

Trade barriers to growth in South Africa: Endogenous investment-productivity-trade interaction*

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Abstract

The relationship between foreign trade openness and growth is a challenge for economic analysis. Econometric approaches struggle with endogeneity of foreign trade and trade policy and endogenous interaction between investment and productivity. We offer an alternative route to identification and quantification of channels of effects based on calibration of a Ramsey growth model. The model is designed to reproduce the changing openness in South Africa 1960-2005. Productivity growth is assumed generated by innovation and adoption, and trade openness affects international productivity spillovers and catching up to the world technology frontier. International sanctions and protectionism are represented by a calibrated tariff equivalent, and the counterfactual elimination of the tariff equivalent shows large potential for GDP growth. According to our preferred parameterization increased trade share by 10% points raises GDP level over time by about 15%. Separating the effects of openness between investment and productivity we find that about 2/3 of the increase in GDP is due to increased productivity, working either directly or indirectly via investment profitability.

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1. Introduction

Foreign trade openness influences productivity growth and investment and thereby economic growth. We concentrate on these basic mechanisms of openness and offer identification and quantification of channels of effects. The econometric trade-growth analyses are critically surveyed by Rodriguez and Rodrik (2001). The econometric approach struggles with endogeneity of trade and trade policy. Even successful econometric identification of trade and trade policy effects on GDP growth does not clarify the adjustments of the vehicles of growth generation, notably investment and productivity. We suggest an alternative route to identification and quantification based on calibration of a Ramsey growth model. The model is designed to reproduce the changing openness in South Africa during 1960-2005. Productivity growth is assumed generated by innovation and adoption, and trade openness affects international productivity spillovers and catching up to the world technology frontier.

The model applies the productivity growth formulation suggested by Benhabib and Spiegel (1994, 2005) expanded to take into account trade barriers. The productivity growth is determined by the gap to the world technology frontier, the degree of interaction with the rest of the world through international trade, and the level of human capital. The investment side is taken care of in a standard Ramsey model with a representative consumer-investor. The model assumes positive effects of reduced tariffs via cheaper imported investment goods and increased international technology spillover, but also includes a demand shift towards foreign goods. The parameters of the growth model are set according to South African and middle income country evidence. The quantification attempts at capturing the investment and productivity responses to openness in this setting. The debate about the East Asia experience has constructed a horserace between capital accumulation and productivity growth. Hulten (2001) argues that productivity improvements contribute to higher capital accumulation and shows how this induced capital accumulation effect can be calculated. We include the interaction of productivity and investment in general equilibrium and separate the channels of effects of reduced trade barriers.

South Africa is an interesting case study of openness. The economic growth was promising post WWII and the country was named 'the Japan of Africa'. This growth period has been understood as catching up growth based on openness and industrial diversification, but ended in the 1970s and was turned into a long period of stagnation. Pritchett (2000) describes South

Africa as a 'mountain', where per capita growth above 1.5% per year is turned into negative numbers. The changing relationship to the world market with sanctions and trade policy reform is the motivation for this country study.

Economic growth is on the policy agenda in South Africa with the government's Accelerated and Shared Growth Initiative (ASGI-SA). The policy program primarily discusses domestic binding constraints on growth. The government has invited a group of experts to do a growth diagnostic, and input to this process has been produced by Aghion, Braun and Fedderke (2008), Edwards and Lawrence (2008), Hausmann and Klinger (2008), and Rodrik (2008), among others. The background growth diagnostic approach is outlined by Hausmann, Rodrik and Velasco (2007). Our analysis concentrates on the links to the rest of the world as constraints for growth in a general equilibrium model.

Due to international sanctions against the Apartheid regime and a complex system of import quotas the degree of protectionism in South Africa cannot be measured directly. Based on the model we offer an openness index by calibrating export and import taxes that reproduces the actual trade and growth path during 1960-2005. The effects of openness are analyzed by gradual elimination of the rise in the tariff equivalent. This counterfactual experiment raises the trade share by about 25% points and leads to an increase in the 2005 end of period GDP by 35%. The robustness of the result is investigated and the GDP-effect is in the range of 25-40% within standard parameterization. The quantitative effect is consistent with econometric studies. The cross-country analysis of Frankel and Romer (1999) finds that an increase in the trade share of 1% point raises the income level by 2%. By comparison a 1% point higher trade share leads to 1.4% higher GDP in our model. Romalis (2007) studying developing countries, finds that 10% points increase in the trade share raises the GDP per capita growth rate by 0.2-0.5% point. Our numbers imply that 10% points higher trade share translates into about 0.3% point higher GDP per capita growth rate during transition.

A more open economy implies higher degree of technological catch-up, and given the productivity mechanism assumed the 2005 productivity level relative to the world technology frontier increases from 33% to 41%. Separating the effects of openness between investment and productivity we find that about 2/3 of the increase in GDP is due to increased productivity (including the induced capital accumulation effect). International technology spillovers feeding productivity are important to raise investment and growth. By decomposing the

growth channels we find that the openness effect on long-run GDP is divided between 1/3 directly via investment, 1/3 directly via productivity and 1/3 indirectly via the productivity effect on investment profitability. Robustness tests show how the quantitative results depend on parameter values, in particular trade and productivity elasticities. The broad conclusion holds over a wide range of parameter values.

The paper presents the modeling of the productivity dynamics (section 2) and the integration into a growth model with full general equilibrium effects (section 3). Section 4 calibrates a reference growth path that is close to the growth observed during 1960-2005, while the calibrated openness index is documented in section 5. Section 6 quantifies the growth effects of trade barriers, and clarifies the importance of the productivity channel. Section 7 checks the robustness of the results based on certain parameter values. Concluding remarks are offered in section 8.

2. Productivity dynamics

Economic growth in middle income countries like South Africa is typically understood as catching up to the world technology frontier. The understanding is based on early contributions by Gerschenkron (1962) and formalized by Nelson and Phelps (1966). The implied international spillovers have emerged as the dominating explanation of the world growth pattern, as argued by Lucas (2007). Growth experiences must be understood as cross-country flows of production-related knowledge from the successful economies to the less successful ones. Klenow and Rodriguez-Clare (2005) and Aghion and Howitt (2006) offer overviews of the growth-literature based on international spillovers. Recent development of the barriers to growth model is offered by Parente and Prescott (1994, 2005). Applied growth models dealing with economic growth and productivity dynamics have been developed by Ngai (2004) for different country groups and Japan, Coleman (2005) for Japan, Duarte and Restuccia (2007) for Portugal, and Diao et al. (2005, 2006) for Thailand. The model applied here is an aggregate version of the two-sector model of Rattsø and Stokke (2007) for South Africa.

Cross-country evidence about the importance of the world technology frontier is supplied by Benhabib and Spiegel (1994, 2005), Caselli and Coleman (2006), and Griffith et al. (2004). In a study of R&D spillover in 77 developing countries, Coe et al. (1997) conclude that a

developing country can boost its productivity by importing a larger variety of intermediate products and capital equipment embodying foreign knowledge. By taking into account the endogeneity of trade and institutional quality, Alcalá and Ciccone (2004) confirm the positive effect of trade on productivity. Benhabib and Spiegel (1994, 2005) show that human capital stimulates both innovation and technology adoption.

Country studies add to the evidence. Based on panel data for UK manufacturing industries Cameron et al. (2005) document a positive and significant effect of the distance to the technological frontier on productivity growth. They also show that international trade stimulates technology transfer. Cameron (2005) finds similar results for Japanese productivity growth. Several studies indicate the importance of openness for the TFP growth in South Africa. Harding and Rattsø (2009) address the endogeneity problem of trade policy and use other regions' tariff development as part of the WTO process as instruments for the tariff reductions since 1988. They find that tariffs have been important for labor productivity and their results are consistent with the importance of the world technology frontier. Fedderke (2005) puts more emphasis to domestic factors, and identifies positive effects of R&D and human capital in South African TFP growth. Inspired by this empirical evidence we study the endogenous formation of productivity growth driven by innovation and technology adoption.

We start out from the analytical formulation of Benhabib and Spiegel (2005, equation 2.3) combining foreign technology adoption with logistic diffusion and own innovations. Consistent with the empirical literature that trade policy and openness affects technology spillovers we extend their specification to include trade barriers.

The rate of growth of labor augmenting technical progress is specified as:

$$\hat{A}_t = g(H_t) + c(H_t, T_t) \left(1 - \frac{A_t}{A_t^*} \right) = H_t^{\theta_1} + \lambda H_t^{\theta_2} T_t^{\theta_3} \left(1 - \frac{A_t}{A_t^*} \right) \quad (1)$$

The first term on the right-hand side of equation (1) represents the contribution from innovation activities, while the second term is the technology adoption function. A_t and A_t^* represent the domestic and frontier level of productivity, respectively, and A_t/A_t^* is relative productivity. The parameters λ , θ_1 , θ_2 and θ_3 are constant. We measure human capital (H_t) by the share of skilled workers in the labor force. The skill ratio is exogenous in the model, but is set according to the observed development in South Africa during 1960-2005. Trade barriers

are represented by total trade as share of GDP (T_t), which is endogenously determined.¹ The linear relationship between productivity growth and the technology gap limits the advantage of backwardness compared to the Nelson-Phelps specification. With low level of absorptive capacity (represented by high trade barriers and/or low level of human capital) long-run technological divergence is a possible outcome. This is consistent with empirical evidence showing convergence among open economies, while high trade barriers may generate a development trap (see Sachs and Warner, 1995).

Figure 1 about here.

The productivity dynamics, as well as the transitional and long-run effects of increased trade share, are illustrated in Figure 1. The horizontal axis shows the relative position to the world frontier, while the productivity growth rate is given on the vertical axis. The further to the left the economy is positioned, the larger is the technology gap. Productivity growth at the technology frontier is set exogenously equal to g . When the productivity growth rate exceeds the growth rate of the frontier, the economy is catching up and the gap decreases. Equivalent, lower productivity growth than the frontier increases the gap. When the economy's absorptive capacity is sufficient to avoid long-run technological divergence, the equilibrium productivity growth rate equals the frontier rate, and the technology gap is constant. The long run equilibrium consequently implies a proportional relationship between A_t and A_t^* :

$$A_t = \frac{H_t^{\theta_1} + \lambda H_t^{\theta_2} T_t^{\theta_3} - g}{\lambda H_t^{\theta_2} T_t^{\theta_3}} \cdot A_t^* \quad (2)$$

The long-run values of human capital and the trade share are constant, and, together with the frontier growth rate and the parameters, they determine relative productivity. The degree of catch-up depends on the level of barriers and the innovative capacity of the economy. Changes in the sources of innovation and adoption generate transitional growth to a new technology gap, represented in Figure 1 by an increase in the trade share.

The formulation allows parameterization according to characteristics of the South African economy and implies endogenous productivity growth responding to changes in the skill ratio and the trade share. Future theoretical and empirical research can strengthen the foundation for the specific form of the productivity relationship.

¹ The complementarity between trade and human capital in technology adoption is also investigated by Stokke (2004) for the case of Thailand.

3. The Ramsey growth model

Calibrated general equilibrium models have been used in the Parente and Prescott (1994) tradition emphasizing barriers to capital accumulation (see for instance Chari et al., 1996; Restuccia, 2004). Technological change is exogenous as in the standard Solow model. Compared to this literature we focus on open economy mechanisms and the interaction between endogenous productivity and investment. The endogeneity of productivity growth with barriers to technology adoption is the essential aspect of this approach, and is based on Nelson and Phelps (1966) and Benhabib and Spiegel (1994, 2005). Open economy dynamics have been investigated by Ferreira and Trejos (2006) combining the Heckscher-Ohlin trade framework with a standard neoclassical model. Quantification of the model illustrates how protectionism may explain cross-country income and productivity differences. Similar results are found by Waugh (2007). While these analyses focus on the productivity effect from comparative advantage, we relate trade barriers to the adoption of foreign technology.

The productivity dynamics explained in the previous section are embedded in a growth model with general equilibrium effects. We assume standard intertemporal decision making of a representative firm and a representative household. The model captures a small open economy, and the growth pattern does not influence world prices or the world interest rate, which are exogenously given. The growth model describes an economy with macroeconomic stability, full employment of resources, and an open capital market. Some rigidity is built in with cost of investment adjustment, imperfect substitution between domestic and foreign goods, and imperfect substitution between sales to export markets versus domestic markets. But the overly flexibility in resource allocation motivates further research emphasizing domestic market imperfections.

Gross output (X_t) is defined as a Cobb-Douglas function of unskilled labor (Lu_t), skilled labor (LS_t) and capital (K_t):

$$X_t = A_t^{\alpha_1 + \alpha_2} L u_t^{\alpha_1} L S_t^{\alpha_2} K_t^{1 - \alpha_1 - \alpha_2} \quad (3)$$

where labor augmenting technical progress (A_t) develops endogenously according to equation (1). The first order conditions equilibrate factor prices with the marginal productivities of each factor. Intermediate goods are employed according to a fixed coefficient. We assume

imperfect substitution between producing for the domestic market and for the world market. The supply functions for exports (E_t) and domestic sales (D_t) are derived from maximizing current sales income subject to the constant elasticity of transformation (CET) function:

$$\text{Max } PD_t \cdot D_t + PWE_t(1 - te_t) \cdot E_t \quad (4)$$

$$\text{s.t. } X_t = ac[mc \cdot E_t^{\frac{1+\sigma_e}{\sigma_e}} + (1 - mc)D_t^{\frac{1+\sigma_e}{\sigma_e}}]^{\frac{\sigma_e}{1+\sigma_e}} \quad (5)$$

where σ_e is the constant elasticity of substitution between domestic and foreign markets. The parameters ac and mc are constant. The producer price is a composite of the exogenous world market price of export goods (PWE_t) adjusted by export taxes (te_t) and the endogenous domestic price (PD_t).²

The representative firm makes its investment decision according to intertemporal profit maximization, subject to the accumulation of the capital stock over time:

$$\text{Max}_{I,K} \sum_{t=1}^{\infty} (1+r)^{-t} [Rk_t \cdot K_t - (P_t \cdot I_t + ADJ_t)] \quad (6)$$

$$\text{s.t. } K_{t+1} = K_t \cdot (1 - \delta) + I_t \quad (7)$$

where r is the exogenous world market interest rate, Rk_t is the capital rental rate, I_t is investments, ADJ_t is investment adjustment costs, and δ is the rate of depreciation. Following the common practice in the literature, unit adjustment costs are specified as a positive function of the investment-capital ratio. Hence, total adjustment costs are given as:

$$ADJ_t = a \cdot P_t \cdot \frac{I_t^2}{K_t} \quad (8)$$

where a is a constant parameter. Total investment demand includes the adjustment costs.

Differentiating the intertemporal profit function with respect to I_t gives:

$$q_t = P_t + 2 \cdot P_t \cdot a \cdot \frac{I_t}{K_t} \quad (9)$$

This relationship says that the investor equilibrates the marginal cost of investment, which is given on the right hand side, and the shadow price of capital, q . Differentiating the same function with respect to K_t gives the following no-arbitrage condition:

² The value added price (PV_t) is defined as $PV_t = PX_t(1 - ta) - P_t \cdot IO$, where PX_t is the producer price, ta is the sales tax rate, P_t is the demand-side price level, and IO is the fixed input-output coefficient. Gross domestic product (GDP_t) is thus given as $GDP_t = PV_t \cdot X_t$.

$$r \cdot q_{t-1} = Rk_t + a \cdot P_t \cdot \left(\frac{I_t}{K_t} \right)^2 - \delta \cdot q_t + \dot{q}_t \quad (10)$$

Equation (10) states that the marginal return to capital must equal the interest payments on a perfectly substitutable asset with a value of q_{t-1} . The first term on the right-hand side is the capital rental rate, while the second term is the partial derivative of the adjustment cost function with respect to capital. The marginal return to capital must be adjusted by the depreciation rate and by the capital gain or loss, \dot{q}_t .

Investments can be financed through foreign borrowing, and the decisions about savings and investment can therefore be separated. The model includes a long-run restriction on foreign debt, and exports response to satisfy the intertemporal budget constraint. Foreign debt ($DEBT_t$) is accumulated over time from trade deficits ($FSAV_t$) and interest payments on outstanding debt:

$$DEBT_{t+1} = DEBT_t \cdot (1 + r) + FSAV_t \quad (11)$$

The representative household receives income through the primary factors, while interest payments on its foreign debt are subtracted. There is no independent government sector, so public tax revenues (sales and trade taxes) are transferred to the household in the form of a lump sum. The household is forward-looking and maximizes an intertemporal utility function taking into account the current budget constraint for each period:

$$Max \sum_{t=1}^{\infty} (1 + \rho)^{-t} U(C_t) \quad (12)$$

$$s.t. P_t \cdot C_t = Y_t - SAV_t \quad (13)$$

Assuming intertemporal elasticity of substitution equal to unity, the utility function is defined as $U(C_t) = \ln C_t$, where C_t is consumption in period t . Y_t is household income, SAV_t is private savings, and ρ is the positive rate of time preference. The utility maximization gives the Euler equation for optimal allocation of consumption over time:

$$\frac{P_{t+1} C_{t+1}}{P_t C_t} = \frac{1 + r}{1 + \rho} \quad (14)$$

Consumption growth depends on the interest rate, the time preference rate, and the price path.

We assume imperfect substitution between domestic and foreign goods, so the model consequently operates with a composite good. The demand functions for imports (M_t) and domestic goods (D_t) are derived from minimizing current expenditure subject to the Armington function:

$$\text{Min } PWM_t(1+tm_t) \cdot M_t + PD_t \cdot D_t \quad (15)$$

$$\text{s.t. } CC_t = aa[ma \cdot M_t^{\frac{\sigma_m-1}{\sigma_m}} + (1-ma)D_t^{\frac{\sigma_m-1}{\sigma_m}}]^{\frac{\sigma_m}{\sigma_m-1}} \quad (16)$$

where σ_m is the constant elasticity of substitution between domestic and foreign goods. CC_t represents total absorption of the composite good, including intermediate, consumption and investment demand. The parameters aa and ma are constant. The price level facing domestic agents (P_t) is a composite of the exogenous world market price of import goods (PWM_t) adjusted by import tariffs (tm_t) and the endogenous domestic price (PD_t). A reduction in trade barriers (lower import tariffs) stimulates investment activities through less expensive investment goods from abroad.

With sufficient level of absorptive capacity, the long-run growth rate is exogenously given as $g+n$, where g is the frontier rate of labor augmenting technical progress and n is the labor supply growth rate. The growth rate of the capital stock and the foreign debt approaches the constant rate in the long run. Productivity growth equals the world frontier rate, and the technology gap is constant. These dynamics are consistent with the common understanding that differences in income and productivity levels are permanent, while differences in growth rates are transitory (Acemoglu and Ventura, 2002). The model reproduction of South African growth during 1960-2005 (explained in the next section) is of transitional character, and thus endogenous.

4. Reproducing the growth path for South Africa

The parameters of the model are set to reproduce the broad economic development in South Africa during the past decades. Starting out from a consistent data base in the base year 1998, we calibrate backward a growth path that is close to the observed real GDP growth during 1960-2005. To reproduce actual GDP growth, the initial levels of capital and productivity are scaled down compared to the steady state path. The scaling back serves as an exogenous shock that takes the economy outside the equilibrium long run path in 1960, and economic

growth is driven by endogenous adjustment back to equilibrium growth. The model parameters are consistent with long run equilibrium, where the growth rate is assumed to equal 2% (1.3% technological progress rate and 0.7% labor growth).³ The long run growth path must be consistent with the macroeconomic equilibrium as represented by the Euler equation: $r = (1 + \rho)(1 + g + n) - 1$, where $g + n$ is the exogenous long-run growth rate. Appendix Table 1 gives an overview of selected calibrated parameters.⁴

The parameters of the productivity specification given in equation (1) are calibrated. The elasticity of productivity growth with respect to the trade share is given by the parameter θ_3 multiplied by the adoption share in productivity growth. In the model simulations the relative importance of technology adoption is endogenous and varies over time and across scenarios. Assuming an elasticity of productivity growth with respect to the trade share in the range 0.6-0.9, we set $\theta_3 = 1.3$. An increase in the trade share of 10% points gives 0.2-0.4% point higher productivity growth when starting from the assumed steady state rate.⁵ The magnitude of the effect is consistent with econometric estimates offered by Romalis (2007). He applies US tariff data as instruments for openness in developing countries, and shows that 10% points increase in the trade share generates 0.2-0.5% point higher GDP per capita growth rate. Cameron et al. (2005) examine the role of international trade (measured by total imports as share of output) for TFP growth in UK manufacturing industries during 1970-92. In their preferred specification 10% points increase in the import share gives about 1% point higher TFP growth.⁶ Compared to this estimate, the elasticity of productivity growth with respect to the trade share applied in our model can be seen as conservative. Calibration of the other productivity parameters, as well as trade elasticities, is documented in the Appendix. In section 7 we investigate how the quantitative effects of trade barriers depend on key parameters.

The degree of openness and the human capital level is important to reproduce the actual growth path. The supply of different labor types is set according to data on employment

³ The assumption of 0.7% labor growth is consistent with data on average annual employment growth in South Africa during 1971-2005 (Quantec Research, 2007).

⁴ Detailed documentation of the calibration and the 1998 Social Accounting Matrix is given in a separate appendix available from the authors.

⁵ The calculation is based on trade shares in the range 0.3-0.6, which is consistent with the values in the model simulations.

⁶ This is calculated based on the coefficient on the interaction term between the import share and the technology gap in regression 2 in their Table 4. We proxy the average value of the technology gap by the average of the 1970 and 1992 value as reported in their Table 2.

shares by skill level (Quantec Research, 2007).⁷ The share of unskilled workers in the total labor force declines from 78% to 44% during 1960-2005, and with a corresponding increase in the skilled labor share from 22% to 56%. The share of skilled workers in the labor force represents our measure of human capital in the productivity specification. An important element of the South African experience is the changing trade conditions over time, and in particular the sanctions and protectionism from the mid 1970s to the early 1990s. We capture the degree of trade barriers by calibrating a tariff equivalent level that reproduces the actual trade path (further explained in section 5 below).

Figure 2 shows how we track the actual growth rate as a steady decline in the model growth rate during 1961-90, followed by constant growth since 1990. The South African growth experience can be understood as neoclassical convergence, trade barriers and human capital affecting international spillovers, and endogenous interplay between productivity and investment profitability. While the initial high growth was driven by investment and profitability, the stagnation involved a drop in productivity growth due to reduced technology adoption and an associated fall in investment profitability. Sanctions and protectionism have served as barriers to productivity growth and investment, and the economy is not able to catch up with the frontier. Elimination of sanctions and trade liberalization have stimulated economic growth with reduced barriers post Apartheid.

Figure 2 about here.

5. Measuring trade barriers by tariff equivalent

The general equilibrium model allows for measurement of the hard to measure protectionist factors affecting international trade. Given the growth projection we calibrate export and import taxes necessary to reproduce the observed export and import paths during 1960-2005. The development of terms of trade and real effective exchange rate are calibrated consistent with data to adjust for the impact of world price shocks on the trade level.⁸ Total trade taxes as share of trade represents our measure of openness. Figure 3 reports the reproduction of the trade path, while the tariff equivalent is illustrated in Figure 4.

⁷ The Quantec Research data separates between three labor types (unskilled, skilled and highly skilled). We label skilled and highly skilled workers as skilled. The supplies of skilled and unskilled labor are extended backwards to 1960 based on average growth rates during 1970-2005.

⁸ The calibration is given in a separate appendix available from the authors.

Figure 3 and 4 about here.

While the tariff equivalent decreases during the 1960s, the slow growth of exports and imports in the 70s and 80s requires a gradual increase of the tariff-equivalent with a peak in the late 1980s of about 55%. After 1990 the removal of sanctions together with a gradual liberalization of the trade policy increased trade rapidly, reflected in the model by decreasing tariffs. The underlying paths of the export tax and the import tax are documented in a separate appendix available from the authors. To reproduce the actual import path the import tax is initially high, decreases during the 1960s, increases to a peak of about 65% in the late 1980s, and then decreases rapidly to 7% in 2005. The export tax is low during the 1960s, but to capture the slowdown in exports in the 1970s and 80s it is necessary to gradually increase the tax to about 45%. The export tax is also declining post Apartheid, but remains above 30% even in 2005 indicating that domestic conditions are holding back South African exports. Interestingly, the calibrated tariff paths are consistent with tariffs calculated from partial analyses of exports and imports with reasonable values of elasticities. The export function is assumed to depend on the world level of GDP and the real effective exchange rate, with elasticities set equal to 1.⁹ The import function is assumed to depend on the South African GDP level and the real effective exchange rate, with elasticities set equal to 1.2 and -1.5, respectively.

Existing measures of openness in South Africa are scarce. A recent contribution by Edwards and Lawrence (2008) offers data on tariffs and surcharges since 1960. The development path (illustrated in their Figure 3) with liberalization in the 1960s, increasing protectionism since the mid 70s, peak in 1990, and liberalization since 1990, is consistent with our calibrated tariff equivalent measure of openness. Aron and Muellbauer (2002) develop an openness indicator for South Africa based on econometric estimation. Their model includes a measure of tariffs and surcharges, while the unobservable effect of sanctions and quotas are captured by a non-linear stochastic trend. The indicator illustrates the changing degree of openness during 1970-2000 with increasing protectionism in the 70s, sanctions and protectionism in the 80s and trade liberalization after 1990. Compared to the analysis by Aron and Muellbauer our openness indicator takes into account that both imports and exports are held back by

⁹ The real effective exchange rate is defined as the nominal exchange rate times the foreign price level relative to the domestic price level, and is given by IMF (2006).

sanctions, covers a longer time period, and gives a more intuitive measure of openness (export and import tax as share of total trade).

6. Quantification of the investment and productivity responses to openness

The growth model allows a counterfactual analysis of the role of international trade and thereby a quantification of the growth effect of trade barriers. Changing trade policy barriers over time leads to prolonged transitional growth. As explained in section 5, we have calibrated a tariff-equivalent growing from the late 60s and with a peak in the late 1980s to reproduce the actual trade and growth path. Eliminating the rise in the tariff-equivalent during the period of sanctions and protectionism, we can simulate the economic development in a more open economy. In the experiment, the import tax decreases gradually from about 60% in 1960 to 7% in 2005, while the export tax decreases from 5% in 1960 and remains equal to zero from 1966. This implies a gradual decrease in the tariff equivalent level (gradual trade liberalization), as illustrated in Figure 4.¹⁰ The average tariff rate during 1960-2005 equals 16%, down from 38% along the reference path reproducing the actual growth in South Africa.

The new GDP growth path is shown in Figure 5 below. Given the investment and productivity links to openness assumed, the analysis shows that South Africa could have avoided some of the decline in the growth rate. The sanctions and protectionism have contributed to more costly investment goods and less technology adoption and consequently held back economic growth. In the counterfactual open economy scenario the average trade share during 1980-2005 is 25% points higher than along the reference path. Productivity growth increases, and the period of technological stagnation is avoided. As seen from Figure 6, the economy catches up relative to the world technology frontier. Relative productivity increases from 33% to 41%, and generates a long-run productivity gap of about 8% points between the two scenarios. Investment profitability is stimulated by less expensive foreign capital goods and higher productivity growth. The quantification shows that investments are raised by nearly 50% compared to the reference path with sanctions and protectionism. The growth effect adds up to a rather large permanent income gap between the two scenarios. The model predicts that the 2005 level of real GDP is 35% higher when trade barriers are eliminated.

¹⁰ The tariff equivalent equals the sum of the export tax and the import tax, weighted by the export and import shares of total trade, respectively. During the first years the export and import tax are equal in the two scenarios, but since the weights are endogenous, the tariff equivalent is somewhat higher in the open economy scenario.

Figure 5 and 6 about here.

The quantitative effects reported above are comparable to econometric studies. The relationship between trade share and GDP is the key issue. Given our parameterization, the tariff liberalization increases the trade share by about 25% points on average for the ‘effect period’ after 1980. The higher trade share is associated with an increase in the 2005 end of period GDP by 35%. The cross-country analysis of Frankel and Romer (1999) finds that an increase in the trade share by 1% point raises the income level by 2%. By comparison a 1% point higher trade share leads to 1.4% higher GDP in our model. Romalis (2007) studying developing countries, finds that 10% point increase in the trade share raises the GDP per capita growth rate by 0.2-0.5% point. Our numbers imply that 10% point higher trade share translates into about 0.3% point higher GDP per capita growth rate during transition.

The model clarifies how the timing and expectation of trade policy can generate a complicated dynamic pattern of response. In our setting, future trade liberalization is expected and influences current investment and production decisions. Gradual trade liberalization gives an immediate drop in both the investment rate and the trade share compared to the reference path. Current investments are postponed since investors will take advantage of cheaper imported investment goods in the future. In addition, higher expected productivity with a more open economy increases the expected profitability of future investments and contributes to lower initial investment rate. Over time the profitability of capital accumulation increases, and the 2005 investment rate is higher in the open economy scenario. Gradual trade liberalization has a similar effect on foreign trade. The initial trade share falls by 2% points, mainly driven by lower export share. When cheaper foreign goods and lower export taxes are expected in the future, current trade is held back. Over time the trade share increases, and is about 25% points higher than along the calibrated South Africa path.

Our main interest is a clarification of the vehicles from openness to growth, the endogenous adjustment of productivity and investment. To separate different channels of effects we run counterfactual experiments with exogenous productivity growth and compare the quantitative

effects of reduced tariffs to the results with endogenous productivity growth.¹¹ The share of the effects of reduced tariffs on GDP, investment, and the trade share working via the productivity channel are illustrated in Table 1.¹²

Table 1 about here.

The effect of trade liberalization on capital investments works via two channels. First, lower tariffs imply less expensive foreign capital goods. Second, a more open economy benefits from technology adoption and has higher productivity level, which in turn increases the profitability of investments. As seen from Table 1, the increase in the 2005 real investment level of 50% is reduced to 17% when the productivity effect is not included. This implies that 2/3 of the investment response to trade liberalization is due to increased productivity. This is the induced capital accumulation effect highlighted by Hulten (2001).

The effect of trade liberalization on long-run GDP works via three channels. First, more openness reduces the cost of adopting foreign technology by limiting the trade barriers to technology transfer, and productivity growth increases (the direct productivity effect). Second, lower tariffs imply less expensive foreign capital goods, which generates more capital accumulation (the direct investment effect). Third, trade liberalization increases GDP growth indirectly through the endogenous interplay between productivity and investment profitability. As seen from Table 1, about 2/3 of the increase in real GDP comes from higher productivity, working either directly or indirectly in interaction with investment profitability. To separate the direct productivity effect from the induced capital accumulation effect, we calculate the long-run GDP effect of trade liberalization without the interaction effect.¹³ The broad conclusion is that the openness effect on growth is divided between 1/3 directly via investment, 1/3 directly via productivity and 1/3 indirectly via the productivity effect on investment profitability.

¹¹ Along the South African reference path productivity growth is stagnant and about equal to the growth rate at the frontier. In the exogenous productivity scenario we therefore assume productivity growth equal to the frontier rate so that the reference path is similar in the two experiments.

¹² Given our focus on international spillover for productivity growth, the feedback from investment to productivity is limited. Investment here basically influences productivity through the composition of the capital stock with respect to domestic and foreign investment goods. As seen from Table 1, the trade/GDP response to lower tariffs is roughly independent of the investment response. The analysis below consequently concentrates on the indirect effect of productivity on capital investment.

¹³ This calculation is based on the capital path from the exogenous productivity scenario and the productivity path implied by the trade share in the exogenous productivity scenario.

7. Robustness tests

The quantitative results reported in the previous section obviously depend on parameter values, in particular trade and productivity elasticities. In the base-run simulations the elasticity of substitution between domestic and foreign goods (σ_m) is assumed to equal 3, while the elasticity of substitution between domestic markets and export markets (σ_e) is set to 2 (consistent with empirical estimates documented in the Appendix). The elasticity of productivity growth with respect to the trade share is given by the parameter θ_3 multiplied by the share of adoption in productivity growth. We set $\theta_3 = 1.3$, giving an elasticity in the range 0.6-0.9 (broadly consistent with available econometric estimates documented in section 4). Below we investigate how the quantitative effects of trade barriers depend on these parameter values.

Table 2 shows how the quantitative results change with the level of trade elasticities. A low elasticity of substitution implies that it is hard to substitute between domestic and foreign goods, as well as between domestic and foreign markets. Trade is therefore kept relatively high also along the reference path with an increasing tariff equivalent. The lower the elasticity of substitution, the smaller the quantitative effects of reducing trade barriers (the difference between a closed and an open economy is reduced). With trade elasticities equal to 1.5 we observe technological catch-up in both scenarios, and the difference in degree of catch-up is 5% points, compared to 8% points in the base run scenario with higher elasticities. The 2005 level of real GDP is 24% (rather than 35%) higher in the more open economy. With high elasticity of substitution (equal to 4.5 for imports and 2.5 for exports) trade is reduced more when the tariff equivalent increases, which means that the degree of catch-up is held back along the reference path (and the economy even diverges). The quantitative effects of reduced tariffs are larger than in the low elasticity scenario.

Table 2 about here.

Table 3 shows how the elasticity of productivity growth with respect to the trade share (θ_3) alters the quantitative effects of trade barriers. A lower value of θ_3 means that the impact of changes in the trade share on productivity growth is smaller. If the trade share increases with

1%, the technology adoption part of productivity growth increases with θ_3 %. During international isolation the trade share decreases and productivity growth is held back. The lower the value of θ_3 , the smaller is the negative effect of isolation on productivity growth and the higher is the degree of catch-up. Hence, the quantitative effects of trade barriers are lower the lower the elasticity of productivity growth with respect to the trade share. With low (0.8) and high (1.8) values of θ_3 the increase in the 2005 real GDP level due to a more open economy is 26% and 43%, respectively, compared to 35% in the base run scenario.

Table 3 about here.

Independent of the values of trade and productivity elasticities the relationship between the trade share and GDP is quite robust. As illustrated in the bottom row of Tables 2 and 3, the GDP effect of an increase in the trade share of 1% point is in the range 1.0-1.7% (compared to 1.4% with the preferred values of elasticities). The decomposition of the effects of trade liberalization is fairly stable across different parametrizations. The importance of the productivity channel for the investment response to lower tariffs remains high and lies in the range 54-72% (compared to 66% with the preferred values of elasticities). Higher productivity (working either directly or indirectly as an induced capital accumulation effect) contributes to 50-75% of the increase in GDP. The endogenous interaction between productivity and investment profitability (the third channel of growth) accounts for 26-40% of the long-run GDP effect of trade liberalization (compared to about 33% with the preferred values of elasticities).

8. Concluding remarks

The analysis addresses the relationship between trade and growth using South Africa as a case study. We offer identification and quantification of the channels of effects using a Ramsey growth model extended to capture catching up and barriers to growth. The econometric literature has estimated the effect of trade barriers for economic growth, but has not clarified the endogenous adjustment of foreign trade, investment and productivity. We show how investment and productivity interact and respond to change of openness based on calibration. Due to international sanctions against the Apartheid regime and a complex system of import quotas the degree of protectionism cannot be measured directly. Based on the model we offer

an openness index by calibrating a tariff equivalent that reproduces the actual trade path during 1960-2005.

The growth model allows a counterfactual analysis of the role of international trade and thereby a quantification of the growth effect of trade barriers. The quantification emphasizes investment and productivity as channels to growth. The effects of openness are analyzed by gradual elimination of the rise in the tariff equivalent. This counterfactual experiment raises the trade share by about 25% points and leads to an increase in the 2005 end of period GDP by 35%. The robustness of the result is investigated and the GDP-effect is in the range of 25-40% within standard parameterization. The implied relationship between trade share and GDP is consistent with recent econometric studies. Given the productivity mechanism assumed, a more open economy reduces the cost of technology adoption and contributes to higher degree of technological catch up. Separating the effects of openness between investment and productivity we find that about 2/3 of the increase in GDP is due to increased productivity (including the induced capital accumulation effect). By decomposing the growth channels we find that the openness effect on long-run GDP is divided between 1/3 directly via investment, 1/3 directly via productivity and 1/3 indirectly via the productivity effect on investment profitability. Robustness tests show how the quantitative results depend on parameter values, in particular trade and productivity elasticities. The broad conclusion holds over a wide range of parameter values.

The quantitative results of the analysis reflect the growth potential assuming well-functioning domestic markets taking advantage of international spillovers. South African growth under new rule has been reluctant and there is widespread disappointment about the recent growth results. The lack of growth response to more openness and human capital points to domestic market imperfections beyond the growth constraints discussed in this paper. The econometric analysis of Aghion, Fedderke, Howitt, Kularatne and Viegli (2008) indicates that competition may be important for the foreign spillover channel in South Africa, which is consistent with the analysis of domestic competition conditions by Aghion, Braun and Fedderke (2008). Our model calibration approach can be extended in this direction in further analysis of how domestic market imperfections hold back the potential gains from openness identified here.

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Appendix: Calibration of trade and productivity elasticities

Productivity growth is given by equation (1) in section 2:

$$\hat{A}_t = H_t^{\theta_1} + \lambda H_t^{\theta_2} T_t^{\theta_3} \left(1 - \frac{A_t}{A_t^*} \right)$$

where H is the human capital level (measured by the skill ratio), T is total trade as share of GDP, and A/A^* is the productivity level relative to the world technology frontier. The elasticity of productivity growth with respect to the trade share is given by the parameter θ_3 multiplied by the adoption share in productivity growth. We assume $\theta_3 = 1.3$, which gives an elasticity of productivity growth with respect to the trade share in the range 0.6-0.9. As documented in section 4, this is consistent with available econometric estimates.

The elasticity of productivity growth with respect to the skill ratio is given by θ_1 multiplied by the innovation share plus θ_2 multiplied by the adoption share. We set $\theta_1 = \theta_2 = 0.6$, which gives an elasticity of 0.6. If the skill ratio increases with 1%, productivity growth increases with 0.6%, and the effect works via both innovation and technology adoption. This implies that an increase in the skill ratio of 10% points gives 0.2-0.35% point higher productivity growth when starting from the assumed steady state rate (1.3%).¹⁴ In an analysis of 19 OECD countries during 1960-2000 Vandenbussche et al. (2006) find that human capital (measured by the share of the adult population with some tertiary education) stimulates TFP growth, and that the positive effect of human capital decreases with the distance to the technological frontier. Evaluated at the average technology gap among the OECD countries in the analysis ($A/A^* = 0.74$) their results imply that 10% points higher skill ratio generates about 1% point higher TFP growth rate.¹⁵ The smaller magnitude of effect assumed in our analysis (0.2-0.35% point) seems reasonable since South Africa is further from the technological frontier.

The effect of the technology gap on productivity growth is given as $\frac{\partial \hat{A}}{\partial (A/A^*)} = -\lambda H^{\theta_2} T^{\theta_3}$,

which equals about -2 when calculated from the base year values of the skill ratio and the trade share. If relative productivity increases by 10% points (for instance from 0.3 to 0.4), productivity growth decreases by 0.2% point (for instance from 1.3% to 1.1%). This reflects the increase in adoption costs (lower learning potential) as the economy catches up towards the frontier. The magnitude of the effect is in line with econometric estimates offered by Hansson and Henrekson (1994). In a cross-country study they find a significant effect of the technology gap in interaction with human capital and trade openness on labor productivity growth. According to their estimates, 10% increase in the technology gap (A/A^*) gives 0.06-0.1% point lower labor productivity growth rate. This implies that if the technology gap increases by 10% points from 0.3 to 0.4 (33% increase), productivity growth decreases by 0.2-0.3% point.

The trade elasticities represent substitution possibilities between domestic and foreign goods (σ_m), and between sales to domestic markets versus export markets (σ_e). We set $\sigma_m = 3$ and $\sigma_e = 2$, which is consistent with available national and international estimates. Hertel et al.

¹⁴ The calculation is based on skill ratios in the range 0.22-0.56, which reflects the development during 1960-2005 in the model simulations.

¹⁵ The calculation is based on estimated coefficients in regression 5 of Table 4 in Vandenbussche et al. (2006). The average technology gap is given in their Table 1.

(2007) combine parameter estimation and general equilibrium modeling. Based on data from five Latin American countries, the US and New Zealand they estimate the elasticity of substitution among imports from different countries. The “rule of two” says that the elasticity of substitution across imports by sources is equal to twice the elasticity of substitution between domestic and foreign goods.¹⁶ Based on this hypothesis the average Armington elasticity across sectors equals 3.5. IDC (1997) and Gibson (2003) offer Armington estimates for South African manufacturing industries and the average elasticity (among significant estimates) equals 1.8 and 1.1, respectively. However, these are short-run elasticities, which are normally smaller than long-run elasticities more relevant in our setting. Available estimates of export elasticities are more limited. Senhadji and Montenegro (1999) estimate export elasticities for 53 developing and developed economies. The average elasticity across middle income countries is 1.7.

Appendix Table 1. Selected calibrated parameters

Parameter	Description	Value
r	World market interest rate	0.11
ρ	Time preference rate	0.09
g	Long-run technical progress rate	0.013
n	Labor growth rate	0.007
α_1	Unskilled labor share in production	0.19
α_2	Skilled labor share in production	0.34
$1-\alpha_1-\alpha_2$	Capital share in production	0.47
δ	Rate of depreciation	0.04
θ_1	Parameter in the productivity specification	0.6
θ_2	Parameter in the productivity specification	0.6
θ_3	Parameter in the productivity specification	1.3
σ_m	Armington elasticity	3.0
σ_e	CET elasticity	2.0

¹⁶ Empirical support for the “rule of two” hypothesis is offered by Liu et al. (2004).

Figure 1. Productivity dynamics: Transitional and long-run effects of increased trade share.

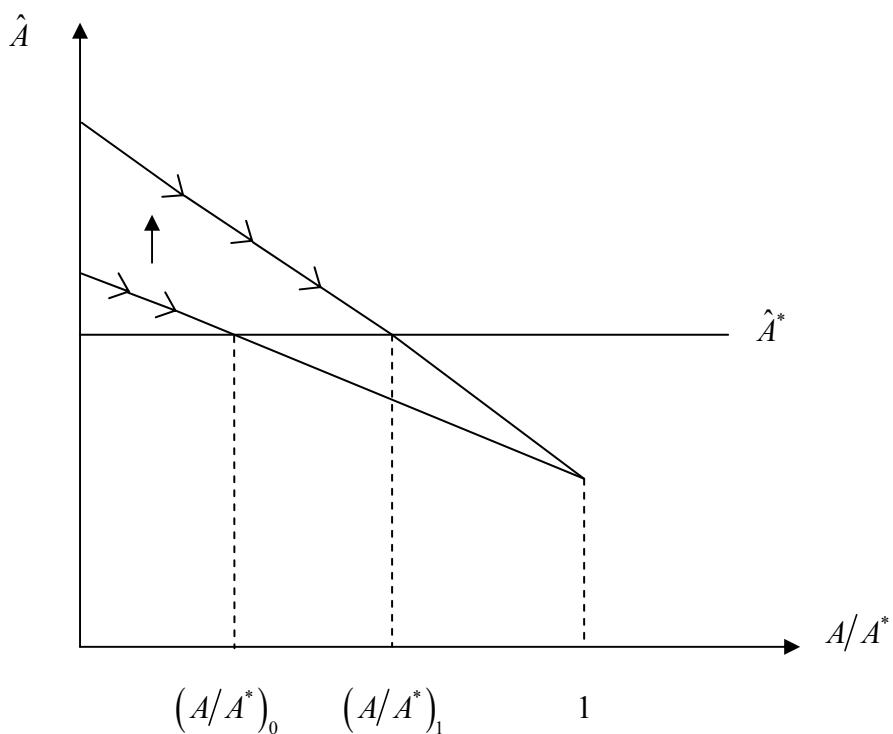


Figure 2. Real GDP growth rate: Calibrated path of model versus actual growth (measured as 3-year moving average)

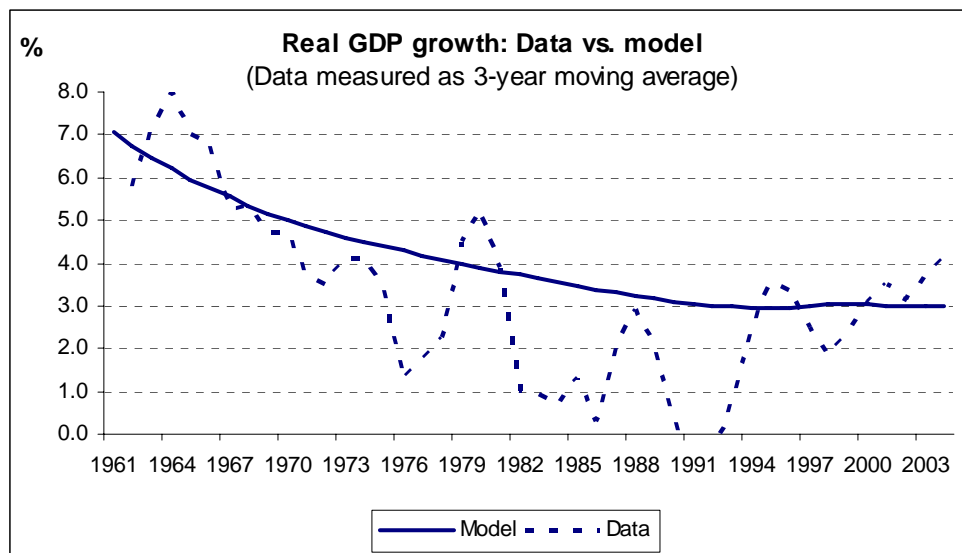


Figure 3. Total trade: Calibrated path of model versus actual path (given in Billions of 1995 rand)

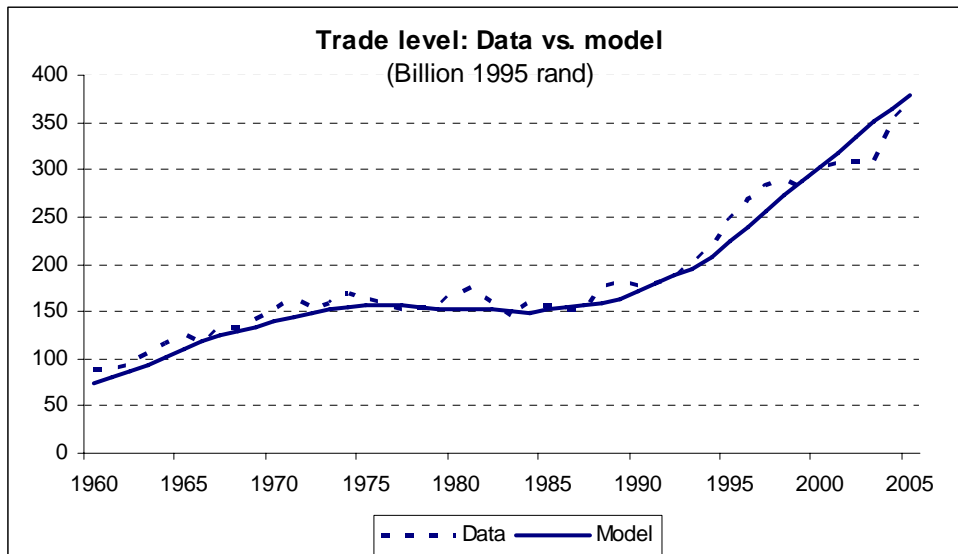


Figure 4. Calibrated openness indicator for South Africa 1960-2005 and counterfactual trade liberalization path. Indicator measured as import tax and export tax as share of total trade.

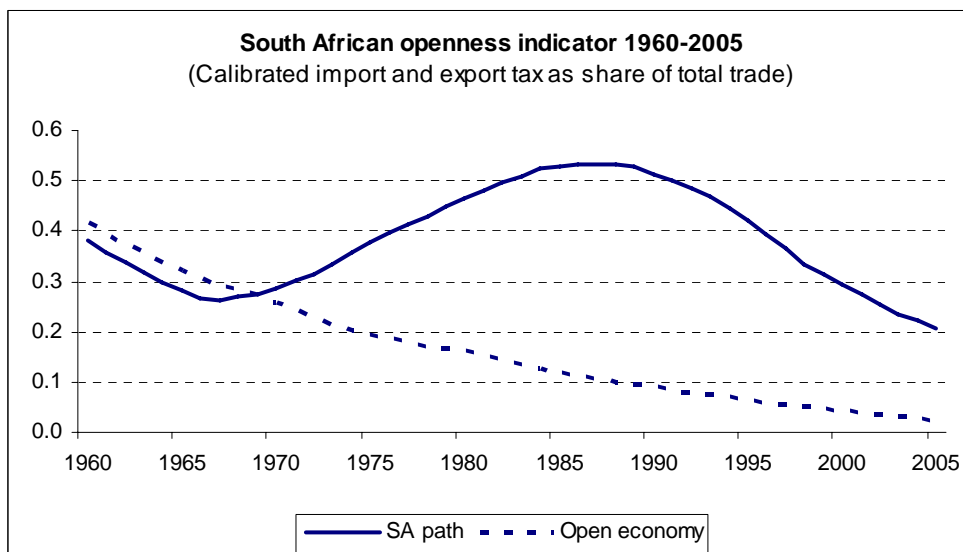


Figure 5. Real GDP growth: Calibrated path versus counterfactual path

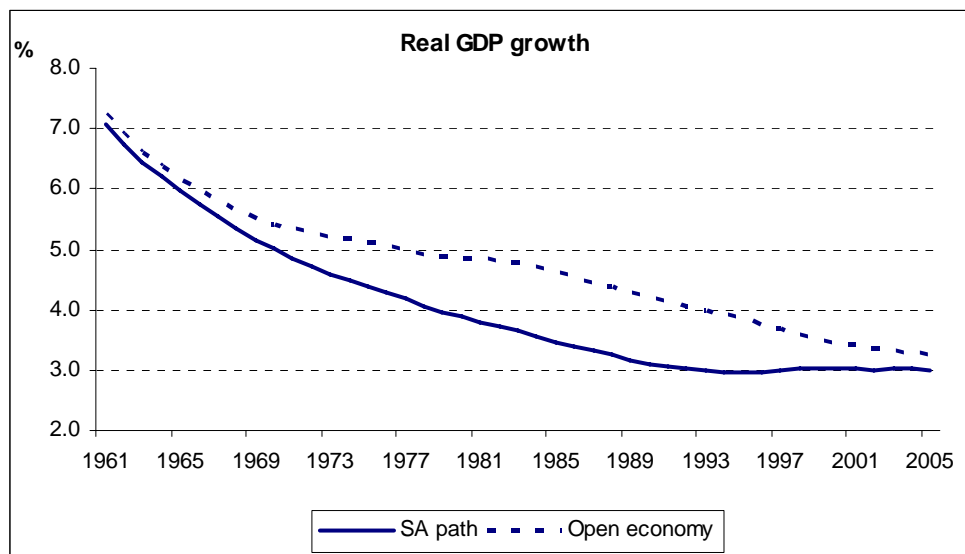


Figure 6. Domestic productivity level relative to the frontier: Calibrated path versus counterfactual path.

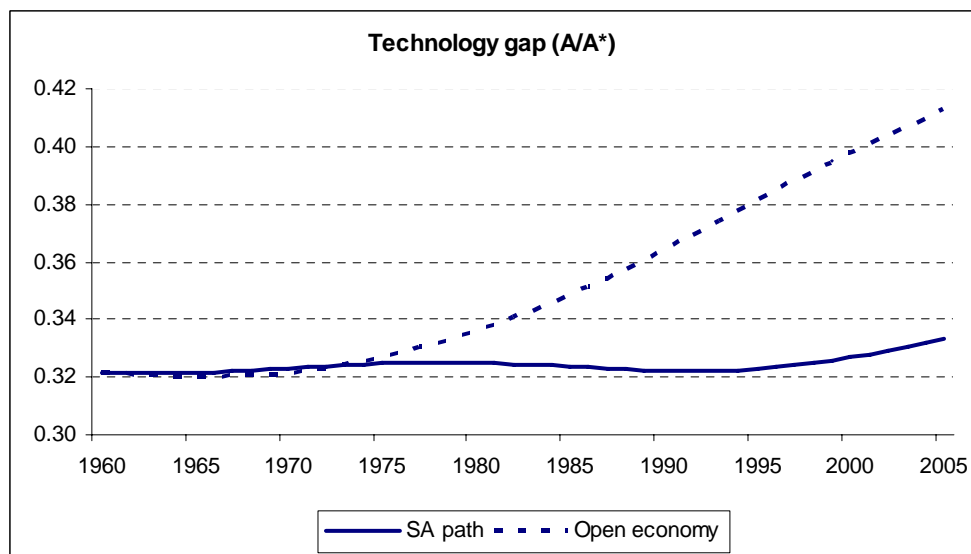


Table 1. The impact of eliminating the rise in the tariff equivalent on key macro variables:
The share of the effect working via increased productivity growth

	Exogenous productivity growth ¹	Endogenous productivity growth ¹	Share of reduced tariff effect working via increased productivity
Real GDP	11 % increase	35 % increase	69 %
Real investment	17 % increase	50 % increase	66 %
Trade/GDP	23 % points increase	25 % points increase	8 %

¹ The values give the impact of tariff reductions on the end of period (2005) level of GDP and investment, and on the average trade share during 1980-2005.

Table 2. Quantitative effects of trade barriers for different values of trade elasticities.

	Low elasticity ¹	Base run ²	High elasticity ³
Real GDP	24 %	35 %	40 %
A/A*	5 % points	8 % points	10 % points
Real investment	37 %	50 %	57 %
Trade/GDP	15 % points	25 % points	31 % points
Implied GDP effect of 1% point increase in trade/GDP	1.6 %	1.4 %	1.3 %

¹ Low elasticity: $\sigma_m = 1.5$ and $\sigma_e = 1.5$.

² Base run: $\sigma_m = 3$ and $\sigma_e = 2$.

³ High elasticity: $\sigma_m = 4.5$ and $\sigma_e = 2.5$.

Note: The values give the impact of tariff reductions on the end of period (2005) level of GDP, relative productivity and investment, and on the average trade share during 1980-2005. The bottom row gives the implied relationship between the trade share and GDP.

Table 3. Quantitative effects of trade barriers for different values of the elasticity of productivity growth with respect to the trade share.

	Low elasticity ¹	Base run ²	High elasticity ³
Real GDP	26 %	35 %	43 %
A/A*	5 % points	8 % points	11 % points
Real investment	38 %	50 %	61 %
Trade/GDP	25 % points	25 % points	26 % points
Implied GDP effect of 1% point increase in trade/GDP	1.0 %	1.4 %	1.7 %

¹ Low elasticity: $\theta_3 = 0.8 \Rightarrow$ The elasticity lies in the range 0.45-0.55.

² Base run: $\theta_3 = 1.3 \Rightarrow$ The elasticity lies in the range 0.6-0.9.

³ High elasticity: $\theta_3 = 1.8 \Rightarrow$ The elasticity lies in the range 0.7-1.3.

Note: The values give the impact of tariff reductions on the end of period (2005) level of GDP, relative productivity and investment, and on the average trade share during 1980-2005. The bottom row gives the implied relationship between the trade share and GDP.