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# **Barriers to growth and skill-biased income distribution in South Africa: Ramsey model growth analysis\***

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## *Abstract*

International sanctions in South Africa represent a natural experiment of changing international trade conditions. Economic growth was turned into stagnation during the sanction period, but the recovery of growth later has been slow. Interestingly the relative wage of unskilled labor has been steadily increasing even during sanctions, contrary to the predictions of standard trade analysis. We reproduce the economic development in South Africa using a Ramsey model combining the recent understanding of barriers to international spillovers and skill-biased technical progress. Barriers affect the balance between innovation and adoption in productivity growth and thereby the skill-bias, and less adoption during sanctions may explain the rising relative wage of unskilled. The model offers a calibrated tariff-equivalence measure of the sanction effect and allows a counterfactual analysis of no-sanctions. The results indicate a tradeoff between barriers and skill-bias, foreign spillover driven productivity growth and income distribution. The slow recovery observed may follow from domestic barriers to competition and spillovers.

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## 1. Introduction

South Africa had promising economic growth post WWII, often called ‘the Japan of Africa’. The country was a successful example of catching-up growth based on industrial diversification. The growth period 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 explanation of the turnaround has been addressed in an extensive literature (recent overviews are offered by Feinstein, 2005, Gelb, 2004, Lewis 2001, Lundahl, 1999, and Plessis and Smit, 2005). The internal struggle over Apartheid obviously was important for the stagnation during the late 1970s and 1980s, but most observers are surprised that catching-up growth never returned. The opening of the economy post-Apartheid has stimulated productivity growth, but not nearly back to old growth rates. This study emphasizes the productivity growth mechanism and the linkages to the world market in an analysis of the growth experience during 1960-2003.

We construct a Ramsey model with barriers to growth related to the openness of the economy. The economic development in South Africa is broadly consistent with the barrier model, and the economic growth was held back during international sanctions due to reduced international spillover. The recovery after sanctions has been slower than predicted, implying that domestic allocation and investment responses have been constrained. The main puzzle experienced is the steady rise in the relative wage of unskilled labor, even during sanctions. According to standard trade theory, international sanctions are expected to hold down relative unskilled wages in an economy with comparative advantage in unskilled labor. The data say that the real wage of skilled fell during sanctions, explaining the rise in the relative wage of unskilled. We address the role of income distribution by taking into account possible skill-bias in the productivity growth. The two main sources of productivity growth, innovation and adoption, have different skill-bias and the openness of the economy influences the balance between the two channels. International sanctions have stimulated domestic innovation with less skill-bias and consequently the relative wage of unskilled has gone up.

The barrier model of economic growth is in accordance with the observed permanent income differences between countries and the stability of the world income distribution (Acemoglu and Ventura, 2002). The model predicts a long-run equilibrium where the growth rate in all countries is determined by the world technology frontier and the technology gap is constant.

All countries can take benefit of the growth of the world technology frontier, albeit in different degrees and speeds, and dependent on the initial conditions. At the country level, the barrier model requires a specification of the catching-up process and thereby the determination of the equilibrium technology gap. Klenow and Rodriguez-Clare (2005) present a nice overview. Aghion and Howitt (2005) show how the catching-up can be integrated into a Schumpeterian growth model clarifying the determination of innovation and adoption. The origins of this thinking in the development literature are old and a key element is the advantage of backwardness called the Veblen-Gerschenkron-effect. Backwardness implies a technology gap to the most advanced countries and poor countries have a potential for catching-up. Nelson and Phelps (1966) first formalized how the growth of a backward economy can be related to the distance to the world technology frontier. A modern restatement is offered by Parente and Prescott (1994, 2005) introducing the concept barriers to technology adoption. Our formulation of the productivity dynamics of South Africa is inspired by the formulation of Benhabib and Spiegel (2005), who extend the approach to include both innovation and adoption. It is related to the more general discussion of domestic and foreign sources of growth by Eaton and Kortum (1997).

The role of innovation and adoption for productivity growth is backed up in an extensive empirical literature. There is broad agreement that international spillovers are important for the total factor productivity (TFP) growth and that the relationship is influenced by trade policy. 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. Cole et al. (2005) show that Latin-American countries have a growth pattern consistent with the barriers model. Cameron (1998) offers a survey of the relationship between innovation and growth. Innovations do contribute to growth, and with spillovers between countries, but R&D activity is limited outside the already rich. In a broader sense, along the lines of Benhabib and Spiegel, innovations can be understood as gradual improvement of productivity based on domestic sources.

Several studies indicate the importance of both openness and domestic factors in the TFP growth in South Africa. The IMF study of Jonsson and Subramanian (2001) is the most enthusiastic about the productivity effect of an open economy. They also find an important role of machinery and equipment investment for TFP growth. Fedderke (2002) offers a richer

study and puts more emphasis to domestic factors. He identifies important effects of R&D and the ratio of skilled to unskilled labor in TFP growth. Harding and Rattsø (2005) address the endogeneity problem of openness and concentrate on tariff measures. They identify a shift from domestic to foreign sources of productivity growth after sanctions. Inspired by this literature we study the endogenous formation of productivity growth driven by adoption and innovation. The adoption part is related to the degree of interaction with the rest of the world through international trade, while the innovation part is related to the investment level.

The relative importance of technology adoption and innovation as sources of productivity growth has consequences for income distribution. New technology innovated in skill-intensive developed countries is likely to be skill-biased following from directed technical change (Acemoglu, 1998). Adoption of foreign technology is therefore expected to generate productivity growth biased towards skilled workers, and the degree of bias increases with the openness of the economy and the availability of foreign technology. Local improvement of technology can be directed based on given factor endowments, which in an unskilled-intensive economy implies technical change biased towards unskilled workers. The more dependent the economy is on adoption of foreign technology, the higher is the degree of skill-bias in technical change. Empirical support is offered by Zhu and Trefler (2005).

To clarify the importance of openness for growth and income distribution in South Africa, we need to place the productivity dynamics in an intertemporal general equilibrium setting. The analysis is embedded in a Ramsey growth model and calibrated to reproduce the main growth path of South Africa during 1960-2003 and projected to 2010. To capture the dual structure of the South African economy, we distinguish between a modern sector using semi-skilled and skilled labor more intensively and a traditional unskilled-intensive sector. On the consumption side, we separate between unskilled households based on unskilled wage income, skilled households based on semi-skilled and skilled wage income, and capitalist households based on profits. The protectionist effect of sanctions is calibrated as a tariff equivalent and with a peak in 1990. This allows the analysis of a counterfactual scenario without sanctions, with consequences for the relationship between adoption and innovation and consequently skill bias and growth. The analysis separates between three time periods: pre-sanctions 1960-74, sanctions 1975-1993, and post-sanctions 1994-2010.

The paper presents the modeling of the productivity dynamics and skill bias (section 2), the integration into an intertemporal general equilibrium model (section 3), the calibration of South Africa's growth path (section 4), discusses the distributive effects of sanctions (section 5) and offers a counterfactual analysis of sanctions (section 6). Section 7 concludes.

## 2. Productivity dynamics and skill bias

The barrier model of economic growth has a long-run equilibrium where all countries grow at the same rate due to international spillovers (Klenow and Rodriguez-Claire, 2005). The mechanics was developed already by Nelson and Phelps (1966) in a model of productivity growth related to the gap to the world technology frontier. The equilibrium gap for each country is determined by country-specific conditions affecting the barrier. In the formulation of the productivity growth mechanism for South Africa we start out from the extension of Nelson-Phelps suggested by Benhabib and Spiegel (2005). Productivity growth is generated by a combination of technology adoption and own innovations. Technology adoption is determined by the distance to the world technology frontier and the barrier. Compared to the original formulation of Nelson and Phelps the relationship between growth and technology gap is linear, and not exponential. This limits the advantage of backwardness and gives possible divergence in cases of high barriers to technology adoption. The international barriers are measured by total trade, as suggested in a broad literature of technology spillovers and formulated by Grossman and Helpman (1991). Innovations are broadly understood as domestic productivity improvements. In the model we assume that the innovation activity is related to the overall investment level. An alternative specification of the productivity dynamics with interaction between trade and human capital as barriers to technology adoption is applied in a Ramsey growth framework by Stokke (2004).

The rate of growth of labor augmenting technical progress is specified as follows (time subscript is omitted):

$$\frac{\dot{A}}{A} = \left( \frac{I}{GDP} \right)^{\theta_1} + \lambda \left( \frac{TRADE}{GDP} \right)^{\theta_2} \left( 1 - \frac{A}{T} \right) \quad (1)$$

where  $A$  and  $T$  represent the domestic and frontier level of productivity, respectively, and  $A/T$  is the technology gap.  $I$  is total investment,  $TRADE$  total trade,  $GDP$  gross domestic product, and  $\lambda$ ,  $\theta_1$  and  $\theta_2$  are constant parameters. Consistent with Benhabib and Spiegel (2005), the

first term on the right-hand side is the contribution from innovation activities, while the second term is the technology adoption function. The formulation implies decreasing returns to innovation and adoption with the shares adding up to 1.

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  $A$  and  $T$ :

$$A = \frac{\left(\frac{I}{GDP}\right)^{\theta_1} + \lambda \left(\frac{TRADE}{GDP}\right)^{\theta_2} - g}{\lambda \left(\frac{TRADE}{GDP}\right)^{\theta_2}} \cdot T \quad (2)$$

The steady state values of  $I/GDP$  and  $TRADE/GDP$  are constant, and the relative productivity of the country,  $A/T$ , is determined by their values, the frontier growth rate, and the parameters. Changes in the sources of innovation and adoption generate transitional growth to a new technology gap. 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).

The productivity dynamics enter as part of the production functions. Value added ( $X$ ) is defined as a Cobb-Douglas function of capital ( $K$ ) and total efficient labor use ( $L$ ). Land ( $LD$ ) enters as a sector specific input in the traditional sector. The supply of land is assumed fixed over time, and to have balanced growth we introduce land augmenting technical progress ( $A_D$ ) growing exogenously at the long-run rate:

$$X_i = K_i^{\alpha_i} L_i^{1-\alpha_i} \quad i = m, s \quad (3)$$

$$X_a = A_D^{\alpha_{LND}} LD^{\alpha_{LND}} K_a^{\alpha_a} L_a^{1-\alpha_{LND}-\alpha_a} \quad (4)$$

Where the subscripts  $a$ ,  $m$  and  $s$  represent traditional sector, modern sector and government services, respectively. Efficient labor is a CES aggregate of unskilled ( $Lu$ ), semi-skilled ( $Se$ ) and skilled ( $Ls$ ) labor:

$$L_i = \left[ \gamma_{1,i} A_i^{v-\frac{1}{2}\beta} Lu_i^v + \gamma_{2,i} A_i^v Se_i^v + (1-\gamma_{1,i}-\gamma_{2,i}) A_i^{v+\frac{1}{2}\beta} Ls_i^v \right]^{\frac{1}{v}} \quad (5)$$

In the traditional and modern sector labor augmenting technical progress ( $A$ ) is equal and develops endogenously according to equation (1). The productivity level in government

services is assumed to grow exogenously at the frontier rate. Labor and capital are mobile across sectors, but not internationally.  $\gamma_1$  and  $\gamma_2$  are the share parameters for unskilled and semi-skilled labor, respectively, and  $\sigma = \frac{1}{1-\nu}$  ( $\nu < 1$ ) is the elasticity of substitution between different labor types. Marginal productivity of skilled relative to unskilled labor is given as:

$$\frac{\partial X_i / \partial L S_i}{\partial X_i / \partial L U_i} = \frac{1 - \gamma_{1,i} - \gamma_{2,i}}{\gamma_{1,i}} A_i^\beta \left( \frac{L S_i}{L U_i} \right)^{\nu-1} \quad (6)$$

Following from decreasing returns, an increase in the relative use of skilled labor reduces the relative marginal productivity. The direction and degree of technological bias is introduced through the parameter  $\beta$ , which gives the elasticity of the marginal productivity of skilled relative to unskilled labor with respect to labor augmenting technical progress. For  $\beta$  equal to zero, technical change is neutral and does not affect the relative efficiency of the three labor types. With a positive value of  $\beta$  technical change favors skilled workers and to a lesser extent semi-skilled workers (skill-biased technical change), while negative values imply that improvements in technology are biased towards unskilled labor.

To have balanced growth neutral technical change ( $\beta = 0$ ) is a necessary long-run condition, but during transition the degree of technological bias is endogenously determined. The common understanding in South Africa is that trade liberalization and skill biased technological change are important to understand the development at the labor market. The specification of technological bias is linked to the relative importance of technology adoption and innovation as sources of productivity growth. The more dependent the economy is on adoption of foreign technology, the higher is the degree of skill-bias in technical change. The reduced form specification of technological bias is assumed to be an increasing and convex function of adoption relative to innovation:

$$\beta = b \left[ \left( \frac{TRADE}{I} \right)^2 - 1 \right] \quad (7)$$

where  $b$  is a constant parameter and  $TRADE/I$  represents the relative contribution of adoption and innovation from equation (1). Given the dimension of the trade and investment level in South Africa, the specification does not need scaling to generate sensible values of technological bias. With adoption as the main source of productivity growth technical change is skill-biased ( $\beta > 0$ ), while technology improvements driven by own innovations are biased

towards unskilled labor ( $\beta < 0$ ). Equal importance of technology adoption and innovation gives neutral technical change.

### **3. The intertemporal general equilibrium model**

The productivity dynamics is built into a standard intertemporal Ramsey growth model for a small open economy. It follows that capital accumulation and productivity growth do not influence world prices and interest rate, which are exogenously given. The model setup of Diao et al. (2005, 2006) is the starting point, but is extended to capture endogenous skill-bias and balance between innovation and adoption in productivity growth, and to analyze income distribution effects. As discussed above, the production structure allows technical change to be biased towards unskilled or skilled labor, and the degree of bias is endogenously determined by the relative importance of adoption versus innovation in productivity improvements. Detailed documentation of the intertemporal general equilibrium model is given in a separate model appendix available from the authors.

Early applied Ramsey models include Goulder and Summers (1989), who study tax policy effects on investment in the US, and Go (1994), who applies the model framework on development issues. Our approach also relates to existing models of growth in dual economies. Stifel and Thorbecke (2003) model the dual character of an archetype African economy that is of relevance here. Irz and Roe (2005) develop a similar Ramsey model to analyze the interaction between agriculture and industry. Love (1997) analyzes industrialization in a dynamic general equilibrium model, also with an emphasis to the role of agriculture.

The Ramsey model describes an economy with macroeconomic stability, full employment of resources, and flexible allocation of resources between sectors according to profitability. The assumptions are certainly heroic, and it is a challenge to develop the model to include political and structural rigidities of the country. At this stage the model should be interpreted as representing the long run market adjustments expected to affect consumption demand and investment behavior, and with labor market adjustments faster than in reality.

The economy is disaggregated into three sectors: traditional, modern and government services. The division is based on skill-intensity, the traditional sector is unskilled-intensive

and the modern sector is skill-intensive. The labor market formulation separates between unskilled, semi-skilled and skilled labor, and the relative wages are the key variables describing the income distribution. The model includes three household types defined according to the source of income: An unskilled household, a skilled household with semi-skilled and skilled wage income, and a capitalist household with capital income. All savings are done by the capitalist household, which also pays interest on the foreign debt.

Except for government services, which are not traded internationally, we assume imperfect substitution between domestic and foreign goods, and the model then operates with two composite goods (traditional and modern). Imports are endogenously determined through an Armington composite system, while exports are determined through Constant Elasticity of Transformation (CET) functions.

The aggregate capital stock is managed by an independent investor who chooses an investment path to maximize the present value of future profits over an infinite horizon, subject to the capital accumulation constraint. With a waste due to the adjustment costs in investment, net profits as returns to capital go to the capitalist household. Investments can be financed through foreign borrowing, and the decisions about savings and investment can therefore be separated. Domestic savings and investments do not have to be equal in each period, but a long-run restriction on foreign debt exists. Increase in foreign capital inflows (i.e., trade deficits) in the current period, together with interest payments on existing debt, augments foreign debt in the next period.

For each household the consumption of traditional good, modern good and services are constant shares of its total consumption. But aggregate consumption of each good as share of total consumption can change over time. The unskilled household is assumed to consume relatively more traditional goods, while the skilled and capitalist households spend a relatively higher share of their income on modern goods. While within period consumption patterns differ between the three households, there exists a common intertemporal allocation of total income to consumption and savings to maximize its intertemporal utility. The intertemporal utility function is maximized subject to a budget constraint, which says that discounted value of total consumption cannot exceed discounted value of total income. Assuming intertemporal elasticity of substitution equal to one we have the well-known Euler equation for optimal allocation of total consumption expenditure ( $E$ ) over time:

$$\frac{E_{t+1}}{E_t} = \frac{1+r}{1+\rho} \quad (8)$$

where  $r$  is the world market interest rate and  $\rho$  the positive rate of time preference. The growth in consumption depends on the interest rate, the time preference rate, and the price path. Higher interest rate or lower time preference rate motivate more savings and thereby higher consumption spending in the future. The model is calibrated to reproduce the economic growth in South Africa.

#### **4. Sanctions and economic growth in South Africa**

South Africa achieved remarkable high growth from 1960 to the mid-1970s, here called the pre-sanctions period. The implication was that the whites enjoyed a living standard at the level of the richest countries of the world, but the majority lived in poverty. Then the economic growth stagnated in the mid-1970s with the liberalization struggle and the international isolation. Many developing and developed economies experienced economic stagnation because of the oil crisis, but the proportional decline in the growth rate was much larger in South Africa. Average GDP growth rate dropped from about 6% in the pre-sanction period to 1.3% during 1975-93. This indicates that the growth process also was affected by local economic and political factors. It is a common understanding that Apartheid labor policies came to be a constraint on growth in South Africa. While initially the discrimination of blacks may have stimulated growth by cheap labor, shortages of skilled labor were building up over time. The sanctions were tightened during a period when political unrest and labor strikes affected the economic development. The higher trade barriers with sanctions contribute to the explanation of the economic stagnation according to the model analysis below. In the post-sanctions period the economic performance has improved, but the growth has been erratic and low on average.

The early growth episode followed by stagnation is clearly described by the relative performance of South Africa. GDP per capita relative to the US was about 0.21 in 1960 and reached a peak of 0.25 in 1974. By 1994 relative GDP per capita has declined to 0.14, and the domestic level of real GDP per capita is lower than in 1970. The relative position to the US is further reduced to 0.13 in 2003. Overall the income gap to the frontier, here defined as the US, is steadily rising since 1974. Dijk (2002) documents a similar pattern of manufacturing labor productivity relative to the US, decreasing from 32% in 1970 to 20% in 1999. Domestic

level of real GDP per capita is rising in the post-sanction period and reaches about the 1970 level in 2003. Table 1 presents some comparing statistics for the three periods.

Table 1 about here.

The growth model described above is calibrated to reproduce the main elements of the economic development during the past decades. The first step of the analysis is to calibrate a growth path that is close to the growth experienced in South Africa during 1960-2003 and projected to 2010. The model allows for a new measure of the protectionist effect of international sanctions. The empirical literature addressing foreign trade and trade policy faces the problem that sanctions cannot be measured directly. We calibrate a tariff-equivalent level that reproduces the actual development of the trade. Figure 1 reports the reproduction of the trade path. The development of terms of trade is calibrated consistent with data (IMF, 2004) to adjust for the impact of world price shocks on the trade level. South Africa experienced a 30% reduction in terms of trade during 1975-82, while the relative price was about constant both before and after this period. The deterioration in terms of trade certainly contributes to the stagnation in total trade in the late 70s, but the protectionist effect of sanctions is important to explain the trade path, especially in the 1980s. While tariffs are kept low (at 3%) during the 1960s, the slow growth of foreign trade during sanctions requires a gradual increase of the tariff-equivalent from the early 70s, and with a peak in 1990 of about 65%. After 1990 the sanctions were gradually removed and trade increased rapidly, reflected in the model by decreasing tariffs. Interestingly, this tariff-equivalent measure of openness is consistent with the openness indicator for South Africa calculated by Aron and Muellbauer (2002) based on econometric estimation. The tariff-equivalent represents the source of the barrier to international spillover.

Figure 1 about here.

Starting from the base year 1998, we calibrate backward a growth path that is close to the observed real GDP growth for the previous four decades and then allow this to project the post-sanctions growth through 2010. The economic growth of the period under study is of transitional character, but is consistent with a long run growth path. Changing barriers lead to transitional growth with a long run equilibrium determined by a constant gap to the world technology frontier. The long-run equilibrium growth rate is assumed to be 3 percent (1

percent technological progress rate and 2 percent labor growth). The parameters supporting the long-run path are discussed in the appendix. To reproduce the actual GDP of 1960, the initial level of the capital stock is reduced to about 10 percent of the base year level. Labor supply and sectoral TFPs are reduced according to the long run growth rate and foreign debt is adjusted to reproduce the initial year. The scaling back serves as an exogenous shock that takes the economy outside the equilibrium long run path in 1960. The initial capital stock is below the long run path and economic growth is driven by endogenous adjustment back to equilibrium growth. Figure 2 shows how we track the declining, but erratic, actual growth rate as a steady decline in the model growth rate. The calibrated economic growth rate during the pre-sanctions period 1961-74 is 6.1% on average, while the growth rate during sanctions (1975-1993) averages 3.7%. The post sanctions period has an increasing model growth rate with an average of about 3.6%. The average calibrated growth rate is compared to the observed growth rate in Table 1.

Figure 2 about here.

The pre-sanctions period broadly observed the prediction of the model with high, but declining, growth. The understanding is that the reduced barriers generated profit opportunities that encouraged high investment. In standard fashion the marginal return to capital consequently was reduced over time. This is the core of the neoclassical convergence mechanism. In the beginning of the growth period studied the low level of the capital stock gives high marginal return to investment with consequent high investment growth and capital accumulation (see Figure 9 in section 6). Part of the investment must be imported from abroad with imperfect substitution between foreign and domestic goods. Technology spillovers embodied in foreign capital goods stimulate productivity growth, and contribute (together with domestic improvements of technology) to the non-decreasing productivity growth path and catching-up relative to the frontier (see Figure 8 in section 6). The capital and GDP growth rates decline over time due to decreasing returns to investment.

During the sanctions period the negative growth trend is strengthened. The terms of trade deterioration contributes to the decline. In addition, the international isolation represented by an increasing tariff-equivalent affects productivity growth by increasing the barriers to technology adoption and limiting the transfer of foreign spillovers. South Africa could have compensated the reduced openness with higher domestic investments. As seen from Table 1,

this did not happen. Our understanding is that the cost of investment increases as imports of capital goods became more expensive, and lower productivity growth further reduces the profitability of investments. The fall in capital growth strengthens the negative effect on productivity growth by reducing the growth in total imports and holding back domestic innovations, and the technology gap relative to the frontier increases over time. The growth path of the model is consistent with the low level of investment and the declining growth rate of productivity during the sanctions period.

The post-sanctions period shows increasing growth rate with our assumptions. The elimination of sanctions reduces the costs of imported investment goods and opens the economy to more technology adoption. Again the investment and productivity effects strengthen each other, but now in a positive direction. The increasing growth rate is closely related to the increased openness and assumes that reduction of protectionism continues steadily. Also the projection is the result of favorable conditions for investment allocation to take advantage of the improved profitability. Finally, the higher growth rate is driven by technology adoption, in practice associated with foreign direct investment. The actual growth has increased according to Table 1, but not fully at the potential indicated by the model projections. This can be due to macroeconomic disturbances excluded from the model. But it is more realistic to assume that the structural conditions of the economy are different from the flexible adjustments assumed in the model. The limited foreign direct investment observed may indicate that technology adoption has been below the projection shown.

## **5. Distributive effects of sanctions in South Africa**

While the broad growth pattern seems to be consistent with the understanding of economic growth with barriers, the development of the income distribution represents a puzzle. The relative wage of unskilled shows a steady growth during the whole period 1960-2003. Standard trade theory suggests that the relative wage of unskilled benefits from openness in an economy with comparative advantage in unskilled labor. International sanctions are expected to reduce the relative wage of unskilled. We are able to reproduce the income distribution taking into account skill-bias in the productivity growth.

The development in highly skilled, skilled and unskilled real wages in South Africa during 1970-98 is described in Figure 3 (based on Fedderke et al., 2003). The unskilled real wage

increases both in the 1970s and in the post-sanction period, while it stagnates during the 1980s. As discussed by Fedderke et al. (2003), the real wage of unskilled is consistent with standard trade theory, where an unskilled intensive economy like South Africa can improve its income distribution by opening up the economy. Comparative advantage in unskilled intensive production pushes up the unskilled wage rate. It follows that the forced protectionism during sanctions holds back the increase in the unskilled real wage. However, Figure 3 also shows a sharp decline in the real wage of highly skilled during the sanction period (see Table 1 as well). The relative wage of unskilled consequently rises steadily also during international sanctions.

Our understanding of the decreasing skilled wage is linked to the degree of skill-bias in technical change. Sanctions limit the transfer of foreign technology and the economy must rely more on own innovations. The domestic innovative activity reduces the degree of skill-bias since domestic technology improvements can be directed towards the abundant production factor. The demand for skilled labor is kept down and contributes to falling real skilled wage. The degree of openness has two opposite effects on the income distribution working via comparative advantage and skill-bias technical change. During the sanction period the positive distributive effect from less skill-biased technical change dominates and generates increasing unskilled relative to skilled wage rate.

Figure 3 about here.

The analysis starts out with a calibration of the labor supply. Figure 4 shows the development in employment shares according to skill level during 1970-2003. The supply of skilled, semi-skilled and unskilled labor is calibrated to reproduce these data and is extended backwards to 1960 based on average growth rates during 1970-2003. The share of unskilled labor in total labor force is assumed to decline from 0.77 to 0.42 during 1960-2003, with a corresponding increase in the skilled and semi-skilled labor shares from 0.02 to 0.17 and 0.21 to 0.41, respectively.

Figure 4 about here.

Demand for different labor types is mainly driven by the development in technological bias, which is endogenously determined by the relative importance of technology adoption and

local productivity improvements. The more dependent the economy is on foreign technology, the higher is the degree of skill-bias in technical change. In the pre-sanction period high investment growth generates a reduction in skill-bias, as seen from Figure 5. This development is strengthened during sanctions. Increased tariffs have a negative effect on both technology adoption and innovation through higher barriers and lower capital accumulation, respectively. In our simulations the first effect dominates, and the relative importance of technology adoption decreases during the sanction period. The terms of trade deterioration in the late 1970s contributes to this development. The economy is forced to rely more on own improvements of technology, and the degree of skill-bias in technical change declines from 0.36 to 0.27. As explained in section 2, the degree of skill-bias is the elasticity of the marginal productivity of skilled relative to unskilled labor with respect to labor augmenting technical progress. Positive values imply bias towards skilled labor. Since technical change is relatively less skill-biased under sanctions, the relative marginal product of unskilled labor increases and stimulates the relative demand for unskilled workers. In the post-sanction period trade liberalization lowers the barriers to technology adoption and the degree of skill bias increases gradually.

Figure 5 about here.

Driven by increasing skill-ratio and lower skill-bias, the relative wage between unskilled and skilled labor increases in the pre-sanction period. Figure 6 shows how this positive distributive effect is strengthened during sanctions as the degree of skill-bias declines more rapidly. The change in income distribution generates shifts in the consumption pattern that strengthen the positive effect on the relative wage. Relative higher income for the unskilled household increases relative demand for traditional goods, which further increases the demand for unskilled labor (since the traditional sector uses unskilled labor relatively more intensively). Declining skill-bias and demand-side effects via consumption improve the income distribution, but the increase in the relative wage is held back due to a shortage of skilled labor. Larger expansion in the skill ratio would keep skilled wages down and contribute to the reduction of the wage gap between skilled and unskilled labor. In the post-sanction period the higher demand for skilled labor from increasing skill-bias is counteracted by increasing skill-supply and gives about constant wage gap over time.

Figure 6 about here.

According to Fedderke et al. (2003), the relative wage for unskilled labor increases from an average of 0.10 in the 1970s, via 0.16 in the 80s, to about 0.25 in the 90s. The relative wage path generated by the model is broadly consistent with this observed pattern. The model shows the importance of technological bias for the relationship between openness and income distribution. While the Heckscher-Ohlin theory claims that trade liberalization improves the income distribution in unskilled-intensive economies, the impact of technological skill-bias on relative labor demand works in the other direction. The total effect of openness on distribution is an empirical issue, and depends on the relative magnitude of the two effects.

Economic research in South Africa has addressed the relationship between wage inequality and skill bias. Edwards (2001) argues that skill bias has contributed to increased skill employment in South Africa. Abdi and Edwards (2002) address the puzzle that relative wages of unskilled has gone up, while unskilled employment has gone down since the mid-1970s. Since this is hard to explain in a standard labor market model, appeal to political and institutional factors to understand this is common, including increased union power. In our setting we emphasize a different channel of effects. The degree of skill-bias is reduced with sanctions and the higher demand for unskilled labor increases the relative wage of unskilled. Institutional factors are not built into our analysis and are hard to handle in this context.

## **6. Counterfactual analysis of sanctions**

South Africa allows an interesting counterfactual analysis of the role of international sanctions and thereby the effect of barriers. As explained above, we have calibrated a tariff-equivalent growing from the early 70s and with a peak in 1990 to reproduce the actual trade and growth path. Eliminating this rise in the tariff-equivalent during the sanctions period, we can simulate the economic development in an open economy without sanctions. In the experiment, the import tariff-equivalent is kept at a constant low level (3%) for the entire period studied. The new GDP growth path is shown in Figure 7 below. The main message is that South Africa could have avoided some of the decline in the growth rate. Sanctions 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. Without sanctions the 1998 level of real GDP would have been about 10 percent higher than along the calibrated South Africa path.

Figure 7 about here.

More openness reduces the cost of adopting foreign technology by limiting the barriers to technology transfer, and productivity growth is stimulated (Figure 8). The terms of trade deterioration holds back trade and spillovers in the early 70s and contributes to falling growth rate. But without sanctions productivity growth is at a higher level and the period of technological divergence along the reference path is avoided. During the period of study we observe a weak degree of catch-up with relative productivity increasing from 0.36 to 0.38. The growth rate effect of higher trade is decreasing over time since the magnitude of the spillover effect and the return to own innovations gradually decline. In accordance with the catching-up hypothesis the learning potential from technology adoption declines as the technology gap decreases. The profitability of capital accumulation is stimulated by less expensive foreign capital goods and higher productivity growth. As seen from Figure 9, decreasing returns to investment is counteracted, and capital growth is kept high over time. Increased capital accumulation generates domestic innovations and implies more imports, generating further technology spillovers from abroad. This productivity-investment interaction stimulates growth and contributes to the large growth differential between the two scenarios during transition. In the early pre-sanction period (1961-74) both capital and GDP growth are slightly higher along the calibrated South Africa path compared to the counterfactual path. This follows from intertemporal adjustment with perfect foresight, since expected higher tariffs (more expensive capital goods) in the future gives an incentive to increase current capital accumulation.

Figure 8 and 9 about here.

Given our model specification, there is a trade-off between economic growth and income distribution. While the aggregate economy benefits from a more open economy, the difference between skilled and unskilled households increases. With lower tariffs the cost of technology transfer is kept low, and the economy takes advantage of foreign technology. The fall in terms of trade in the late 1970s limits technology transfer, but the relative importance of technology adoption is higher than in the sanction scenario. The new technology favors skilled workers, and the degree of skill-bias in technical change is at a higher level (see Figure 5). This generates an increase in the relative demand for skilled labor with a reduction in the

relative unskilled wage rate compared to the reference path. Changes in the consumption pattern following relative larger wage gap strengthen the negative effect on the income distribution. The skilled household consumes relatively more modern goods, which uses skilled labor more intensively. This increases the demand for skilled labor and widens the wage gap even more. The economy is stuck in a vicious circle, where skill-biased technical change and demand-side effects of changing consumption pattern work together to worsen the income distribution. On average the unskilled wage relative to the skilled wage drops about 2 percentage points compared to the sanction scenario (see Figure 6). But even though the relative unskilled wage rate is lower, the absolute income level for the unskilled household is eventually at the same level as along the calibrated path due to higher growth.

## **7. Concluding remarks**

The analysis addresses the role of barriers for economic growth and income distribution in South Africa. The barriers to productivity growth are integrated in a standard intertemporal Ramsey growth model. Barriers to international technology spillovers influence both productivity growth and skill-bias. Reduced barriers stimulate transitional productivity growth and leads to more skill-intensive technology. The model is disaggregated to capture interactions between traditional and modern industrial sectors and adjustments at the labor markets for skilled, semi-skilled and unskilled labor. South Africa is an interesting case study of changing openness with consequences for technology adoption and skill-bias and thereby productivity growth and income distribution.

The model reproduces the declining growth rate since 1960 and separates between the pre-sanctions, sanctions and post-sanctions periods. The high and declining growth during pre-sanction 1961-1974 is consistent with reduced barriers and neoclassical convergence, the exploitation of profit opportunities with declining return. To understand the low growth during sanctions, 1975-1993, the importance of barriers to international spillovers should be recognized in addition to the observed deterioration in terms of trade. The isolation of the economy implies higher costs of investment and reduced technology adoption. Interestingly, this period shows an increase in the relative wage of unskilled labor. The protected economy has less skill-bias in technology. The model projects an increasing growth rate in the post-sanctions period, driven by cheaper investment goods and technology adoption with reduced barriers. The actual growth is somewhat below this projection, presumably reflecting

domestic barriers to competition and spillover. The allocation and investment responses assumed in the model are constrained.

The analysis reveals a trade off between economic growth and income distribution. Openness stimulates growth (spillovers, less expensive capital goods and productivity-investment interaction), but worsens the income distribution because foreign technology is skill-biased. The development of relative wages depends on the sources of productivity growth. While adoption of foreign technology generates skill-biased technical change, local improvement of technology through innovation can be directed towards unskilled labor. The relationship between barriers and income distribution works through both supply-side effects (higher degree of skill-bias in technical change increases the demand for skilled labor) and demand-side effects (changes in the consumption pattern). Since the unskilled household consumes relatively more traditional goods, a worsening of the income distribution shifts consumption away from unskilled-intensive goods and reduces the demand for unskilled labor. The general equilibrium model puts this demand story in a broader context.

Compared to existing analyses of trade and growth, we have shown the importance of openness for income distribution via skill-biased technical change. The more dependent the economy is on foreign technology, the higher is the demand for skilled labor. The skill-bias modifies the income distribution effects expected from comparative advantage and explains the steady rise in the relative unskilled wage even during international sanctions. It is of interest if future empirical research can throw light on the relationship between openness and distribution and test the relative importance of comparative advantage and skill-biased effects on the relative wage path.

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Figure 1. Total trade: Calibrated path of model versus actual path (given in Billions of 1995 Rand)

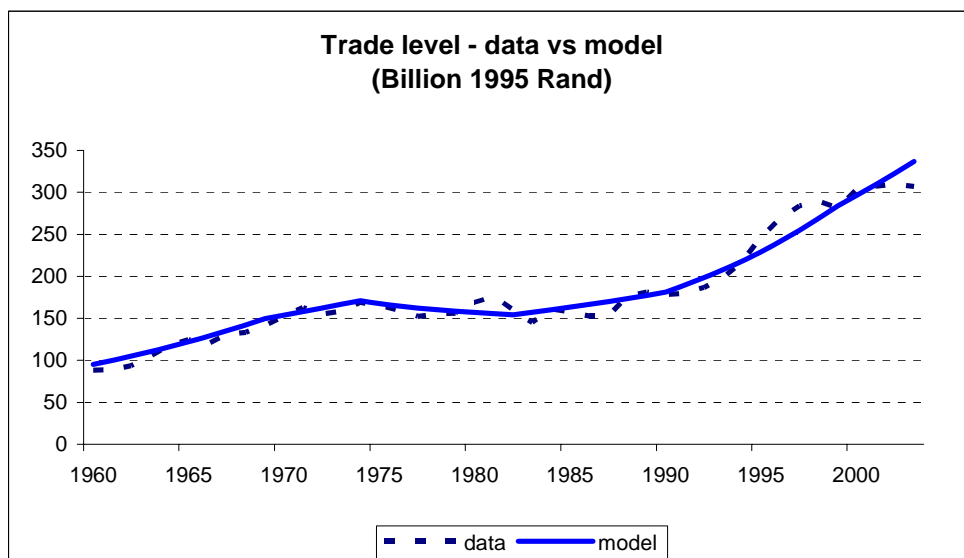


Figure 2. Real GDP growth rate: Calibrated path of model versus actual growth (measured as 5-year moving average)

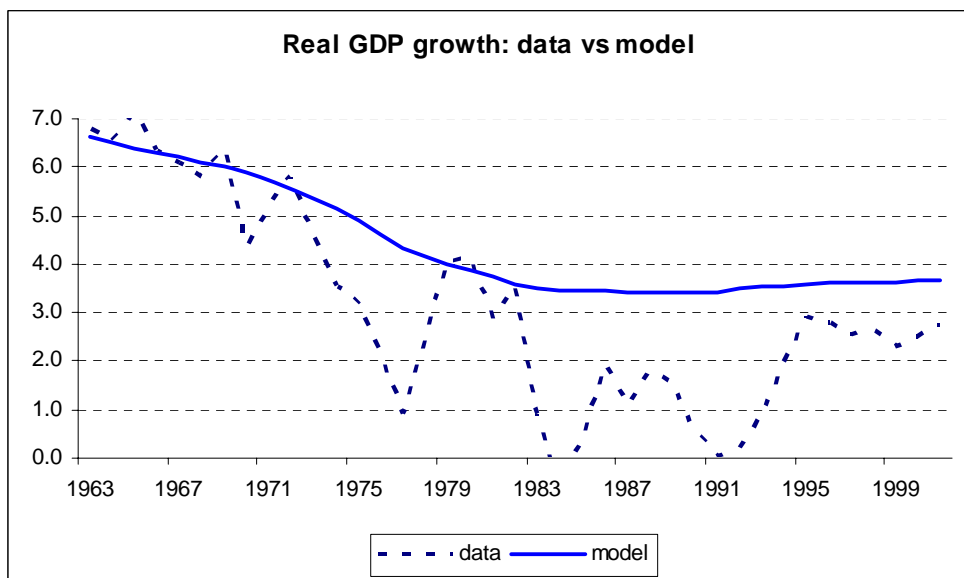


Figure 3. Real remuneration per employee by skill level: South African aggregate manufacturing. Source: Fedderke et al. (2003).

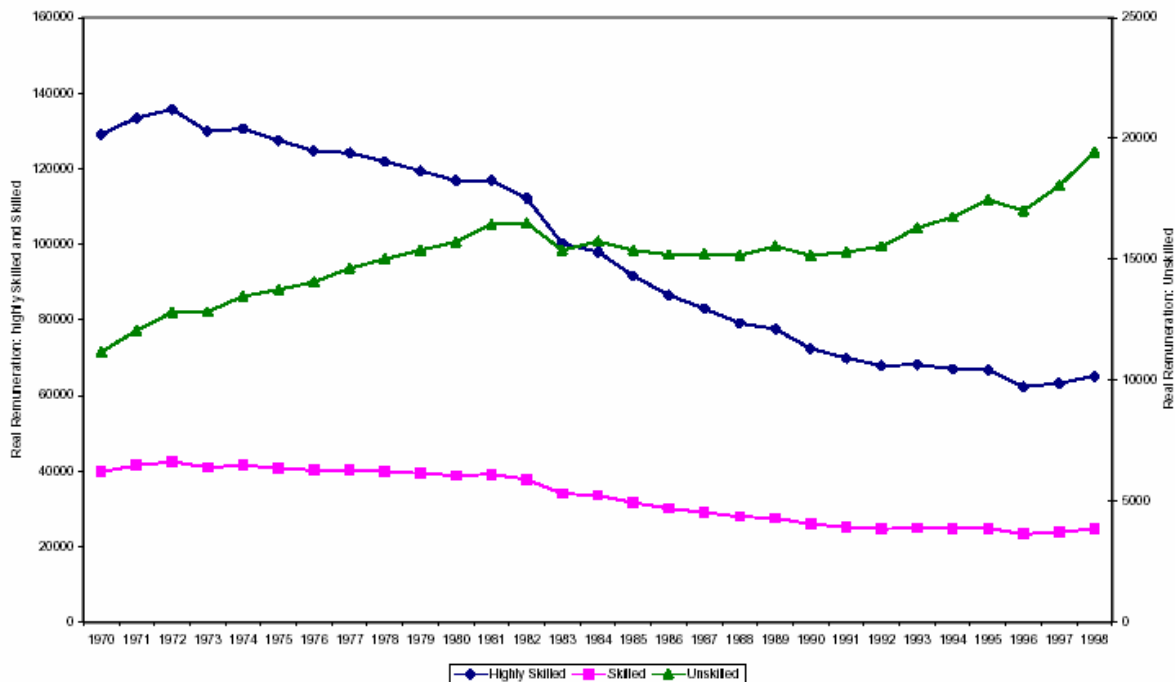


Figure 4. Shares of highly skilled, skilled and unskilled labor in South Africa, 1970-2003. Source: TIPS (2004).



Figure 5. Degree of skill-bias in technical change: Calibrated path versus counterfactual path

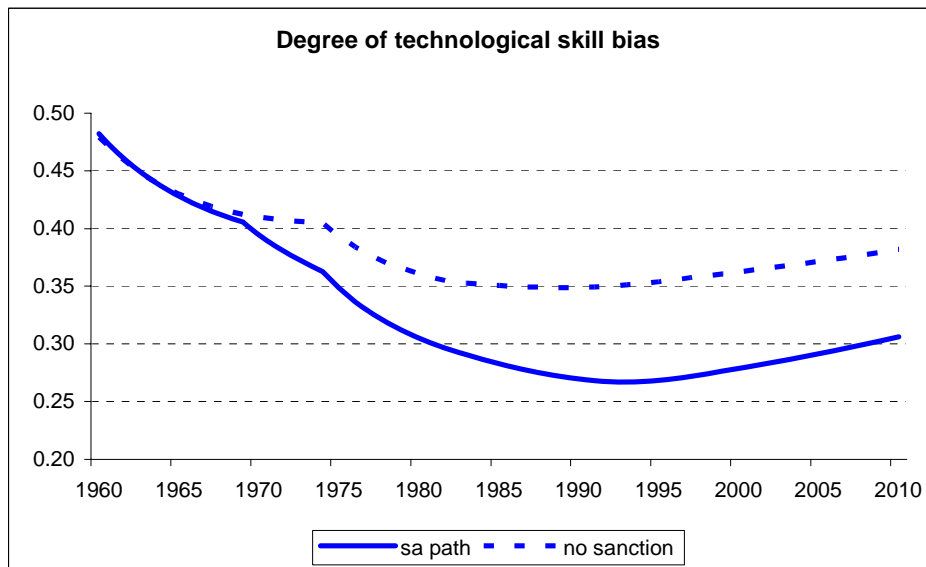


Figure 6. Unskilled wage rate relative to skilled wage rate: Calibrated path versus counterfactual path.

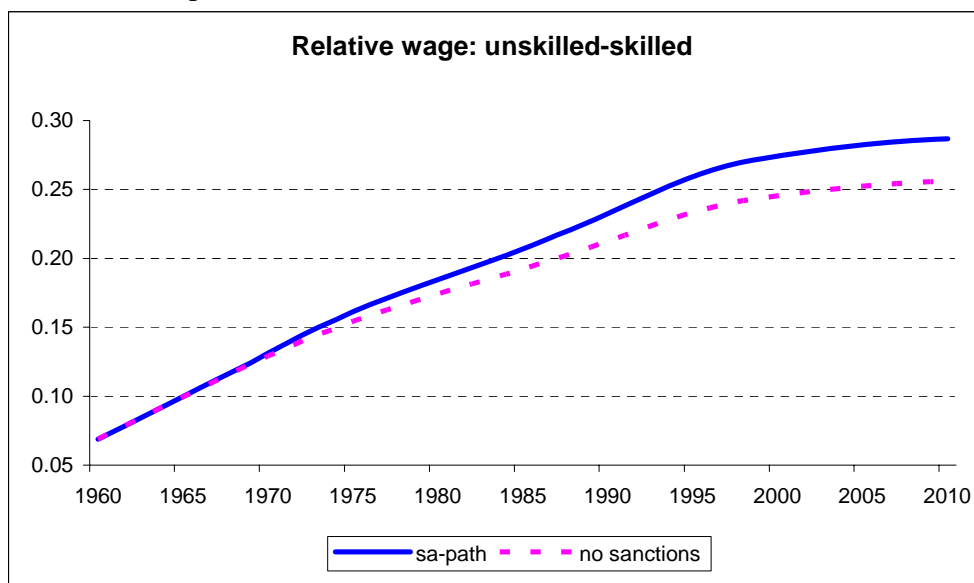


Figure 7. Real GDP growth: Calibrated path versus counterfactual path

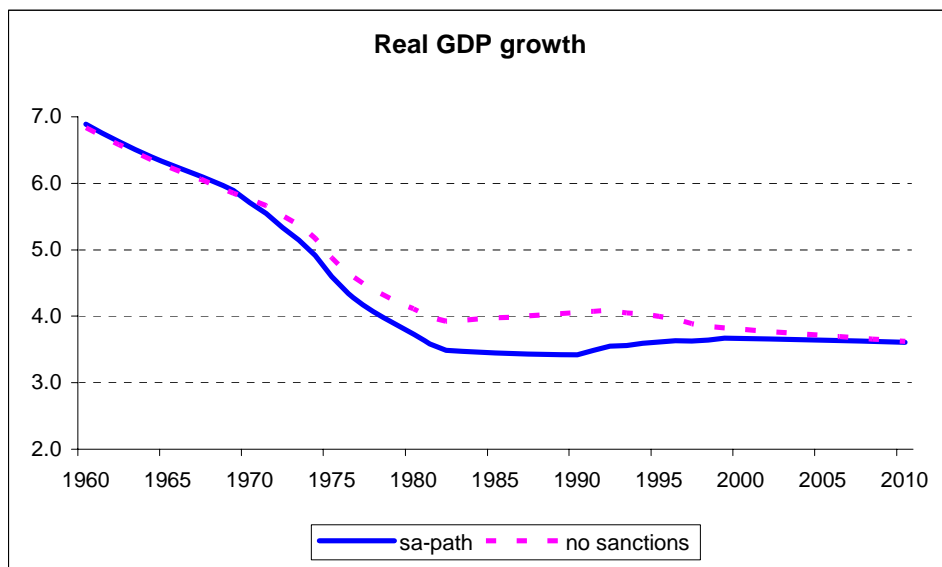


Figure 8. Labor augmenting technical progress: calibrated path versus counterfactual path

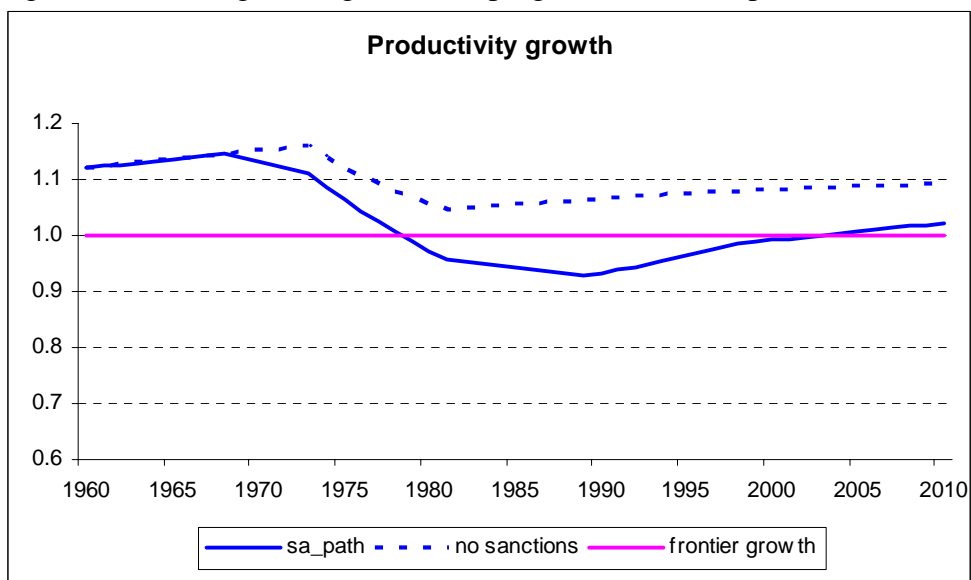


Figure 9. Growth rate of capital: calibrated path versus counterfactual path

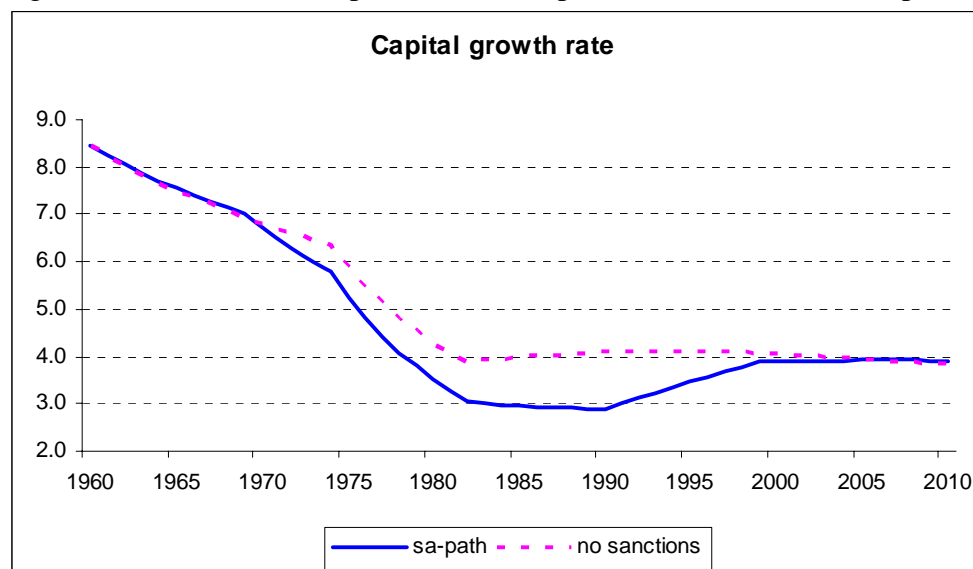


Table 1. South Africa growth experience 1961 – 2003

	<b>1961 – 74 Pre- sanctions</b>	<b>1975 – 93 Sanctions</b>	<b>1994-2003 Post- sanctions</b>
GDP growth rate	6.1 %	1.3 %	2.7 %
Calibrated GDP growth rate	6.1 %	3.7 %	3.6 %
Growth in total trade	4.9 %	1.0 %	4.6 %
Growth in gross fixed capital formation	8.1 %	-0.2 %	3.9 %
Growth in skilled wages*	0.2 %	-3.2 %	-0.8 %

Source: World Bank Development Indicators 2004

\* Data on skilled wages is based on Fedderke et al. (2003) and is only available for the period 1971-98. The pre-sanction and post-sanction period therefore corresponds to 1971-74 and 1994-98, respectively.

## Appendix: Calibration

The parameters in the production, demand, and trade functions are set according to the method adopted in most static computable general equilibrium models and are based on the 1998 social accounting matrix (SAM) documented in a separate model appendix available from the authors. The calibration assumes long run balanced growth, i.e. the savings-investment balance can support a sustainable growth path, the structure of the economy is stable, and the trade surplus with interest payments balances the projected development of foreign debt. The long run growth path calibrated as supply side response to sectoral investment and productivity adjustments must be made 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. With a world market interest rate of 12.5 percent and long-run growth rate of 3 percent, the time preference rate is equal to 9.2 percent. Then, with the long run assumptions, most parameters of the intertemporal part of the model can be calibrated from the SAM. Given marginal product of capital, the initial capital stock is calculated based on capital income. Investment is calibrated from the long-run constraint on capital accumulation, for given values of depreciation rate and long run growth rate. The shadow price of capital equals the firm value relative to the capital stock, and follows when we know the interest rate. The initial level of foreign debt is set by the long-run constraint on debt accumulation, given data about trade deficit/surplus together with the long-run growth rate and interest rate. The  $\theta$  values in the productivity growth function allocate the effects of the two sources of productivity growth, and  $\theta_1$  is set to 0.3 and  $\theta_2$  to 0.7. Based on the long run technological progress rate, initial values of the adoption and innovation variables, and the relative level of productivity, the parameter  $\lambda$  follows as a residual. To have balanced growth the skill-bias variable ( $\beta$ ) is set equal to 0 in the calibration. The elasticity of substitution in both the Armington and CET functions are assumed to be 2, in accordance with national and international estimates as documented by Gibson (2003). These elasticities represent substitution possibilities between domestic and foreign goods (Armington), and between sales to domestic markets versus export markets (CET). The elasticity of substitution between different labor categories is important for the adjustment of relative wages, and is set equal to 2, which implies that unskilled, semi-skilled and skilled labor are substitutes. The development in terms of trade is calibrated according to data (IMF, 2004). We reproduce the terms of trade deterioration of about 30% observed during 1975-82, while the relative price is kept constant both before and after this period.