of trade liberalization on productivity and growth is a negative function of the distance from the technological frontier of national firms. Moreover, AH allows us to think about the effect of unilateral liberalization, where tariffs on imports are reduced without a parallel change in export conditions: in this context, the increase in productivity will be a response of national firms to an increase in competitive pressure, but it will only happen if no other instruments of market control are available to the firm.

In this paper, we test the theoretical model of Aghion and Howitt in a middle-income country context, using South African manufacturing sector data, for three-digit SIC industrial sectors. The case of South Africa is interesting because the country underwent significant trade liberalization; it has a heterogeneous manufacturing

[2] This result was first pointed out by Alesina *et al.* (2005).

[3] This knowledge spillover effect has been analysed at length by Keller (2002) – and see also Sachs and Warner (1995) and Coe and Helpman (1995).

sector and it has significant internal market monopolies. Moreover, the South African experience with trade liberalization and economic growth has been extensively analysed in the literature, which provides a useful set of results to use as comparative check of our analysis. Previous studies have examined the relationship between pricing power of industry and growth,[4] market structure and growth,[5] investment in R&D and human capital and growth,[6] and one study has considered the relationship between openness and growth of total factor productivity in the South African context.[7] It found a strong positive correlation, although mitigated by market imperfections, but the specification estimated did not capture the full set of theoretical considerations detailed below (as is true of most studies examining trade and growth effects).

The objective of this paper is to evaluate the composition and the nature of productivity gains (if any), which result from trade liberalization. Section 2 outlines the open economy Schumpeterian theoretical framework employed in the paper. Section 3 provides background on the nature and extent of South African trade liberalization. In Section 4, the empirical strategy of the paper is explained, including the datasets employed, while Section 5 reports estimation results, which highlight the strict relationship between trade liberalization and the internal competitive environment. Section 6 concludes discussing how trade liberalization and internal regulatory environment are two necessary and complementary components of outward-oriented growth strategy.

2. Theoretical framework

The theoretical model of this study is provided by the Schumpeterian framework of Aghion and Howitt (1992) extended to an open economy in Aghion and Howitt (2009). The Schumpeterian paradigm has proved to be useful in considering extensions of models of economic growth beyond the impact of innovation on economic development. Since the endogeneity of innovation requires an explicit treatment of the source of efficiency gains, the Schumpeterian framework is useful in analyzing the interaction between institutions and economic growth. Trade policies are just another set of institutions that define the dimension of the market and the level of competition that national firms face. On the one hand, trade liberalization increases the size of the potential market, thus increasing the expected profits from successful innovation. On the other hand, trade liberalization increases the level of market competition, and the ability of the national firms to successfully expand and innovate depends critically on their ability to 'compete.'

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[4] See Aghion *et al.* (2008).
[5] See Fedderke and Szalontai (2009) and Fedderke and Naumann (2011).
[6] See Fedderke (2006).
[7] See Fedderke (2006).

2.1 The closed economy

Consider first the closed-economy version of the model. A unique final good, which also serves as numéraire, is produced competitively using a continuum of intermediate inputs according to:

$$Y_t = L^{1-\alpha} \int_0^1 A_{it}^{1-\alpha} x_{it}^{\alpha} di, \ 0 < \alpha < 1 \tag{1}$$

where L is the domestic labour force, assumed constant, A_{it} is the quality of intermediate good i at time t, and x_{it} is the flow quantity of intermediate good i being produced and used at time t.

Each intermediate sector has a monopolist producer who uses the final good as the sole input, with one unit of final good needed to produce each unit of intermediate good. The monopolist's cost of production is therefore equal to the quantity produced x_{it}. The price p_{it} at which this quantity of intermediate good is sold to the competitive final sector is the marginal product of intermediate good i in (1). The monopolist will choose the profit-maximizing level of output:

$$x_{it} = A_{it} L \alpha^{2/(1-\alpha)} \tag{2}$$

with profit level:

$$\pi_{it} = \delta A_{it} L \tag{3}$$

where $\delta \equiv (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}$.

Equilibrium level of final output in the economy can be found by substituting the x_{it}'s into (1), which yields

$$Y_t = \zeta A_t L \tag{4}$$

where A_t is the average productivity parameter across all sectors $A_t = \int_0^1 A_{it} di$, and $\zeta = \alpha^{\frac{2\alpha}{1-\alpha}}$.

Productivity growth comes from innovations. In each sector, at each date, there is a unique entrepreneur with the possibility of innovating in that sector. He is the incumbent monopolist, and an innovation would enable him to produce with a productivity (quality) parameter $A_{it} = \gamma A_{i,t-1}$ that is superior to that of the previous monopolist, by the factor $\gamma > 1$. Otherwise his productivity parameter stays the same: $A_{it} = A_{i,t-1}$. Innovation with any given probability μ entails the cost $c_{it}(\mu) = (1-\tau) \cdot \phi(\mu) \cdot A_{i,t-1}$, of the final good in research, where $\tau > 0$ is a parameter that represents the extent to which national policies (institutions) encourage innovation, and ϕ is a standard convex cost function. Thus, the local entrepreneur's expected net profit is:

$$
\begin{aligned}
V_{it} &= E\pi_{it} - c_{it}(\mu) \\
&= \mu\delta L\gamma A_{i,t-1} + (1-\mu)\delta L A_{i,t-1} - (1-\tau)\phi(\mu)A_{i,t-1}.
\end{aligned} \tag{5}
$$

Each local entrepreneur will choose a frequency of innovations μ^* that maximizes V_{it}. The first-order condition for an interior maximum $\partial V_{it}/\partial\mu = 0$, can be expressed as the research arbitrage equation:

$$
\phi'(\mu) = \delta L(\gamma - 1)/(1-\tau). \tag{6}
$$

If the research environment is favourable enough (τ is large enough), or the population large enough, so that:

$$
\phi'(0) > \delta L(\gamma - 1)/(1-\tau),
$$

then the unique solution μ to (6) is positive, so in each sector the probability of an innovation is that solution ($\widehat{\mu} = \mu$), otherwise the local entrepreneur chooses never to innovate ($\widehat{\mu} = 0$). As each A_{it} grows at the rate $\gamma - 1$ with probability $\widehat{\mu}$, and at the rate 0 with probability $1 - \widehat{\mu}$, the expected growth rate of the economy is:

$$
g = \widehat{\mu}(\gamma - 1).
$$

So, we see that countries with a larger population and more favourable innovation conditions will be more likely to grow, and grow faster.

2.2 *Opening the economy*

Now open trade in goods (both intermediate and final) between the domestic country and the rest of the world. For simplicity, assume two countries, 'home' and 'foreign', with an identical range of intermediate goods and final product, and no transportation costs. Within each intermediate sector, the world market can then be monopolized by the lowest cost producer. Asterisks denote foreign-country variables.

The immediate effect of this opening up is to allow each country to take advantage of more productive efficiency. In the home country, final good production will equal:

$$
Y_t = \int_0^1 Y_{it}di = L^{1-\alpha}\int_0^1 \widehat{A}_{it}^{1-\alpha}x_{it}^{\alpha}di, 0<\alpha<1 \tag{7}
$$

where $\widehat{A}_{it}$ is the higher of the two initial productivity parameters $\widehat{A}_{it} = \max\{A_{it}, A_{it}^*\}$. The effect on the foreign country will be symmetric.

Monopolists' profit will now be higher than under autarky, because of increased market size. For price p_{it}, final good producers will buy good i up to the point where marginal product equals p_{it}:

$$x_{it} = \widehat{A}_{it}L(p_{it}/\alpha)^{\frac{1}{\alpha-1}} \text{ and } x^*_{it} = \widehat{A}_{it}L^*(p_{it}/\alpha)^{\frac{1}{\alpha-1}} \tag{8}$$

so that price will depend on global sales relative to global population:

$$p_{it} = \alpha\left(\frac{X_{it}}{(L+L^*)\widehat{A}_{it}}\right)^{\alpha-1}. \tag{9}$$

Accordingly, the monopolist's profit π_{it} will equal revenue $p_{it}X_{it}$ minus cost X_{it}, and profit maximization requires that:

$$X_{it} = \widehat{A}_{it}(L+L^*)\alpha^{2/(1-\alpha)}$$

with price $p_{it} = 1/\alpha$ and profit level:

$$\pi_{it} = \delta\widehat{A}_{it}(L+L^*). \tag{10}$$

Substitution of prices $p_{it} = 1/\alpha$ into the demand functions (8) yields

$$x_{it} = \widehat{A}_{it}L\alpha^{2/(1-\alpha)} \text{ and } x^*_{it} = \widehat{A}_{it}L^*\alpha^{2/(1-\alpha)}$$

and substituting these into the production functions, final good production in the two countries will be proportional to their populations:

$$Y_t = \zeta\widehat{A}_tL \text{ and } Y^*_t = \zeta\widehat{A}_tL^* \tag{11}$$

and the cross-sectoral average of the $\widehat{A}_{it}$'s, $\widehat{A}_t = \int_0^1 \widehat{A}_{it}di$.

2.2.1 The impact of trade liberalization on innovation

The impact of trade liberalization on innovation is analogous to that of competition on innovation.[8] Here, the stylization is that the competitor comes from the foreign country. Consider the innovation process in a given sector i. In the country where the monopoly currently resides, the country is on the global technology frontier for sector i, and the local entrepreneur will aim at making a frontier innovation that raises the productivity parameter from $\widehat{A}_{it}$ to $\gamma\widehat{A}_{it}$. If so, that country will retain a global monopoly in intermediate product i. In the other country, the local entrepreneur will be trying to catch up with the frontier by implementing the current frontier

[8] See Aghion *et al.* (2005), Aghion and Griffith (2005), and Aghion *et al.* (2008).

technology. If he succeeds and the frontier entrepreneur fails to advance the frontier that period, then the lagging country will have caught up, both countries will be on the frontier, and we can suppose that each entrepreneur will monopolize the market for product i in her own country. But if the frontier entrepreneur does advance the frontier, then the entrepreneur in the lagging country will still remain behind and will earn no profit income.

The optimization problem of the firm (5) is then amended considering the new competitive conditions. The first-order condition for an interior maximum gives three possible research arbitrage equations, function of the distance from the technological frontier of the national firm[9]:

A. Case A is the case in which the lead in sector i resides in the home country, while the foreign country lags behind. In this case, the open-economy research arbitrage equation governing μ_A:

$$(1-\tau)\phi'(\mu_A)/\delta = (\gamma - 1)(L + L^*) + \mu_A^* L^* \tag{12}$$

makes clear that for the technology leader, innovation will be greater than under the closed economy [compare Equation (6)]. This arises because of:

- Scale effects realized because the successful innovator gets enhanced profits from both markets $(L + L^*)$, not just the domestic market, L, thus giving a stronger incentive to innovate.
- Escape entry effects arising because the unsuccessful innovator in the open economy is at risk of losing the foreign market to the foreign rival, avoidable by innovation $\left(\mu_A^* L^*\right)$. The unsuccessful innovator in the closed economy loses nothing to a foreign rival and thus does not have this extra incentive to innovate.

B. Case B is the case in which the domestic and foreign sectors are neck-and-neck. In this case, the open-economy research arbitrage equation governing μ_B:

$$(1-\tau)\phi'(\mu_B)/\delta = (\gamma - 1)L + \mu_B^* L + \left(1 - \mu_B^*\right)\gamma L^*$$

again has scale $\left(\left(1 - \mu_B^*\right)\gamma L^*\right)$ and escape competition $\left(\mu_B^* L\right)$ effects, with symmetrical intuition as for μ_A above.

C. Case C is the case in which the foreign country starts with the lead. Here, the open-economy research arbitrage equation governing μ_C:

$$(1-\tau)\phi'(\mu_C)/\delta = \left(1 - \mu_C^*\right)L$$

shows that sectors behind the world technology frontier will be discouraged from innovating by the threat of entry because even if it innovates, it might lose

[9] For a detailed derivation of the research arbitrage conditions in an open economy, see Aghion and Howitt (2009).

out to a superior entrant. Provided that the foreign country's innovation rate is large enough when it has the lead, then the right-hand side of this research arbitrage equation will be strictly less than that of the closed economy [compare Equation (6)], so we will have $\mu_C < \mu$.

It follows that $\mu_A > \mu$, $\mu_B > \mu$, and $\mu_C^* > \mu^*$, $\mu_B^* > \mu^*$, with μ_C and μ_A^* indeterminate. It therefore follows that a sufficient (not necessary) condition for the innovation of the domestic economy to be higher under openness is that $|\mu_A + \mu_B| > |\mu_C|$, and symmetrically for the foreign country that $|\mu_B^* + \mu_C^*| > |\mu_A^*|$.

2.2.2 The impact of unilateral trade liberalization

The main conclusion of the model, namely that trade openness induces productivity growth by increasing the return to successful innovation, can be extended to capture the effect of unilateral trade liberalization. With unilateral trade liberalization, we identify a policy of reduction of trade barriers aimed at opening the national economy to competition from foreign imports of intermediate inputs. The competitive production of the unique final good continues to be characterized by (1).

Before unilateral liberalization, users of an imported intermediate good face a tariff of χ units of the final good per unit of the intermediate input acquired. While demand for intermediate inputs from domestic producers continues to reflect the marginal product on intermediate inputs directly:

$$p_{it} = \alpha L^{1-\alpha} \left(\frac{A_{it}}{x_{it}} \right)^{1-\alpha} \tag{13}$$

the demand for foreign intermediate inputs reflects marginal product net of import tariffs:[10]

$$p_{it}^*(1+\chi) = \frac{\delta Y}{\delta x_{it}} = \alpha L^{1-\alpha} \left(\frac{A_{it}^*}{x_{it}} \right)^{1-\alpha} \tag{14}$$

$$p_{it}^* = \frac{1}{(1+\chi)} \alpha L^{1-\alpha} \left(\frac{A_{it}^*}{x_{it}} \right)^{1-\alpha}. \tag{15}$$

Final goods production then employs the intermediate good with the highest productivity net of taxes, so that:

$$Y_t = L^{1-\alpha} \int_0^1 \widehat{A}_{it}^{1-\alpha} x_{it}^{\alpha} di, 0 < \alpha < 1 \tag{16}$$

[10] We assume that the domestic market is small, so that domestic demand does not affect world price.

where:

$$\widehat{A}_{it} = \max\left\{A_{it}, \frac{A^*_{it}}{(1+\chi)^{\frac{1}{1-\alpha}}}\right\}. \tag{17}$$

The tariff operates as a wedge between national and international productivity. Hence, as before, liberalization will increase the productivity of the final good sector and corresponding labour income. However, the profit of the intermediate input producing monopolist, will inevitably decrease under liberalization, as the reduction in tariffs, being unilateral, will reduce aggregate profits due to the substitution of domestic intermediate goods with foreign, without compensation through an increase in profits due to an increase in the market size for the surviving domestic firms. Thus, the impact is certainly negative on monopoly profits.

On the other hand, the impact of liberalization on innovation and research is more ambiguous. In an unilateral trade liberalization, the incentive to innovate comes only from the need of incumbent firms to maintain market share in the local market. As before, we have three different possibilities:

A. For a firm that is a technological leader, unilateral liberalization of imports does not change the optimal level of research spending. Because the dominance in the local market is guaranteed by technological superiority and not by trade barriers, the impact of liberalization generates neither a scale effect of capturing foreign markets (foreigner has not liberalized by assumption), nor an escape entry effect.[11]

B. For firms that are close to the technological frontier, the result is significantly different. When the country imposes trade barriers to import, the national firm incentive to innovate comes only from the possibility of gaining control of the foreign market. Thus, with unilateral trade barrier, the expected profit of the entrepreneur in the home country is:

$$EU_B = \left\{\mu_B\left[L + \left(1-\mu^*_B\right)L^*\right]\gamma + (1-\mu_B)\right\}\pi - (1-\tau)\phi(\mu_B)$$

and the corresponding research arbitrage equation would be:

$$\frac{(1-\tau)\phi'(\mu)}{\pi} = (\gamma-1)L + (1-\mu^*)L^* \tag{18}$$

where the second term gives the incentive to innovation produced by the access to export market. The reduction on import tariffs introduces the possibility that a foreign successful innovator might gain control of national market, thus

[11] Notice that this conclusion is derived under the assumption of the Step-by-Step innovation process (see Aghion and Howitt, 2009). Because there cannot be leapfrogging in the innovation process, the national monopoly of the leading firm is guaranteed by technological superiority, which might be contested only in the future after a series of unsuccessful innovation attempts.

increasing the incentive to innovate for the national firms. In fact, the research arbitrage equation after liberalization is:

$$\frac{(1-\tau)\phi'(\mu)}{\pi} = (\gamma - 1)L + (1-\mu^*)L^{*0} + \mu^* L. \tag{19}$$

Thus, the rate of innovation of firms close to the technological frontier (net of any remaining tariff) will increase after the unilateral opening of the economy.

C. For firms lagging behind the technological frontier, the effect of unilateral opening will be unchanged from the case of bilateral liberalization, and the rate of innovation after liberalization will be lower than under the closed economy.

The theory gives a rich set of empirical predictions After a reduction in trade barriers, any sector in the economy should experience an increase in productivity, either because the final sector adopts more advanced foreign technology or because only the more productive intermediate good firms survive international competition (selection effects). At the same time, the positive effect of trade liberalization on productivity would be limited by the extent that national firms can maintain anti-competitive behaviour. This limits the extent of penetration of more productive foreign firms and technology. The further away from the technological frontier a country is, the greater the productivity gain that can be achieved via trade liberalization, because of the jump in technological adoption that trade openness allows. On the other hand, the adoption of more advanced foreign technology in the final good sector will reduce the variety of national production of intermediate goods, with the exit of the least productive firms.

A second set of results refer to the dynamic effect of an increase in competition on the incentives to invest and innovate. For this, the most important variable is the distance from the technological frontier of national firms and the size of the potential market for successful innovators. Thus, firms closer to the technological frontier will have an incentive to increase investment in technological innovation as a defensive measure against foreign competitors and as an instrument to gain access to a much larger potential market. This should be particularly true for firms located in small countries. Instead, if a firm is far away from the technological frontier, trade liberalization will discourage further investment in innovation. This, coupled with the selection effect, should induce significant exit from the market of inefficient firms. The rest of the paper will take these theoretical observations to the data, looking at the experience of trade liberalization in South Africa from the end of the 1980s to the present.

3. The South African experience of trade liberalization and growth

South Africa represents an interesting case where trade liberalization can be well located in time and at the sectoral level. After an early import substitution strategy, policies of trade liberalization were followed from the early 1970s to the early 1980s. This timid process of liberalization was interrupted and partly reverted after the debt crisis of 1985 and the following economic downturn. It is only at the beginning of the 1990s and in particular with the new democratic government in 1994 that the policy takes a decisive turn towards a more liberal trade regime. Although in the literature there is some disagreement about the extent of effective trade liberalization,[12] Edwards (2005) provides the most recent re-evaluation of the extent to which South Africa has liberalized its trade since the late 1980s. He finds that significant progress has been made in terms of reducing tariff protection. In particular, between 1994 and 2004, the protection in manufacturing fell from 48 percent to 12.7 percent.

Table 1 shows the change in effective rate of protection and nominal tariffs (both including surcharges) for the sectors used in this study between 1994 and 2003 and the effective rate of protection and the nominal tariffs at the end of the sample. It is evident that there is a generalized reduction in trade protection, but the extent of liberalization is differentiated across sectors.

The 5th column of Table 1 shows the change in employment in each industry from 1994 to 2003 relative to the average change in employment in the manufacturing sectors used in the study, which saw a reduction of employment of 11 percent. It is clear that some sectors have seen a significant reduction in employment, especially footwear and textile, which are still protected by a relatively high effective rate of protection, and glass & glass products, basic iron & steel and basic non-ferrous metals, which have seen instead a significant reduction in tariff protection. Other sectors, instead, have seen a significant expansion in employment following the change in tariff protection. Overall, the correlation between change in tariffs and change in employment is not significant while change in employment is correlated (0.4) with changes in pricing power, shown in the last column of Table 1. The objective of the empirical analysis is to make sense of these different patterns relating the different responses of manufacturing sectors to trade liberalization to their distance from the technological frontier, as suggested by the theory.

4. Empirical strategy

4.1 The datasets

For this study, we employ industry-level data from a number of distinct sources:

1. Industry-level panel data for South Africa from the Trade and Industry Policy Strategies (TIPS) database. The data employed for this study focus on the three-digit manufacturing industries, over the 1988–2003 period. Variables for the manufacturing sector include the output, capital stock, and labour force

[12] See, for example, Fedderke and Vaze (2001) for a sceptical view on the real extent of trade liberalization in South Africa, and Rangasamy and Harmse (2003) for a more positive assessment.

Table 1. Change in trade protection, employment and pricing power in 3-digit manufacturing sectors included in the study (1994–2003)

Sector	Effective rate of protection (change 1994–2003)	Nominal tariff (change 1994–2003)	Effective rate of protection 2003	Nominal tariff 2003	Change in relative employment (1994–2003)	Change in pricing power (1994 –2003)
Food (301–304)	−18.9	−7.0	36.40	11.79	−0.06	0.12
Beverages (305)	−26.7	−15.0	25.29	14.31	−0.19	0.05
Tobacco (306)	−25.1	−5.6	315.40	36.02	−0.04	0.09
Textiles (311–312)	−64.4	−18.7	85.33	22.60	−0.18	0.12
Wearing apparel (313–315)	−121.7	−40.1	96.68	34.97	0.01	0.00
Leather & leather products (316)	−40.5	−14.3	19.20	11.56	0.06	0.20
Footwear (317)	−55.3	−25.3	50.66	22.74	−0.34	0.32
Wood & wood products (321–322)	−7.0	−5.4	14.75	9.14	0.11	−0.09
Furniture (391)	−36.3	−14.4	46.29	17.69	0.06	−0.02
Paper & paper products (323)	−5.7	−5.1	10.07	6.23	0.08	0.13
Industrial chemicals	−13.4	−6.7	5.85	3.25	0.25	0.35
Rubber products (337)	−13.3	−7.1	33.25	11.43	0.04	0.00
Plastic products (338)	−16.0	−10.0	20.22	9.77	0.20	−0.12
Glass & glass products (341)	−17.7	−9.5	14.32	7.66	−0.22	0.14
Non-metallic minerals (342)	−19.1	−9.4	10.79	5.60	−0.26	0.34
Basic iron & steel (351)	−9.0	−4.4	11.05	4.34	−0.21	0.44
Basic non-ferrous metals (352)	−14.7	−8.5	3.13	2.24	−0.11	0.46

Table 1 (Continued)

Sector	Effective rate of protection (change 1994–2003)	Nominal tariff (change 1994–2003)	Effective rate of protection 2003	Nominal tariff 2003	Change in relative employment (1994–2003)	Change in pricing power (1994 –2003)
Metal products excluding machinery (353–355)	−20.1	−10.2	16.60	8.13	0.01	0.04
Machinery & equipment (356–359)	−9.0	−6.7	2.97	3.67	0.14	0.09
Television, radio & communication equipment (371–373)	−21.5	−13.3	12.33	6.73	−0.09	0.10
Transport equipment (381–387)	−11.4	−9.6	28.62	14.03	0.10	0.06
Professional & scientific equipment (374–376)	−15.8	−11.8	−6.32	0.33	0.40	0.19
Other manufacturing (392–393)	−79.2	−20.4	17.32	6.02	0.30	0.00

Notes: Effective rate of protection and Nominal Tariff: from Edwards (2005); change in employment: authors calculations from Trade and Industry Policy Strategies (TIPS) database; and change in pricing power: from Aghion *et al.* (2008). The Change in Employment is calculated relative to trend.

variables their associated growth rates, the distribution of value added between factor inputs, and the skills composition of the South African manufacturing labour force by manufacturing sector.

2. Industry-level panel data for South Africa and the USA and 28 manufacturing industries from 1963–2003, obtained from UNIDO's International Industry Statistics 2004. These data are used to compute South Africa and US industry total factor productivity and distance from the technological frontier of South African 3-digit manufacturing industry. This dataset contains yearly

information on output, value added, total wages, and employment, gross capital formation, and the distribution of value added between factor inputs. From the gross capital formation data, we compute capital stock data on the basis of the perpetual inventory methodology.[13]
3. For measures of industry pricing power, we employ the estimated values of the mark-up of price over marginal cost of production of Aghion *et al.* (2008) obtained from the Roeger (1995) methodology.
4. Given the focus of the present study on the impact of trade liberalization on productivity growth, accurate measures of openness or protection are crucial. For our openness indicators, we employ data on effective rates of protection and scheduled nominal tariff rates obtained from Edwards (2005).[14]

While most indicators employed for this study are available over the 1970–2004 or 1970–2002 period, the trade measures are restricted to the 1988–2004 period. In addition, data comparability issues between the US and SA reduced the total number of comparable sectors from 28 to 23 sectors. The list of sectors included in the panel is that specified in Table 1. This generated a panel of dimension $23 \times 17 = 391$ observations.[15]

4.2 The distance from frontier measures

Following Aghion *et al.* (2005) and Aghion and Griffith (2005), we generate an industry- and time-specific measure of distance from the technological frontier, under the assumption that the US constitutes the technological leader for South African industry.[16] The measure we employ is given by

$$M_{i,t} = tfp_{SA,i,t}/tfp_{US,i,t} \tag{20}$$

where the measure of distance from the frontier, M, for industry i in year t, in country $X = [SA,US]$, is the difference between total factor productivity (TFP) in the US

[13] As the comparison of distance from the frontier is conducted over the 1970–2002 period, and data for the US are available from 1963, implementation employed a 7-year lead, under an assumption of 15 percent depreciation rates.

[14] Note that Edwards (2005) also contains measures of export taxes and anti-export bias. We also used both these measures in estimation, with symmetrical results. In the case of the anti-export bias measure, however, strong sectoral outliers render the measure less reliable in the sense of raising standard errors. Full results are available from the authors on request.

[15] On the nature and quality of these data, see the discussion in Aghion *et al.* (2008).

[16] South Africa, relative to its trading partners, has developing country characteristics. Due to her international isolation, there has been a heavy reliance on trading with developed countries, making the US (rather than African countries) a relevant comparator. Edwards and Schöer (2002) report that 85 percent (57 percent) of South African imports (exports) in 1990 were sourced from the 25 OECD countries, declining to 72 percent (53 percent) in 1999. South African trade is thus heavily biased towards developed countries over the sample period of this study, although middle-income and developing countries have begun to feature more prominently in South African trade during the 1990s.

from that in SA for that industry and year. TFP is computed by means of the primal decomposition, with factor shares given by the share of labour remuneration in value added. We compute the distance measure both by comparing US TFP with Rand-denominated and Dollar-denominated South African TFP to ascertain how much real exchange rate depreciation has helped the competitiveness of national firms. Figure 1 shows the data patterns

We find three broad patterns in the data.

One grouping of 13 sectors sees a steady widening of the technological gap between South African and US TFP. While for six sectors the widening gap occurs from a base that is already very low (defined as less than 10 percent of US TFP productivity levels),[17] for two sectors, there is a dramatic increase in the distance of TFP productivity from relatively close levels (defined as greater than 50 percent of US TFP productivity levels),[18] and for four sectors, the growing productivity gap occurs for mid-range productivity sectors (defined as between 10 percent and 50 percent of US TFP productivity levels).[19]

A second grouping of five sectors sees a narrowing of the TFP productivity gap between South Africa and the US – although for a number of these sectors, the final few years see a reversal in the trend. Again, there is a distinction between one sector for which the productivity gain has been substantial (to the point of rising to TFP productivity levels that exceed that of the US),[20] and four sectors for which the gain has been moderate.[21]

The third grouping of five sectors sees a catch-up of South African TFP productivity levels with the US from 1988 through the mid-1990s, but with a subsequent reversal in the catch-up. In the case of one sector, this decline is both dramatic and off a relatively high base,[22] for two sectors, the decline occurs off a mid-level plateau,[23] one sector experiences both substantial catch-up, but equivalent decline towards the end of our sample period,[24] and for one sector, the movements are small leaving the sector at moderate US TFP productivity levels throughout.[25] All these patterns are shown in Figure 1.

What is particularly noteworthy is that productivity catch-up for South African manufacturing sectors does not in general occur in sectors that are obviously natural resource extractive, where South Africa should have most of its comparative advantage. Non-metallic minerals, Basic iron & steel, Basic non-ferrous metals, Metal

[17] Beverages, Tobacco, Leather & leather products, Industrial chemicals, Basic non-ferrous metals, Other manufacturing equipment.

[18] Footwear and Paper & paper products.

[19] Food, Non-metallic mineral products, Basic iron & steel, Metal products.

[20] Plastics & plastic products.

[21] Wearing apparel, Wood & wood products, Furniture, Rubber & rubber products.

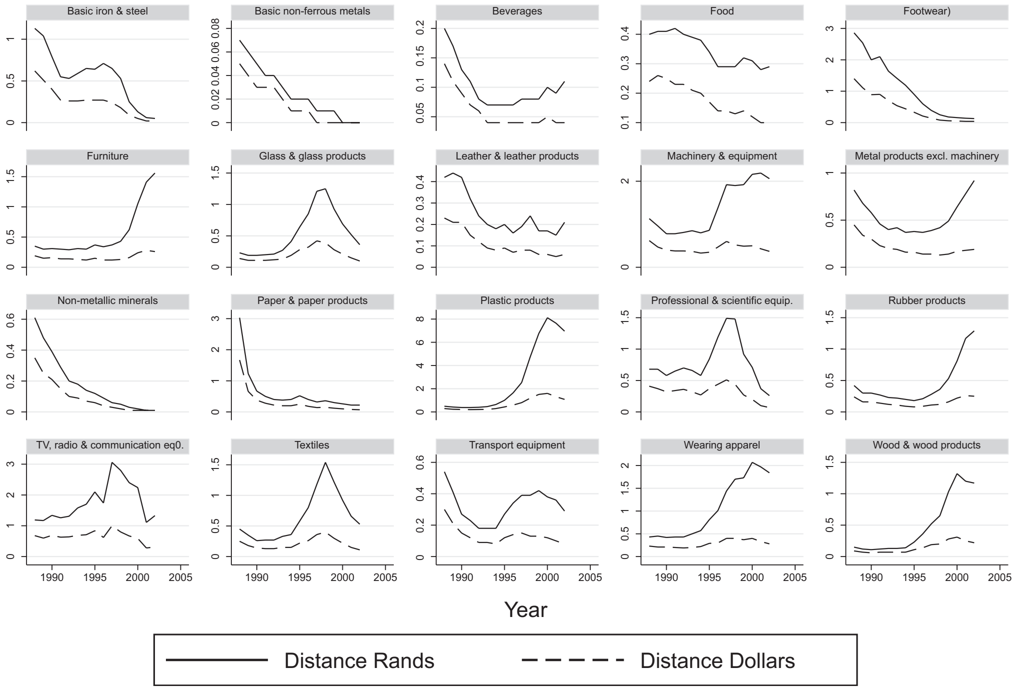
[22] Television, radio & communication equipment.

[23] Textiles and Professional & scientific equipment.

[24] Glass & glass products.

[25] Machinery & equipment.

Figure. 1. Distance from technological frontier (USA) by sector – TFP levels



products, and Paper & paper products all consistently lose ground relative to US productivity levels, and in the case of virtually all of these sectors, South African TFP productivity is never close to US levels – the only possible exception is Paper & paper products.

However, given the findings of Aghion *et al.* (2008) on the impact of market structure on productivity growth, and of Fedderke (2006) on the impact of poor human capital endowments and low R&D investment by South African manufacturing on productivity growth, these findings are not surprising.

4.3 The empirical specification

Our model hypothesizes two fundamental effects of trade liberalization. First, trade liberalization increases aggregate productivity (and wages) through selection effects and increases in competitive pressure. Second, innovation in sectors in which firms are sufficiently close to the technological frontier reacts positively to an increase the level of product market competition due to trade liberalization. Where they lag considerably behind the frontier, the impact of the liberalization reverses. Thus, increasing distance from the technological frontier should raise the deleterious effect of trade liberalization on productivity growth.[26]

To test these predictions of the theoretical framework, we examine productivity dynamics in South African manufacturing sectors for the period 1988–2002 for the three-digit SIC-level data. The baseline specification tests for a direct linear impact of the trade protection measure on productivity growth:

$$\Delta A_{it} = a_1 P_{i,t} + \alpha_i + \beta_t + u_{it} \tag{21}$$

where ΔA_{it} denotes productivity growth in sector i in year t, measured by TFP growth or growth in output per worker. P_{it} is a measure of effective trade barriers as detailed in the data section above. The P measure is given by measures of nominal tariffs and of effective protection rates. The measure is thus an inverse of openness. Finally, α_i represents fixed effects, and β_t time effects. The theoretical prior is that $a_1 < 0$, as protection (as an inverse of openness) induces a decrease in the level of productivity growth either by preventing an increase in technological innovation by more advanced firms or by preventing the import of new technology. To capture some of the entry–exit flows that are central to the theoretical analysis, we also use the sectoral change in the output-to-labour ratio $\Delta(Y_{it}/L_{it})$ as an alternative measure of productivity growth for all specifications we estimate.

As the theoretical framework outlined above also identifies an indirect impact of trade liberalization, that differentiates the impact of liberalization conditional on the distance of the industrial sector from the technological frontier, we supplement the baseline specification by incorporating the impact of distance from the technological leader into the productivity growth dynamics. Formally, for the three-digit SIC-level data, we specify:

$$\Delta A_{it} = a_0 + a_1 P_{i,t} + a_2 M_{i,t} P_{i,t} + \alpha_i + u_{it} \tag{22}$$

where terms are defined as before, $M_{i,t}$ denotes the distance from the technological frontier defined in Equation (20), and the term $M_{i,t}P_{i,t}$ represents an interaction term that captures the relationship between openness and technological innovation. Additional priors are that $a_2 < 0$, such that the maximum effect of trade liberalization occurs in sectors that are closer to the technological frontier.

[26] A third impact of trade liberalization that emerges from our model is that the magnitude of the positive effect of increasing openness on productivity depends on the increase in the potential market size for winning firms. This requires a comparison of the relative market size winning firms have access to, *ex ante* and *ex post* trade liberalization. An immediate proxy that offers itself is a comparison of a country's market size relative to world markets. However, this would be true only in the absence of any differentials in the rates at which countries lowered their trade barriers. As we have data only on the levels of tariff barriers for South Africa (and not its trading partners), we are unable to employ this proxy of the scale effect of trade liberalization. We therefore do not model this effect empirically.

Specification (22) ignores one important additional factor known to be relevant to productivity growth in South African manufacturing. Aghion *et al.* (2008) demonstrated both that product market competition has strong predictive power for productivity growth in South African manufacturing, and that pricing power of domestic producers in manufacturing appears to be substantial. Rodrik (2008), by contrast, has argued that the relative price of manufacturing in the South African economy has declined, due in considerable measure to the rising import penetration associated with the liberalization of the economy, placing domestic producers under a profit squeeze. For this reason, we also test for the robustness of our findings on a_1 and a_2 , by controlling for the impact of a Lerner index of pricing power.[27] We also allow for the possibility of interaction between product market competition and trade protection and distance from technological frontier, providing us with

$$\Delta A_{it} = a_0 + a_1 P_{i,t} + a_2 M_{i,t} P_{i,t} + a_3 \mathcal{L}_{it} + a_4 \mathcal{L}_{it} P_{i,t} + a_5 \mathcal{L}_{it} M_{i,t} + \alpha_i + u_{it} \tag{23}$$

with all terms defined as before, and with $\mathcal{L}$ denoting the measure of pricing power.

Additional priors are that $a_3 < 0$, given that lower product market competition hampers the escape competition effect. $a_4 < 0$, as a decrease in trade protection should have greater productivity growth effects for sectors with low rather than high product market competition. We do not have explicit theoretical priors for a_5. Nonetheless, we posit $a_5 < 0$ on the grounds that sectors with strong competitive pressure far from the technological frontier would be vulnerable to entry without the possibility of recourse to an escape competition response by incumbent producers.

5. Results

Our estimation strategy proceeds as follows: first we consider the direct effects of trade protection on industry productivity growth, as specified in Equation (21), and the non-linear specification given by Equation (22) under two alternative productivity measures, and for two measures of trade protection, effective protection rates and nominal tariff rates, respectively.

[27] Mark-ups are obtained following the contributions by Hall (1990) and Roeger (1995) by means of:

$$\begin{aligned} NSR =& \Delta(p+q) - \alpha \cdot \Delta(w+l) - (1-\alpha) \cdot \Delta(r+k) \\ =& (\mu - 1) \cdot \alpha \cdot [\Delta(w+l) - \Delta(r+k)] \end{aligned}$$

where $\mu = P/MC$, with P denoting price, and MC denoting marginal cost. Under perfect competition $\mu = 1$, while imperfectly competitive markets allow $\mu > 1$. Δ denotes the difference operator, lower case denotes the natural log transform, q, l, and k denote real value-added, labour and capital inputs, and α is the labour share in value-added. See the additional discussion in Fedderke *et al.* (2007).

We follow the baseline estimation with a series of robustness checks. It is possible that the protection measures we use are not exogenous to productivity growth. Sectors that are subject to low productivity growth have an incentive to lobby for protection. We allow for this possibility by estimating (21) and (22) under the systems GMM methodology. A further concern using panel estimation methodology might be that the underlying assumption of homogeneity across the manufacturing sectors required for the pooling of the data is not appropriate, resulting in bias and inconsistency of estimation results. For this reason, we employ the Pooled Mean Group (PMG) estimation methodology and control for manufacturing group heterogeneity. Finally, we check the impact of product market competition using specifications (23).

5.1 *The direct productivity effect of trade protection*

We start by estimating the specification (21). For the panel of South African manufacturing sectors listed in the first column of Table 1, we control for industry-fixed effects. Results are reported in Table 2 for the TFP productivity growth measure, and Table 3 for growth in the output labour ratio. In columns (1)–(5), we present the results using the effective rate of protection as the trade liberalization measure, while in columns (6) to (9), we show the results using nominal tariffs.

Estimation results consistently confirm the negative direct impact of trade protection on productivity growth ($a_1 < 0$) both for the TFP growth measure and the growth in output per worker. We note that for both effective rate of protection and nominal tariff rate measures, the negative impact is robust to industry-fixed effects (column (2) and (7)). Symmetrically, results are robust to the inclusion of time effects in the case of the TFP productivity growth measure – although not for the labour productivity growth measure (see columns (3) of Tables 2 and 3).[28]

Both sets of results imply an economically significant marginal impact. A 10 percentage point decrease in effective protection increases TFP growth by $0.2-0.4$ percentage points and growth of output per worker by $0.1-0.3$ percentage points. A reduction in nominal tariffs by 10 percentage points increases TFP growth by $1-2$ percentage points and growth of output per worker between 0.5 and 1 percentage points.

We also allow for the possibility of endogeneity of trade protection, by employing the dynamic GMM estimator,[29] as well as the possibility of possible heterogeneity across industry group beyond the time-invariant industry heterogeneity controlled for by fixed effects, by employing a pooled mean group estimator.[30] We note that the data employed for estimation under both pooled OLS, the Within estimator, GMM and PMGE are uniformly stationary (see the Appendix reporting panel

[28] Note that for the sake of parsimony, we report only the inclusion of time effects in the case of the ERP protection measure. Results are symmetrical.

[29] See Arellano and Bond (1991) and Blundell and Bond (1998).

[30] See Pesaran *et al.* (1999) A fuller discussion of the estimator is included in an Appendix.

Table 2. Productivity growth in TFP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Measure of trade liberalization	ERP	ERP	ERP	ERP	ERP	Nom Tar	Nom Tar	Nom Tar	Nom Tar
P	−0.001* (3.4e-005)	−0.0004 * (6.9e-005)	−0.0002* (5.1e-005)	−0.0002* (7.2e-005)	−0.0004* (0.0001)	−0.001** (0.004)	−0.0022* (0.0006)	−0.0002* (0.0001)	−0.0030* (0.0004)
TFP(−1)				−0.08 (0.10)				−0.11 (0.11)	
PHI					−1.03* (0.05)				−1.004* (0.05)
Ind. Effs	No	Yes	Yes	No	Yes	No	Yes	No	Yes
Time Effs	No	No	Yes	No	No	No	No	No	No
GMM	No	No	No	Systems 2-step	No	No	No	Systems 2-step	No
PMGE	–	–	–	–	AIC(1)	–	–	–	AIC(1)
N	368	368	368	345	391	368	368	345	–
Adj-R2	0.01	0.04	0.23	–	–	0.02	0.05	–	–
Wald (joint)	10.76*	37.72 *	24.08*	10.62*	–	3.17	13.51*	8.25**	–
Wald (dummy)	–	–	499.2*	5.512*	–	–	–	7.96*	–
Sargan	–	–	–	22.30	–	–	–	22.27	–
AR(1)	1.87	−0.37	−0.66	−2.97 *	–	1.78	−0.78	−2.74*	–
AR(2)	1.12	−2.21 *	−2.40*	−1.06	–	1.00	−2.60*	−1.36	–
(Hausman h-Test for homogeneity)	–	–	–	–	1.61 [0.20]	–	–	–	0.78 [0.38]
RLL	–	–	–	–	−1,135	–	–	–	−1,129
ULL	–	–	–	–	−1,117	–	–	–	−1,116
Instruments for transformed equation	–	–	–	GMM (TFP,3,5) GMM (P,3,5)	–	–	–	GMM (TFP,3,5) GMM (P,3,5)	–
Instruments for level equation				GMM Level (TFP,4,D) GMM Level (P,4,D)				GMMLevel (TFP,4,D) GMMLevel (P,4,D)	

***Notes*:** Standard deviations in parentheses; square brackets denote probability values; * significance at 5%, ** at 10% level; PHI denotes the error-correction coefficient under the PMGE methodology; Instruments for GMM estimation: in GMM(Variable, $t,t+n$), t refers to the minimum, $t+n$ to the maximum lag; in GMMLevel (Variable, t,D), t refers to the lag, D to the use of the first differenced instrument.

Table 3. Productivity growth in output/labour (Y/L) ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Measure of trade liberalization	ERP	ERP	ERP	ERP	ERP	Nom Tar	Nom Tar	Nom Tar	Nom Tar
P	−0.0127* (0.005)	−0.0298* (0.011)	−0.005 (0.007)	−0.024* (0.009)	−0.025* (0.008)	−0.1019* (0.045)	−0.2192* (0.0673)	−0.243* (0.147)	−0.202* (0.045)
$[d(Y/L)/dt](-1)$				−0.10 (0.14)				−0.17 (0.17)	
PHI					−1.05* (0.04)				−1.12* (0.08)
Ind. Effs	No	Yes	Yes	No	Yes	No	Yes	No	Yes
Time Effs	No	No	Yes	No	No	No	No	No	No
GMM	No	No	No	Systems	No	No	No	Systems	No
PMGE	–	–	–	–	AIC(1)	–	–	–	AIC(2)
N	368	368	368	345	–	368	368	345	–
Adj-R2	0.01	0.012	0.19	–	–	0.02	0.03	–	–
Wald (joint)	7.21*	7.92*	0.68	6.62**	–	5.04*	10.61*	3.26	–
Wald (dummy)	–	–	166.7*	3.49	–	–	–	4.53*	–
Sargan	–	–	–	21.05	–	–	–	21.61	–
AR(1)	1.07	−0.79	−1.04	−2.40*	–	0.94	−1.12	−1.97*	–
AR(2)	1.45	−2.06*	−2.37	−1.11	–	1.18	−2.52*	−1.28	–
Hausman h-Test for homogeneity	–	–	–	–	1.04 [0.31]	–	–	–	2.21 [0.14]
RLL	–	–	–	–	−1,212	–	–	–	−1,186
ULL	–	–	–	–	−1,195	–	–	–	−1,171
Instruments for transformed equation:	–	–	–	GMM (Y/L,2,5) GMM(P,2,5)	–	–	–	GMM (Y/L,3,6) GMM(P,3,6)	–
Instruments for level equation:				GMM Level (Y/L,4,D) GMM Level (P,4,D)				GMM Level (Y/L,4,D) GMM Level (P,4,D)	

***Notes*:** Standard deviations in parentheses; square brackets denote probabiltiy values; * significance at 5%, ** at 10% level; PHI denotes the error-correction coefficient under the PMGE methodology; Instruments for GMM estimation: in GMM(Variable, t, $t+n$), t refers to the minimum, $t+n$ to the maximum lag; in GMMLevel(Variable, t,D), t refers to the lag, D to the use of the first differenced instrument.

unit root tests), rendering the distributional assumptions underlying the results from the regressors consistent.[31]

Our results prove to be robust to controlling for the possibility of endogeneity of the trade protection measure under systems GMM, as reported in columns (4) for effective protection rates, and in column (8) for nominal tariffs, of Table 2 (for TFP growth) and Table 3 [for $\Delta(Y_{it}/L_{it})$], respectively. The negative impact and both economic and statistical significance of trade protection on productivity growth is maintained under the GMM estimator. We employ the two-step GMM estimator,[32] under higher order lags as instruments in estimation as reported in Tables 2 and 3.[33] The Sargan test of the overidentifying moment restrictions, distributed χ^2 under the null that the restrictions are valid, in all instances provides support for the instruments employed (by not rejecting the null). The AR tests confirm the presence of AR (1) and absence of AR(2), as required to be consistent with the AR structure in the GMM specifications.[34]

Allowing for the possibility of heterogeneity across manufacturing sectors by means of the PMG estimator, in columns (5) for effective protection rates and column 9 for nominal tariffs, of Table 2 (TFP growth) and Table 3 ($\Delta(Y_{it}/L_{it})$) respectively, further confirms the robustness of the finding of the negative impact of trade protection on productivity growth.[35] In application, the PMG estimator confirms the homogeneity of the impact of the trade protection measure in the long-run specification (see the Hausman h-test statistic), as well as adjustment to long-run equilibrium by virtue of the negative PHI coefficient. Indeed, under the ARDL specification of the PMGE estimator, the strength of the long-run impact of trade protection if anything increases from that obtained under the static fixed-effects estimation.

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[31] While the PMGE can deal with non-stationary data, it is also consistent with stationary data. The case of stationary regressors for the PMGE is explicitly derived in Pesaran *et al.* (1999: section 4.1), while the case of non-stationary data is dealt with in section 4.2 of the paper. Thus, the PMGE can be used for either stationary or non-stationary data.

[32] As under potential endogeneity of the non-autoregressive regressors, the weight matrix employed to construct the single step GMM-estimator is no longer known, the gain in efficiency in the two-step estimator is held to be substantial in the literature. See the discussion in Bond (2002).

[33] The reason for the higher order lags is that in the presence of MA(1)-processes in the error structure, the first differenced error term under GMM becomes MA(2). Hence, lower order lags of the instruments are no longer valid. While results under the use of lower order lags are consistent with those reported, we report those that preclude the possiblity of the impact of the MA processes.

[34] The AR-structure implied by the GMM structure appears well specified, as confirmed by the fact that the AR-coefficient under OLS estimation lies above, and that obtained under Within Group estimation lies below that obtained under GMM estimation. As we know analytically that the OLS estimator is biased upwards, the Within is biased downwards, while the GMM estimator of the AR coefficient is consistent, it is reassuring that empirically the GMM estimates of the AR coefficient proves to be located between the OLS and Within limiting cases, providing further confidence in the GMM specification. See also the discussion in Bond (2002).

[35] An Appendix provides a more detailed exposition of the PMG estimator. Here we note that it exploits the statistical power of the panel data structure by imposing homogeneity on the long-run association between variables, while allowing for industry heterogeneity in the short-run dynamics, and hence (through the solution of the implied difference equations) in the steady states to which different industries converge.

Results for the TFP and output per worker productivity growth results are symmetrical throughout.

The empirical results are thus encouraging for our posited theoretical framework. That the impact of trade protection should be pervasively negative, even without controlling for the indirect effects identified by the theory, and under alternative estimation methodologies that control both for potential endogeneity and panel group heterogeneity, suggests some robustness of the link between trade dispensations and growth. It remains to be seen whether controlling for the interaction effects implied by our theory adds additional insight.

5.2 *Testing the robustness of the productivity effect of trade protection*

Under the specification (22), we explicitly control for the differential impact of trade liberalization on productivity growth for sectors that differ in terms of their distance from the technological frontier. To determine the robustness of our results, we again estimate (22) under both productivity growth measures, for both measures of trade protection, and under fixed effects, GMM (to control for endogeneity), and PMG (to control for sector heterogeneity) estimation methodologies.

Results are reported in Tables 4 and 5 for the TFP and output–labour ratio productivity growth measures, respectively. Columns (1) and (5) report results under fixed-effects estimation for effective protection rates and nominal tariff rates, respectively. Columns (3) and (6) report GMM, and (4) and (7) report the PMGE estimations.

Note immediately that the negative impact of trade protection on productivity growth is confirmed for all specifications that control for the impact of distance from the technological frontier (with the single exception of the specification in labour productivity growth and nominal tariffs). More importantly in the present context, our results also confirm our prior that sectors that are closer to the technological frontier benefit more from trade liberalization in productivity growth terms ($a_2 < 0$), than do sectors far from the technological frontier. The result is again robust across the alternative productivity growth measures, the alternative trade protection measures, as well as the estimation methodologies that control for sectorial heterogeneity by means of fixed effects or the more elaborate dynamic PMGE methodology,[36] as well as the GMM approach that allows for endogeneity of the protection measure.

Note that the indirect impact of trade liberalization conditional on distance from technological frontier is of significant magnitude in economic terms. For a 10 percentage point decrease in trade protection, each percentage point increase in

[36] Only for the PMGE methodology under the nominal tariff measure does the interaction term report coefficients of the wrong sign (for both productivity growth measures) – but under this specification, the coefficient is statistically insignificant.

Table 4. Productivity growth in TFP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Measure of trade liberalization	ERP	ERP	ERP	ERP	Nom Tar	Nom Tar	Nom Tar
P	−0.0004*	−0.0002*	−0.00014*	−0.0004*	−0.0021*	−0.002*	−0.0030*
	(5.6e-005)	(4.8e-005)	(6.8 e-005)	(0.0001)	(0.0007)	(0.0007)	(0.0004)
$M(-1)\times P(-1)$	−0.0009*	−0.001**	−0.0013*	−0.0002	−0.0013**	−0.002	0.0010
	(0.0003)	(0.0003)	(0.0005)	(0.0003)	(0.0007)	(0.002)	(0.0007)
TFP(−1)			−0.06 (0.13)			−0.03 (0.17)	
PHI				−1.003* (0.05)			−1.02* (0.05)
Ind. Effs	Yes	Yes	No	Yes	Yes	No	Yes
Time Effs	No	Yes	No	No	No	No	No
GMM	No	No	Systems 2-step	No	No	Systems 2-step	No
PMGE	–	–	–	AIC(1)	–	–	AIC(1)
N	338	338	338	391	338	338	–
Adj-R2	0.06	0.27	–	–	0.07	–	–
Wald (joint)	71.10*	43.94*	18.14*	–	37.80*	8.85**	–
Wald (dummy)	–	305.1*	3.26	–	–	4.58*	–
Sargan	–	–	21.05	–	–	20.33	–
AR(1)	−1.17	−1.36	−2.70*	–	−1.60	−2.38*	–
AR(2)	−2.11*	−2.41*	−0.90	–	−2.43*	−0.62	–
Hausman h-Test for homogeneity	–	–	–	3.26 [0.20]	–	–	1.87 [0.39]
RLL	–	–	–	−1,003	–	–	−1,004
ULL	–	–	–	−953	–	–	−956
Instruments for transformed equation	–	–	GMM(TFP,3,5) GMM(P,3,5) GMM(MP,3,5)	–	–	GMM(TFP,3,5) GMM(P,3,5) GMM(MP,3,5)	–
Instruments for level equation			GMM Level(TFP,4,D) GMM Level(P,4,D) GMM Level(MP,4,D)			GMM Level (TFP,4,D) GMM Level(P,4,D) GMM Level(MP,4,D)	

Notes: Standard deviations in parentheses; square brackets denote probabiltiy values; * significance at 5%, ** at 10% level; PHI denotes the error-correction coefficient under the PMGE methodology; Instruments for GMM estimation: in GMM (Variable, t, $t+n$), t refers to the minimum, $t+n$ to the maximum lag; in GMMLevel (Variable, t,D), t refers to the lag, D to the use of the first differenced instrument.

Table 5. Productivity growth in output/labour (Y/L) ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Measure of trade liberalization	ERP	ERP	ERP	ERP	Nom Tar	Nom Tar	Nom Tar
P	−0.0207*	−0.002	−0.017*	−0.024*	−0.1755*	−0.091	−0.217*
	(0.0077)	(0.01)	(0.007)	(0.009)	(0.0641)	(0.21)	(0.054)
$M(-1)\times P(-1)$	−0.1280*	−0.08	−0.146	−0.035	−0.2305*	−0.91	0.045
	(0.0436)	(0.04)	(0.11)	(0.056)	(0.1135)	(1.28)	(0.126)
$[d(Y/L)/dt]\,(-1)$			−0.14			−0.04	
			(0.12)			(0.15)	
PHI				−1.01* (0.05)			−1.01*
							(0.05)
Ind. Effs	Yes	Yes	No	Yes	Yes	No	Yes
Time Effs	No	Yes	No	No	No	No	No
GMM	No	No	Systems	No	No	Systems	No
PMGE	–	–	–	AIC(1)	–	–	AIC(1)
N	338	338	338	–	338	338	–
Adj-R2	0.02	0.21	–	–	0.04	–	–
Wald (joint)	20.06*	5.62	9.62*	–	20.67*	3.58	–
Wald (dummy)	–	162.0	2.37	–	–	2.12	–
Sargan	–	–	20.85	–	–	18.20	–
AR(1)	−1.22	−1.31	−2.39*	–	−1.47	−2.14*	–
AR(2)	−2.26*	−2.51*	−1.50	–	−2.58*	−0.54	–
Hausman h-Test for homogeneity	–	–	–	2.94 [0.23]	–	–	2.04[0.36]
RLL	–	–	–	−1,071	–	–	−1,071
ULL	–	–	–	−1,024	–	–	−1,035
Instruments for transformed equation	–	–	GMM(Y/L,2,5) GMM(P,2,5) GMM(MP,2,5)	–	–	GMM(Y/L,2,5) GMM(P,2,5) GMM(MP,2,5)	–
Instruments for level equations:			GMM Level(Y/L,4,D) GMM Level(P,4,D) GMM Level(MP,4,D)			GMM Level(Y/L,4,1) GMM Level(P,4,1) GMM Level(MP,4,1)	

Notes: Standard deviations in parentheses; square brackets denote probabiltiy values; * significance at 5%, ** at 10% level; PHI denotes the error-correction coefficient under the PMGE methodology; Instruments for GMM estimation: in GMM(Variable, t, $t+n$), $t+n$ refers to the minimum, $t+n$ to the maximum lag; in GMMLevel (Variable, t,D), $t+n$ refers to the lag, D to the use of the first differenced instrument.

distance from the technological frontier lowers productivity growth by between 0.1 and 0.2 percentage points under the TFP productivity growth measure, and 0.13 and 0.44 percentage points under the output–labour ratio measure.

Trade liberalization thus stands to benefit sectors closer to the technological frontier considerably more, than those that lag the frontier.

5.3 Controlling for the impact of product market competition

In Table 6 we report the results of estimations under the specification given by (23). We allow for the impact of our measure of pricing power evident in South African manufacturing sectors, and for different levels of pricing power for a differential impact of both trade liberalization and distance from the technological frontier. Columns (1)–(3) report results for TFP growth using the effective rate of protection and columns (4)–(6) report results using the nominal tariff as protection measure.

Table 6. Productivity growth in TFP: robustness under controls for product market competition

	(1)	(2)	(3)	(4)	(5)	(6)
Protection measure	ERP	ERP	ERP	Nom Tar	Nom Tar	Nom Tar
P	−0.0003*	−0.0002*	−0.0003*	−0.0018*	−0.0009	−0.0011
	(5.9e-005)	(9.6e-005)	(9.3e-005)	(0.0007)	(0.0008)	(0.0008)
$M(-1)\times P(-1)$	−0.0015*	−0.0019*	−0.0012*	−0.0024*	−0.0040*	−0.0023*
	(0.0003)	(0.0003)	(0.0003)	(0.0010)	(0.0010)	(0.0010)
$L(-1)$	−0.1835*	−0.1818*	−0.1265*	−0.1532*	−0.1433*	−0.0916**
	(0.0456)	(0.0473)	(0.0513)	(0.0448)	(0.0472)	(−1.81)
$L(-1)\times P(-2)$		−0.0002*	−0.0002*		−0.0019*	−0.00156**
		(7.0e-005)	(6.2e-005)		(0.0009)	(0.0009)
$L(-1)\times M(-1)$			−0.4426*			−0.4203*
			(0.1110)			(0.1020)
Ind. Effs	Yes	Yes	Yes	Yes	Yes	Yes
N	338	315	315	338	315	315
Adj-R2	0.10	0.10	0.13	0.09	0.11	0.13
Wald (joint)	75.70*	331.5*	357.4*	43.76*	58.45*	90.73*
AR(1)	−0.87	−0.70	−1.41	−1.13	−0.95	−1.63
AR(2)	−2.21*	−2.50*	−2.55*	−2.36*	−2.58*	−2.63*

***Notes*:** Standard deviations in parentheses * significance at 5%, ** at 10% level.

Our findings of both the direct negative impact of trade protection and the greater positive impact of trade liberalization for sectors closer to the technological frontier are robust to the additional controls for product market competition.

The impact of pricing power continues to have the statistically significant negative impact on productivity growth ($a_3 < 0$) noted in Aghion *et al.* (2008). Indeed, the economic size of the impact is approximately double that found for the closed economy model of the earlier study. Aghion *et al.* (2008) found that a 0.1 unit increase in the Lerner index resulted in the loss of approximately 1 percentage point in productivity growth as measured by TFP. Under the present open-economy specifications, the implication is that a 0.1 unit increase in the Lerner index now results in a 1–2 percentage point loss in productivity growth under the TFP productivity growth measure (see columns (1) and (4)), and a loss of between 2 and 3 percentage points under output–labour ratio productivity growth (see columns (7) and (10)).[37]

For the pricing power interaction terms, our results suggest that trade liberalization has greater productivity growth effects for sectors with low rather than high product market competition ($a_4 < 0$).[38]

The results also support the inference that sectors with strong competitive pressure far from the technological frontier experience lower productivity growth ($a_5 < 0$).

Our findings on the impact of trade liberalization (direct and indirect) are therefore robust to the inclusion of the measure for pricing power in the form of the proxy of the Lerner index.

6. Conclusion and evaluation

This paper has provided a new approach to the examination of the linkage between trade liberalization and productivity growth.

The theoretical framework employed in the paper, while acknowledging a direct impact of openness on growth, also serves to highlight that the impact of trade liberalization on growth may also operate through indirect channels. Specifically, the

[37] While Rodrik (2008) was therefore correct to caution that the trade context is important to the quantification of the impact of pricing power on productivity growth, the impact of trade liberalization is not such as to eliminate the impact of pricing power – instead, it enhances its importance. Not controlling for the reduction in trade protection biases the impact of pricing power downwards. Furthermore and crucially for the policy context, we also note that liberalization of the South African economy is not only incomplete at present, but that the regulatory framework on output markets in South Africa is more stringent than even for the OECD (see OECD, 2008: 65), thus creating non-tariff barriers to entry that continue to protect incumbent firms even under trade liberalization.

[38] Note that there is no clear theory that specifies the length of time it takes for dynamics to take effect. Given only adjustment costs, there is no need for the impact to be instantaneous. In the absence of close theoretical guidance, therefore, our reasoning is straightforwardly one of sequencing: change in protection (−2) impacts pricing power (−1) and the resultant combined effect impacts on productivity growth. This is applied consistently in all instances of this interaction term, see also Table 7.

prediction is that sectors that are closer to the world technological frontier should benefit more from trade liberalization.

We report empirical results from panel estimations at industry level for the South African manufacturing sector.

Our results confirm that the productivity growth impact of trade liberalization is positive, both in terms of its direct and in terms of its indirect impacts. Trade protection has a direct negative impact on productivity growth. Sectors which are closer to the international technological frontier benefit most significantly from trade liberalization. These findings are robust to controlling for potential endogeneity of the trade protection measure by means of GMM estimation, and manufacturing sector heterogeneity by means of fixed effects and pooled mean group estimation, as well as to controlling for the impact of product market competition.

Additional findings indicate that sectors with low product market competition benefit most significantly from trade liberalization. Furthermore, we report results that indicate that sectors close to the technological frontier that have greater product market competition experience higher productivity growth.

Our results also strengthen findings of a positive impact of product market competition on productivity growth. Under our open-economy specifications, controlling for trade liberalization serves to verify the positive impact of competitive pressure on productivity growth, and suggests that the impact of competition is in fact greater than suggested by specifications that do not control for the extent of trade protection. Our findings indicate a productivity growth impact of double the magnitude obtained from estimations that do not control for trade protection measures.

These results highlight the strict relationship between trade liberalization and the internal competitive environment. While trade liberalization has a positive effect on productivity growth (but not necessarily on sector size), this effect is possible only if internal market conditions are competitive enough. The results seem to suggest that the reason we do not see a technological catching up in some sectors after trade liberalization is that the market power of the national firms is actually increased, thus limiting in a different way the effect of international competition on productivity. The main policy implication of the study is therefore that trade liberalization and addressing the restrictiveness of the regulatory environment are two necessary and complementary components of outward-oriented growth strategy.

What remains to analyse is the extent of 'destruction' caused by trade liberalization, for which, ideally, we would need information about entry and exit of firms in different sectors. Nevertheless, we can notice that, according to the theory, the process of destruction and the process of technological catching up are positively correlated, because only firms able to compete internationally would be able to survive in the new competitive environment. It is therefore arguable that the limited technological catching up that we see in the data is probably a reflection of the limited amount of overall liberalization.

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Appendix A

TFP measure for South Africa and US

To calculate the Total Factor Productivity at the industry level, we have used Industry-level panel data for South Africa from the TIPS database. The variables in the dataset for the manufacturing sector include output, capital stock, and labour force variables and their associated growth rates, the distribution of value added between factor inputs, and the skills composition of the South African manufacturing labour force by manufacturing sector. The TFP is then calculated directly using production function methods, assuming a Cobb–Douglas production function with capital and labour shares of value added calculated from the data.

For the United States, instead, we use Industry-level data for 28 manufacturing industries from 1963–2003, obtained from UNIDO's International Industry Statistics 2004. This dataset contains yearly information on output, value added, total wages, and employment, gross capital formation and the distribution of value added between factor inputs From the gross capital formation data, we compute capital stock data on the basis of the perpetual inventory method. The remainder of the computation is in line with the computation for South Africa. The main objective was to make the two series of TFP comparable, thus using the same production function method.

The measure of distance is then calculated by the ratio of TFP in SA sectors relative to corresponding US sectors.

Appendix B

The pooled mean group estimator

The relationships proposed by our theory tend to hold in the long-run and deviate from its equilibrium path in the short-run. The underlying economic theory does not explore these issues, but there is still a potential need to control for dynamics. To this end, we use the PMG dynamic heterogeneous panel estimator of Pesaran *et al.* (1999).

Consider the unrestricted error-correction ARDL(p,q) representation:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \beta_i' \mathbf{x}_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}' \Delta \mathbf{x}_{i,t-j} + \mu_i + \varepsilon_{it}, \tag{A1}$$

where $i = 1,2, \ldots, N$, $t = 1,2, \ldots, T$, denote the cross-section units and time periods respectively. Here y_{it} is a scalar-dependent variable, $\mathbf{x}_{it}$ ($k \times 1$) a vector of (weakly exogenous) regressors for group i, and μ_i represents fixed effects. We allow the disturbances ε_{it}'s to be independently distributed across i and t, with zero means and variances $\sigma_i^2 > 0$, and assume that $\phi_i < 0$ for all i. Then, there exists a long-run relationship between y_{it} and $\mathbf{x}_{it}$:

$$y_{it} = \theta_i' \mathbf{x}_{it} + \eta_{it}, \; i = 1, 2, \ldots, N, \; t = 1, 2, \ldots, T, \tag{A2}$$

where $\theta_i = -\beta_i' \phi_i$ is the $k \times 1$ vector of the long-run coefficients, and η_{it}'s are stationary with possibly non-zero means. This allows (A1) to be written as the error-correction model:

$$\Delta y_{it} = \phi_i \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}' \Delta \mathbf{x}_{i,t-j} + \mu_i + \varepsilon_{it}, \tag{A3}$$

where ϕ_i is then the error-correction coefficient measuring the speed of adjustment towards the long-run equilibrium.

This general framework gives the formulation of the PMG estimation, which allows the short-run coefficients and error variances to differ freely across groups, but the long-run coefficients to be homogenous; *i.e.* $\theta_i = \theta \; \forall \; i$. Group-specific short-run coefficients and the common long-run coefficients are computed by pooled maximum likelihood estimation. Denoting these PMG estimators by $\tilde{\phi}_i$, $\tilde{\beta}_i$, $\tilde{\lambda}_{ij}$, $\tilde{\delta}_{ij}$ and

$\tilde{\theta}$, we obtain them by $\hat{\phi}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\phi}_i}{N}$, $\hat{\beta}_{PMG} = \frac{\sum_{i=1}^{N} \tilde{\beta}_i}{N}$, $\hat{\lambda}_{jPMG} = \frac{\sum_{i=1}^{N} \tilde{\lambda}_{ij}}{N}$, $j = 1,\ldots,p-1$, and $\hat{\delta}_{jPMG} = \frac{\sum_{i=1}^{N} \tilde{\delta}_{ij}}{N}, j = 0, \ldots, q-1$, $\hat{\theta}_{PMG} = \tilde{\theta}$. PMGE provides an intermediate case between the dynamic fixed-effects (DFE) estimator, which imposes the homogeneity assumption for all parameters except for the fixed effects, and the mean group estimator (MGE) proposed by Pesaran and Smith (1995), which allows for heterogeneity of all parameters. It exploits the statistical power offered by the panel through long-run homogeneity, while admitting short-run heterogeneity. To test the validity of long-run homogeneity, we employ a Hausman (1978) test (denoted *h* test in the paper) on the difference between MG and PMG estimates of long-run coefficients.

Note that the PMG estimator, while able to deal with non-stationary data (Pesaran *et al.*, 1999, section 4.2), does not preclude stationary data in estimation (Pesaran *et al.*, 1999, section 4.1).

Appendix C

Panel unit root tests

We performed the Im *et al.* (2003) and Levin *et al.* (2002) Panel Unit Root Tests, on the following variables: TFP Productivity Growth (TFP); growth in labour productivity (Y/L); the effective rate of protection (ERP), the nominal tariff rate (Nom Tar), and distance from technological frontier (M). Lag length is selected on the basis of information criteria. For all variables, test statistics reject the null of non-stationarity.[39]

Results are reported in Table A1.

Table A1. Panel unit root test

	Im-Pesaran-Shin			Levin-Lin-Chu		
	t	*P*	Lag length	*t*	*p*	Lag length
TFP	−2.523	0.000	2	−2.247	0.012	2
Y/L	−2.556	0.000	2	−1.89	0.029	2
ERP	−1.865	0.029	Varies	−6.89	0.00	Varies
Nom Tar	−1.812	0.04	Varies	−4.31	0.00	Varies
M	−1.910	0.008	Varies	−1.085	0.1390	Varies

***Note*:** *t* denotes the test statistic under the null of non-stationarity; *P* denotes the probability value of the test statistic. Varies indicates lag length different for different cross-sectional units.

[39] The sole exception is the Levin–Lin–hu test statistic for M, which only rejects the null at the 14 percent level. However, Im-Pesaran-Shin confirms the stationarity property of the variable.