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

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Abstract

The changing openness of South Africa over time invites an analysis of the trade – growth relationship. The endogenous interaction between foreign trade, investment and productivity is a challenge for the econometric studies. As an alternative approach to quantification we calibrate a Ramsey growth model to reproduce the economic development during 1960-2005. The model embodies recent open economy growth theory with international productivity spillovers and domestic barriers affecting 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 in this setting. According to our preferred quantification the trade share is increased by about 25% points and GDP in 2005 is raised by 35%. 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.

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1. Introduction

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'. The 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 is the motivation for this study to clarify and quantify the relationship between trade and growth, a key issue in development research.

Economic growth is on the policy agenda 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 (2006), Edwards and Lawrence (2006), Hausmann and Klinger (2006), and Rodrik (2006), among others. The background growth diagnostic approach is outlined by Hausmann, Rodrik and Velasco (2007). We leave the domestic factors for others to analyze and concentrate on trade barriers as constraints for growth in a general equilibrium model.

The background literature relevant for this analysis includes econometric analyses of the trade-growth relationship and the debate about investment versus productivity as source of Asian growth. The trade-growth analyses critically surveyed by Rodriguez and Rodrik (2001) struggle with the endogeneity of trade and trade policy and are unclear about the channels of effects. 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. Model calibration adds information about adjustment mechanisms. 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 link openness to investment and productivity and analyze how they interact in order to quantify the effects. Our model analysis allows quantification of the responses of investment and productivity.

The model approach assumes international spillovers as the main source of productivity growth. A standard Ramsey model with a representative consumer-investor builds in the technology adoption formulation suggested by Benhabib and Spiegel (1994, 2005) expanded to take into account trade barriers. The productivity growth is related to 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 model assumes positive effects of reduced tariffs via cheaper imported investment goods and increased international technology spillover, while the demand shift towards foreign goods holds back domestic production. The parameters of the growth model are set according to South Africa and middle income country evidence. The quantification attempts at capturing the investment and productivity responses to openness in this setting. Our main contribution is to identify important channels of effects of reduced trade barriers based on econometric evidence regarding key parameters of investment and productivity determination. The analysis assumes flexible domestic markets and exports response to satisfy intertemporal budget constraints. Future research should address the role of domestic market imperfections that may hold back the economic gains showed here.

The analysis concentrates on a tariff equivalent set to reproduce the actual foreign 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 comparable to 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%. Romalis (2007) studying developing countries finds that 10% points increase in the trade share raises the GDP growth rate by 0.2-0.5% point. Our numbers imply that 25% points higher trade share translates into about 0.7% point higher GDP growth rate.

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 via the endogenous interplay between productivity and 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. To capture the degree of trade barriers in South Africa (including sanctions) we calibrate a tariff equivalent level that reproduces the actual trade path (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 (2005) 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, Alcala 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 (2007) 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 catching up to the world technology frontier. Fedderke (2005) puts more emphasis to domestic factors, and identifies important effects of R&D and human capital in 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:

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

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 the

technology gap. λ, θ_1, θ_2 and θ_3 are constant parameters. 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 during 1960-2005. Trade barriers are represented by total trade as share of GDP (T_t), which is endogenously determined. The complementarity between trade and human capital in technology adoption is also investigated by Stokke (2004) for the case of Thailand. The linear relationship between productivity growth and the technology gap limits the advantage of backwardness compared to the Nelson-Phelps specification and gives possible divergence in cases of high barriers to technology adoption. 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).

Under symmetric growth, the long-run productivity growth is given by the exogenous frontier growth rate g, and the technology gap is constant. The degree of catch-up depends on the level of barriers and the innovative capacity of the economy. The long run equilibrium consequently implies a proportional relationship between A_t and A_t^*:

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

The equilibrium values of human capital and the trade share are constant, and, together with the frontier growth rate and the parameters, they determine relative productivity. Changes in the sources of innovation and adoption generate transitional growth to a new technology gap, as illustrated in Figure 1 below. The dynamics is consistent with the common understanding that differences in income levels are permanent, while differences in growth rates are transitory (Acemoglu and Ventura, 2002).

Figure 1 about here.

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.

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., 1997; 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 above 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. Investments can be financed through foreign borrowing, and the decisions about savings and investment can therefore be separated, although with a long-run restriction on foreign debt. 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 and imperfect substitution between domestic and foreign goods. But the overly flexibility in resource allocation motivates further research emphasizing domestic market imperfections.

The production technology and the intertemporal dynamics are outlined below. Detailed documentation of the growth model is given in a separate model appendix available from the authors. Value added (X_t) is defined as a Cobb-Douglas function of unskilled labor (Lu_t), skilled labor (Ls_t) and capital (K_t):

$$X_t = A_t^{\alpha_1+\alpha_2} Lu_t^{\alpha_1} Ls_t^{\alpha_2} K_t^{1-\alpha_1-\alpha_2} \tag{3}$$

where labor augmenting technical progress (A_t) develops endogenously according to equation (1).

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

$$\underset{I,K}{Max} \sum_{t=1}^{\infty}(1+r)^{-t}\left[Rk_t \cdot K_t - (P_t \cdot I_t + ADJ_t)\right] \tag{4}$$

$$s.t.\ K_{t+1} = K_t \cdot (1-\delta) + I_t \tag{5}$$

where r is the exogenous world market interest rate, Rk_t is the capital rental rate, P_t is the price level, 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:

$$ADJ_t = a \cdot P_t \cdot \frac{I_t^2}{K_t} \tag{6}$$

where a is a constant parameter.

Differentiating the intertemporal profit function with respect to K_t gives the following no-arbitrage condition:

$$r \cdot q_{t-1} = Rk_t + a \cdot P_t \cdot \left(\frac{I_t}{K_t}\right)^2 - \delta \cdot q_t + \dot{q}_t \tag{7}$$

Equation (7) states that the marginal return to capital must equal the interest payments on a perfectly substitutable asset with a value of q_{t-1}, where q is the shadow price of capital. 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, $\dot{q}_t$.

The representative consumer maximizes an intertemporal utility function taking into account the current budget constraint for each period:

$$Max \sum_{t=1}^{\infty}(1+\rho)^{-t}U(C_t) \tag{8}$$

$$s.t.\ P_t \cdot C_t = Y_t - SAV_t \tag{9}$$

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:

$$\frac{P_{t+1}C_{t+1}}{P_tC_t} = \frac{1+r}{1+\rho} \tag{10}$$

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

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[1], where the long run growth rate is assumed to equal 2% (1.3% technological progress rate and 0.7% labor growth[2]). 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.

The parameters of the productivity specification given in equation (1) are set according to available econometric estimates. 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

[1] The calibration is documented in a separate appendix available from the authors.
[2] The assumption of 0.7% labor growth is consistent with data on average annual employment growth in South Africa during 1971-2005 (TIPS, 2006).

the assumed steady state rate[3]. 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[4]. Compared to this estimate, the elasticity of productivity growth with respect to the trade share applied in our model can be seen as conservative. In section 7 we investigate how the quantitative effects of trade barriers depend on the 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 TIPS (2006) data on employment shares by skill level[5]. The share of unskilled labor in the total labor force declines from 0.78 to 0.44 during 1960-2005, and with a corresponding increase in the skilled labor share from 0.22 to 0.56. 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 post Apartheid. The South African growth experience can be understood as neoclassical convergence, trade 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

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

[4] 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.

[5] The TIPS 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.

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[6]. 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.

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. The import tax declines rapidly from more than 60% in 1990 to 7% in 2005. 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. In the model simulations the tariff equivalent represents the barrier to international spillovers.

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[7], with

[6] The calibration is given in a separate appendix available from the authors.
[7] 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).

elasticities set equal to 1. With export taxes equal to zero, we reproduce the export path in 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%. Consistent with the results in the general equilibrium model the export tax remains high in the post Apartheid period. 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. To reproduce the actual import path tariffs are initially high, decreases during the 60s, increases to a peak of about 70% in 1986, and then decreases rapidly, broadly consistent with the calibrated import tariff path in the general equilibrium model.

Existing measures of openness in South Africa are scarce. A recent contribution by Edwards and Lawrence (2006) offers data on tariffs and surcharges since 1960. The development path (illustrated in their Figure 6) 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 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 40% 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.[8] The average tariff rate during 1960-2005 equals 18%, down from about 40% along the South African reference path.

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. 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. The productivity level increases from 33% to 41% of the world technology frontier. Investments are raised by nearly 50%. The average trade share during 1980-2005 is 25% points higher in the open economy scenario.

Figure 5 about here.

More openness reduces the cost of adopting foreign technology by limiting the trade barriers to technology transfer, and productivity growth increases. The period of technological stagnation is avoided and the economy catches up relative to the frontier. As seen from Figure 6 relative productivity increases over time, and generates a permanent productivity gap of about 8% points between the two scenarios. The growth rate effect of higher trade share is decreasing over time since the learning potential from technology adoption declines as the economy catches up. Investment profitability is stimulated by less expensive foreign capital goods and higher productivity growth. Increased capital accumulation implies more trade, which generates further technology spillovers from abroad. The productivity-investment interaction stimulates growth and contributes to the large growth differential between the two scenarios during transition.

Figure 6 about here.

[8] 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.

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 will influence 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.[9] 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.

Table 1 about here.

Lower tariffs stimulate investments via less expensive foreign capital goods and higher productivity that 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 effect of a more open economy on investments is due to increased productivity.

The productivity effect on trade works via investment and GDP, but also depends on the development in relative prices. Higher productivity growth has opposite effects on the real

[9] 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.

exchange rate. The positive supply-side effect decreases the relative domestic price, while the income effect increases demand and holds back the price decline. In the simulations the first effect dominates and the productivity effect generates a depreciation of the real exchange rate. As seen from the last column of Table 1, 8% of the effect of reduced tariffs on the trade share works via higher productivity growth. If we consider the export share separately, the relative importance of the productivity effect is 16%. The positive productivity effect on exports is driven by the real depreciation, which shifts production sales towards export markets, together with increased investment and production. Regarding the import share, increased productivity growth limits the positive effect of reduced tariffs due to the depreciation of the real exchange rate.

Trade liberalization stimulates productivity directly by lowering the barriers to technology adoption. As discussed above, higher productivity generates relative price effects and more capital accumulation that increases the trade share. This works as a feedback effect and generates further productivity improvements. To separate the direct and indirect effects of lower trade barriers we calculate the productivity path implied by the trade share from the exogenous productivity scenario. This gives the development in the productivity level when the endogenous interaction between productivity and investment is not included. We find that the feedback effect accounts for 15% of the total productivity increase. Similarly, the technological catch up of 8% points found in the base-run scenario is reduced to 6.8% points when the interaction with investment is not taken into account.

The effect of trade liberalization on long-run GDP works through three main 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 productivity-investment interaction. Higher productivity increases investment profitability, and more capital accumulation feeds back on productivity growth by generating more trade. 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. The calculations include the induced capital accumulation effect emphasized by Hulten (2001). To separate the direct productivity effect from the interaction effect, we calculate the long-run GDP effect of trade liberalization

without the interaction effect.[10] 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 via the endogenous interplay between productivity and investment profitability.

7. Robustness tests

The quantitative effects reported above are comparable to econometric studies. The relationship between trade share and GDP is the key issue. In our preferred calibration alternative 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 growth rate by 0.2-0.5% point. Our numbers imply that 25% point higher trade share translates into about 0.7% point higher GDP growth rate.

The quantitative effects of trade barriers 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 is assumed to equal 3, while the elasticity of substitution between domestic and export markets is set to 2 (consistent with empirical estimates documented in the Appendix). Table 2 shows how the quantitative effects of trade barriers change with the level of trade elasticities.

Table 2 about here.

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

[10] 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.

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.

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. In the base-run simulations 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). Table 3 shows how the value of θ_3 alters the quantitative effects of trade barriers.

Table 3 about here.

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.

Independent of the values of trade and productivity elasticities the relationship between the trade share and GDP is quite robust. 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 an attempt at quantifying the 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. Using parameters calibrated based on the econometric evidence, we have shown how investment and productivity respond and interact. 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. Eliminating the rise in the tariff equivalent during the period of sanctions and protectionism increases the 2005 GDP and investment levels by 35% and 50%, respectively. 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. The analysis confirms the positive interaction between productivity and investment profitability. More than 2/3 of the effect of reduced barriers on investment and GDP comes from higher productivity growth.

The quantitative results in 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. Future research should address 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 technology gap relative to the frontier. The parameters of the productivity specification are set in line with available econometric estimates.

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%)[11]. 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[12]. 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.

[11] 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.

[12] 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.

The effect of the technology gap on productivity growth is given as $\frac{\partial \hat{A}}{\partial\left(A/A^{*}\right)} = -\lambda H^{\theta_2} T^{\theta_3}$, 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 (Armington), and between sales to domestic markets versus export markets (CET). We assume an Armington elasticity equal to 3, and a CET elasticity equal to 2, which is consistent with available national and international estimates. Hertel et al. (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[13]. 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.

[13] Empirical support for the "rule of two" hypothesis is offered by Liu et al. (2004).

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

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

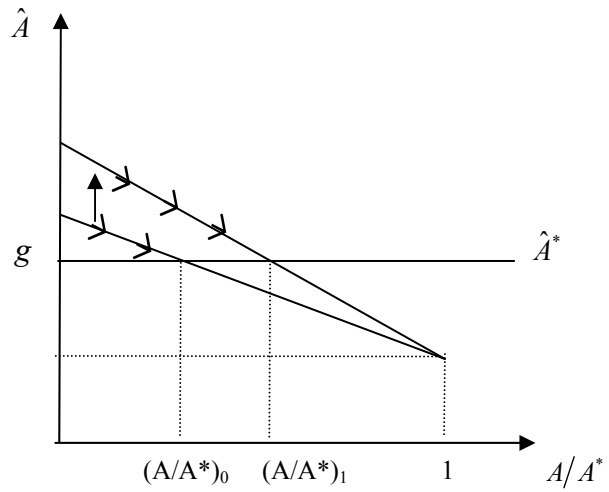

Figure 2. Real GDP growth rate: Calibrated path of model versus actual growth (measured as 3-year moving average)

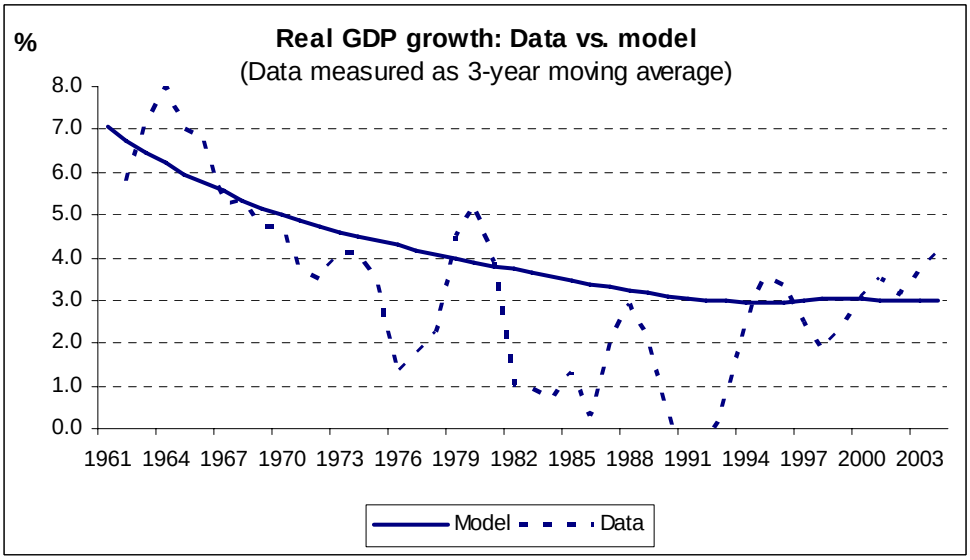

Figure 3. Total trade: Calibrated path of model versus actual path (given in Billions of 1995 rand)

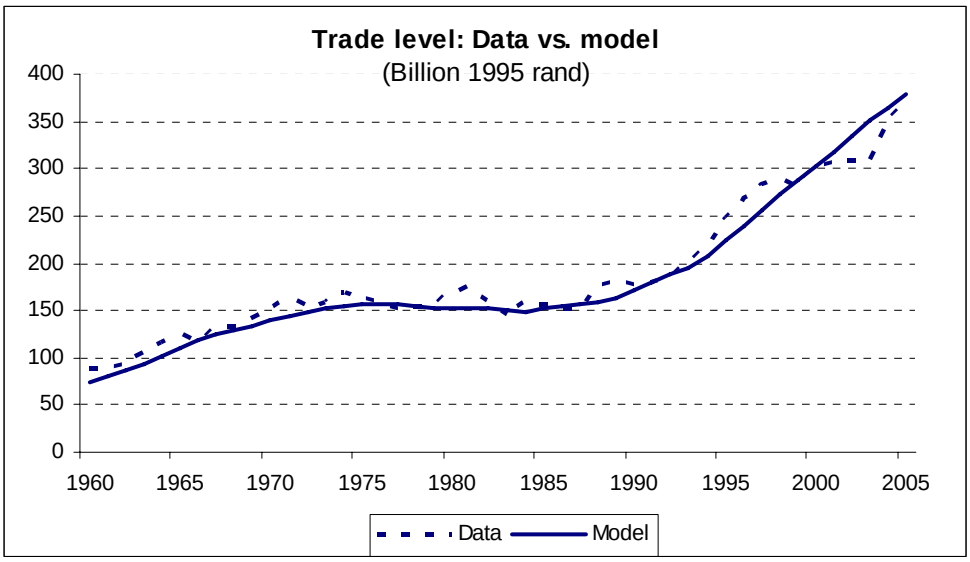

Figure 4. Calibrated openness indicator for South Africa 1960-2005 and counterfactual trade liberalization path. Indicator measured as import tax and export tax as share of total trade.

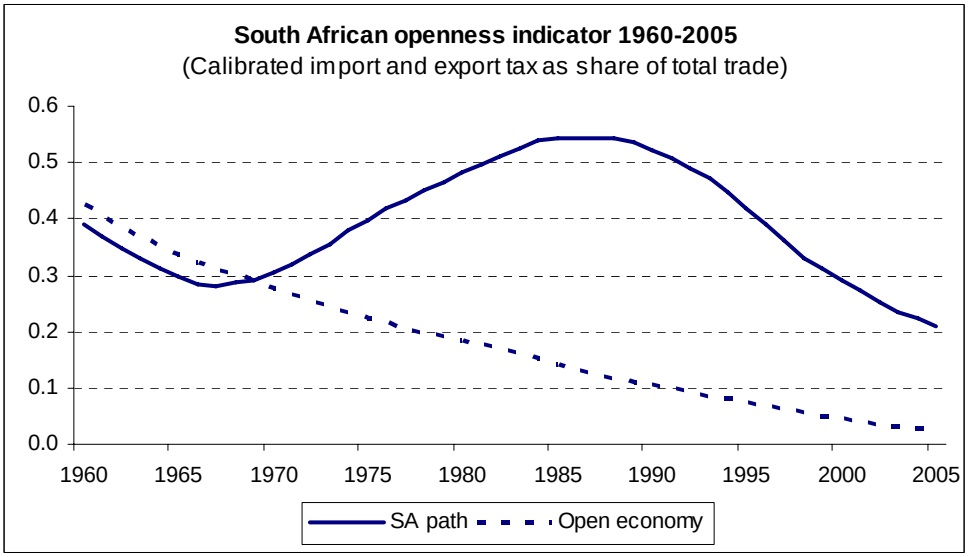

Figure 5. Real GDP growth: Calibrated path versus counterfactual path

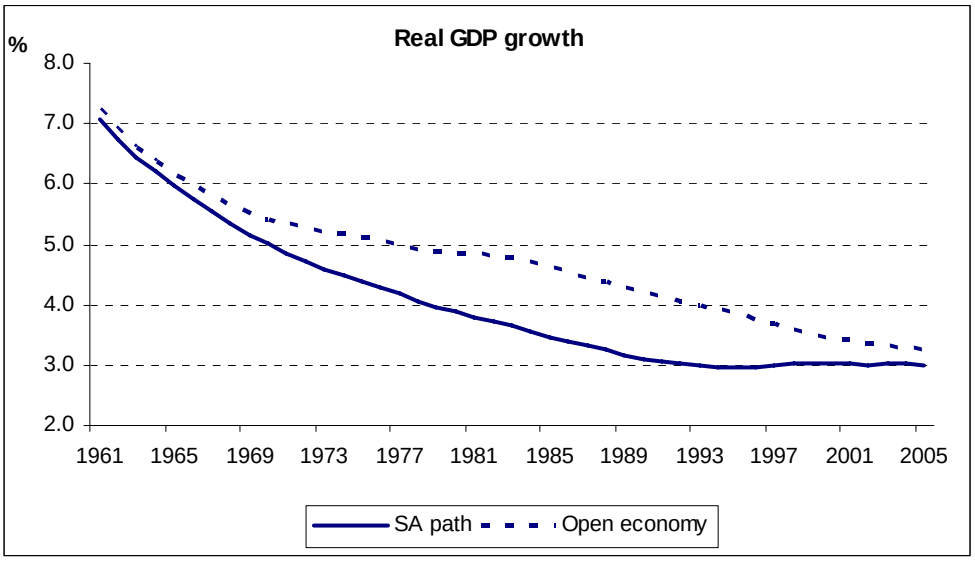

Figure 6. Domestic productivity level relative to the frontier: Calibrated path versus counterfactual path.

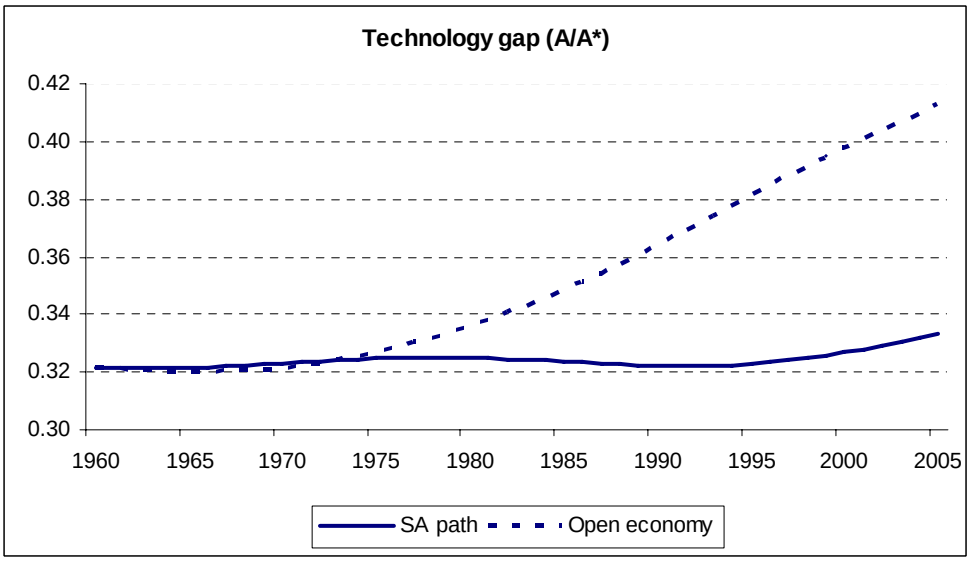

Table 1. The impact of eliminating the rise in the tariff equivalent on key macro variables: The share of the effect working via increased productivity growth

	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

[1] Low elasticity: Armington = 1.5 and CET = 1.5.
[2] Base run: Armington = 3 and CET = 2.
[3] High elasticity: Armington = 4.5 and CET = 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.

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

	$\theta_3 = 0.8$	Base run: $\theta_3 = 1.3$	$\theta_3 = 1.8$
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

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.