

Trade, skill biased technical change and wage inequality in South Africa^{*}

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Abstract

Trade openness influences the wage structure via technology adoption in middle income countries. Given the econometric challenges of handling endogenous trade and technology interaction, we offer an alternative quantification based on calibration of a general equilibrium model. We expand the standard open economy Ramsey model to include comparative advantage, technology adoption and skill bias influenced by investment decisions. The calibration constructs a reference path for South Africa and allows counterfactual analysis of trade openness. The quantitative results imply that trade effects via technology adoption and skill bias can be an important determinant of wage inequality in middle income countries.

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1. Introduction

The broad understanding is that increased trade openness has not been important for increased wage inequality in developed economies, notably the US. Krugman (2008) summarizes decades of research and debate. The analyses have concentrated on the factor content of trade, and have recently addressed issues of vertical specialization and outsourcing of production. Acemoglu (1998) presents the main alternative explanation of increasing wage inequality based on skill biased technological development. The main issue in the US debate has been trade versus technology.

The relationship between trade openness and wage inequality is different in semi-industrialized middle income countries where trade is important for technological change. Technological innovation is concentrated to the few most advanced economies, and most other countries take benefit of innovations by foreign technology adoption. Keller (2004) gives an overview of the literature showing the importance of international technology spillovers. Lucas (2009) understands the world growth pattern as a result of cross-country flows of production-related knowledge from the successful economies to the less successful ones. Caselli and Coleman (2006) show how adoption can be understood related to the gap to the world technology frontier. Alcalá and Ciccone (2004) separate the trade effect between productivity and capital accumulation and conclude that trade is a significant determinant of productivity. The simultaneous determination of productivity and investment in channeling trade effects are handled in this study.

Technical change typically is skill biased and has a positive effect on the demand for skilled workers. Acemoglu (1998) suggests that technical change is not skill biased by nature, and offers a theoretical explanation of why new technologies complement skills based on endogenous directed technical change. In a skill-intensive economy the market size effect implies that it is profitable to develop technologies directed towards skilled workers. It follows that countries adopting technology innovated in skill-intensive countries end up with skill bias. Acemoglu (2003) argues that international trade induces skill biased technical change and that the two explanations of wage inequality, trade and technology, are related. He attributes the original idea to Wood (1994), who introduces skill biased innovations as a response to increased trade. Further evidence about the link between trade openness and skill biased technical change is offered by Attanasio, Goldberg and Pavcnik (2004) and Zhu and

Trefler (2005). Berman and Machin (2000) compare different types of countries and conclude that skill biased technology transfer is central to the demand for skilled labor in middle income countries.

Our analysis is related to a large literature of country studies addressing trade and inequality. Hanson and Harrison (1999) turned the attention towards developing countries, as Mexico experienced a dramatic increase in the skilled-unskilled wage gap during a period of trade liberalization. They conclude that Mexico has a comparative advantage in skilled labor. The more recent literature offers closer examination of the technology channel. Esquivel and Rodriguez-Lopez (2003) argue that trade liberalization should have led to a reduction of the wage gap in Mexico, and conclude that a large negative impact of technological progress has reduced the real wage of unskilled workers. Verhoogen (2008) develops the understanding of the technological channel in an analysis of quality upgrading in Mexican industries. The econometric approach attempts at separating the trade and the technology effects, but does not take into account that trade affects the technology channel. Underestimation of the trade effect then is likely. Interestingly, Esquivel and Rodriguez-Lopez acknowledge the problem that technological change is strongly associated to the opening of the economy. Goldberg and Pavcnik (2007) provide a nice overview of the empirical research on how globalization affects wage inequality in developing countries. They discuss the methodological challenges of separating between trade and technology when both are endogenous. It is of particular importance that trade affects technology and the total effect of trade includes both the direct trade effect and the indirect effect of trade via technology. The shortcomings of econometric studies such as these have led us to look for an alternative approach.

We offer quantification of the relationship between trade openness and wage inequality by calibrating a general equilibrium model. A few studies using calibration have appeared recently. Atolia (2007) do numerical simulations for a stylized Latin-American economy to show that transitory capital accumulation following trade liberalization may give rising wage inequality. Burstein and Vogel (2010) and Helpman, Itzhoki and Redding (2011) calibrate models more relevant for developed economies and capture more recent innovations in trade theory concerning differentiated products and firm heterogeneity. Our starting point is the standard open economy Ramsey growth model with intertemporal decision making of a representative firm/household and an open world capital market. The model is designed to capture the basic trade channels of comparative advantage and technology adoption relevant

for middle income countries. The strength of the Ramsey framework is the consistent handling of investment in intertemporal equilibrium and we emphasize the interaction between investment and technology adoption. The model can be developed to include a broader variety of trade theories, notably product differentiation and scale effects.¹ At this stage our main focus is to quantify the technology adoption channel.

The model formulation is assumed relevant for middle income countries. The setup separates between a traditional unskilled-intensive sector, a modern skill-intensive sector, and a non-traded service sector. The model includes the endogenous interaction between trade, technology adoption and technological bias, and allows for comparative advantage in unskilled labor. Productivity growth is generated by adoption of foreign technology and is related to the technology gap to the world frontier. The technology adoption is assumed to depend on the share of foreign capital goods in the total capital stock. The foreign capital as channel is in accordance with Dawid, Greiner and Zoe (2010). The degree of skill bias in technical change is endogenously determined and increases with the economy's dependence on foreign technology in a similar way. It follows that adoption and skill bias respond to trade openness and are influenced by investment decisions.

Our quantification of the relationship between trade openness and wage inequality is based on data from South Africa. The country has experienced dramatic shifts in trade openness and large changes in wage inequality, and is broadly representative of middle income countries with some advanced industry competing at international markets. Edwards (2006) shows that it has comparative advantage in unskilled labor. The development of relative wages reflects the puzzle observed elsewhere. According to comparative advantage, the international isolation during the 1980s is expected to increase the wage gap, while the recent trade liberalization post Apartheid should improve the wage inequality. The opposite has happened. While the wage gap decreased in the 1970s and 1980s, there was a distributional break in the mid 1990s with increased inequality post Apartheid (Fedderke, Shin and Vaze, 2004, Leibbrandt et al., 2006). The declining wage gap follows from the supply side of the labor market and structural shift. We argue that opening of the economy in the 1990s increased the dependence of foreign technology with higher skill bias and increased wage inequality.

¹ Recent econometric analyses have used micro data motivated by these new trade theories such as Amity and Konings (2007) and Amity and Davis (2008) for Indonesia.

The quantification of the effects involved is obtained by studying the counterfactual of a shock. We analyze the effects of increased openness with consequences for the choice between domestic and foreign investment goods and thereby technology adoption and skill bias. Eliminating the rise in the tariff equivalent during the period of sanctions and protectionism the model predicts an increase in technological skill bias as the economy becomes more dependent on foreign technology. Interestingly, the degree and direction of comparative advantage has only minor impacts on the relative wage path. The quantitative results imply that an increase in trade as share of GDP of 10% points generates an increase in the wage gap in the order of 3-10%. Trade effects via technology adoption and skill bias can be an important determinant of wage inequality in middle income countries. However, the size of the effect is well below econometric estimates where all the technology effect is assigned to trade, which can be interpreted as an upper limit of the trade effect. The range indicated is robust to large changes in parameter values.

The three sector Ramsey model of trade, technology adoption, skill biased technical change and wage inequality is presented in section 2. Section 3 calibrates a trade and relative wage path that broadly reproduces the development in South Africa during 1960-2005. The quantification of the importance of trade for wage inequality is discussed in section 4. Section 5 offers concluding remarks.

2. Model of growth and distribution

The starting point is the standard open economy Ramsey growth model with intertemporal decision making of a representative firm/household and an open world capital market. We separate between foreign and domestic capital based on foreign and domestic investment goods, and assume installation costs of investment. The long-run growth rate is exogenously given, while transition growth is endogenous. Turnovsky (2009) offers an overview of small open economy models in this tradition. The role of the technology gap in this setting has been analyzed by Duczynski (2003), but has not been related to trade openness.

We add these elements to analyze the interaction between trade, technology and wages: First, we disaggregate to include a traditional unskilled-intensive sector, a modern skill-intensive sector, and a non-traded service sector. We assume imperfect substitution between sales to domestic markets versus export markets and allow the substitution possibilities to differ

across sectors to reflect the degree and direction of comparative advantage in the economy. Second, productivity growth is endogenously determined by technology adoption and depends on the investment decision of the firm, in particular the share of foreign capital goods in the total capital stock. Foreign investment goods generate technology adoption and represent the link between trade and technology. The share of foreign capital goods also determines the skill bias of the technical change. Third, unskilled and skilled labor operate in the labor market and the skill bias influences wages via labor demand. The relative wage is the key variable describing the wage inequality effect.

The model gives a stylized description of a middle income country with a modern skill-intensive sector, important role of technology adoption and skill biased technical change. The extensions of the standard open economy Ramsey model regarding skill biased technical change and comparative advantage are outlined in sections 2.1 and 2.2, respectively, while the full model documentation is given in a separate appendix available from the authors.

2.1 Production technology, productivity dynamics and skill biased technical change

Sectoral value added ($X_{i,t}$) is defined as a Cobb-Douglas function of foreign capital ($K_{F,i,t}$), domestic capital ($K_{D,i,t}$), and total efficient labor use ($L_{i,t}$):

$$X_{i,t} = K_{F,i,t}^{\alpha_{1,i}} K_{D,i,t}^{\alpha_{2,i}} L_{i,t}^{1-\alpha_{1,i}-\alpha_{2,i}} \quad i = TR, M, S \quad (1)$$

where $i = TR, M, S$ represents the traditional unskilled-intensive sector, the modern skill-intensive sector and the non-traded service sector, respectively. Efficient labor is a CES aggregate of unskilled ($Lu_{i,t}$) and skilled ($Ls_{i,t}$) labor:

$$L_{i,t} = \left[\gamma_i A_{i,t}^{\frac{v-1}{2}\beta_{i,t}} Lu_{i,t}^v + (1-\gamma_i) A_{i,t}^{\frac{v+1}{2}\beta_{i,t}} Ls_{i,t}^v \right]^{\frac{1}{v}} \quad i = TR, M, S \quad (2)$$

The share parameters for unskilled labor are given by γ_i , and $\sigma_L = \frac{1}{1-v}$ ($v < 1$) is the elasticity of substitution between the two labor types (which is assumed to be equal across sectors). The first order conditions equilibrate factor prices with the marginal productivities of each factor.

The direction and degree of technological bias is defined as a relationship between the overall labor efficiency $A_{i,t}$ and the relative marginal productivities of the two labor types as in

Acemoglu (1998). It is represented by the parameter $\beta_{i,t}$, which gives the elasticity of the marginal productivity of skilled relative to unskilled labor with respect to labor augmenting technical progress. The relative marginal productivity, which equals the relative wage, is given as:

$$\frac{\partial X_{i,t} / \partial L_{S_{i,t}}}{\partial X_{i,t} / \partial L_{U_{i,t}}} = \frac{1-\gamma_i}{\gamma_i} A_{i,t}^{\beta_{i,t}} \left(\frac{L_{S_{i,t}}}{L_{U_{i,t}}} \right)^{\gamma_i-1} \quad i = TR, M, S \quad (3)$$

For $\beta_{i,t}$ equal to zero, technical change is neutral and does not affect the relative efficiency of the two labor types. With a positive value of $\beta_{i,t}$ technical change favors skilled workers (skill biased technical change), while negative values imply that improvements in technology are biased towards unskilled labor. In the service sector technical change is assumed to be neutral, and technological bias is set exogenously equal to zero ($\beta_{S,t} = 0$). It should be noticed that our specification of skill bias differs from the conventional separation between ‘old’ and ‘new’ technology. Beaudry, Doms and Lewis (2006) show the basic analytics of a CES production function in this case.

Labor augmenting technical progress ($A_{i,t}$) is endogenously determined in the traded sectors. We focus on a middle income country where technology adoption varies with trade openness. The model formulation assumes that productivity growth is related to the world technology frontier and affected by the share of foreign capital in the total capital stock. The productivity formulation is consistent with Dawid, Greiner and Zoe (2010) relating absorptive capacity and technology transfer to the presence of foreign capital in the domestic economy. The main difference in our suggested specification is that the absorptive capacity is affected by the investment decision of the domestic firm, and is not exogenously given from abroad. The growth contribution from innovation is assumed exogenous and thus independent of the trade openness.

The productivity growth rate is specified as follows:

$$\hat{A}_{i,t} = g_i + \lambda_i \left(\frac{K_{F,t}}{K_t} \right)^{\theta_i} \left(1 - \frac{A_{i,t}}{A_{i,t}^*} \right) \quad i = TR, M \quad (4)$$

In the technology adoption function $A_{i,t}$ and $A_{i,t}^*$ represent domestic and frontier productivity at the sector level, and $A_{i,t}/A_{i,t}^*$ is relative productivity. The foreign capital share is given by $K_{F,t}/K_t$, where $K_{F,t}$ is the sum of foreign capital across all sectors and K_t is the total capital

stock. The elasticity of productivity growth with respect to the foreign capital share is constant and given by the parameter θ_i . The constant term (g_I) can be understood as exogenous domestic innovation. In the long-run equilibrium productivity growth equals the exogenous world frontier rate, and the technology gap is constant. Changes in the composition of the capital stock generate transitional growth to a new technology gap. Productivity in services is assumed to grow exogenously at the long-run rate.

To have balanced growth, neutral technical change is a necessary long-run condition, but during transition the degree of technological bias in the traditional and the modern sector is endogenously determined. The specification of technological bias is linked to the relative importance of technology adoption in productivity growth. New technology innovated in skill-intensive developed countries is likely to be skill biased following from directed technical change. The more dependent the developing economy is on adoption of foreign technology, the higher is the degree of skill bias in technical change. We parameterize this based on a reduced form specification of technological bias assumed to be an increasing function of the foreign capital share:

$$\beta_{i,t} = b_i \left(\frac{K_{F,t}}{K_t} \right)^{\eta_i} \quad i = TR, M \quad (5)$$

where b_i is a positive parameter and η_i is the elasticity of technological bias with respect to the foreign capital share. Given this specification, technical change is always skill biased ($\beta_{i,t} > 0$), but the degree of bias is determined by the relative dependency on foreign technology as measured by the foreign capital share.

2.2 Trade and modeling of comparative advantage

The handling of comparative advantage in a country model can be taken care of by assuming different substitution elasticities between domestic and foreign markets of the two traded sectors. The tradable sectors face imperfect substitution between producing for the domestic market and for the world market. The supply functions for exports ($E_{i,t}$) and domestic sales ($D_{i,t}$) are derived from maximizing current sales income subject to the constant elasticity of transformation (CET) functions:

$$\text{Max } PD_{i,t} \cdot D_{i,t} + PWE_{i,t}(1 - te_{i,t}) \cdot E_{i,t} \quad (6)$$

$$\text{s.t. } X_{i,t} = a_{X,i} \left[m_{X,i} \cdot E_{i,t}^{\frac{1+\sigma_{X,i}}{\sigma_{X,i}}} + (1 - m_{X,i}) D_{i,t}^{\frac{1+\sigma_{X,i}}{\sigma_{X,i}}} \right]^{\frac{\sigma_{X,i}}{1+\sigma_{X,i}}} \quad i = TR, M \quad (7)$$

where $a_{X,i}$ is a shift parameter and $m_{X,i}$ is the distribution parameter. The producer price is a composite of the exogenous world market price of export goods ($PWE_{i,t}$) adjusted by export taxes ($te_{i,t}$) and the endogenous domestic price ($PD_{i,t}$). The constant elasticity of substitution between sales to domestic and foreign markets for sector i is given by $\sigma_{X,i}$. The degree and direction of comparative advantage is determined by assumptions about the substitution possibilities in the sectors. Relatively higher elasticity of substitution in the traditional unskilled-intensive sector implies better international competitiveness compared to the skill-intensive modern sector, and the economy has comparative advantage in unskilled labor.

We model imperfect substitution between foreign and domestic consumption and intermediate goods, and import demand is endogenously determined from the Armington composite system. Total imports of good i include the demand for foreign capital goods. Foreign debt is accumulated over time from trade deficits and interest payments on outstanding debt.

3. Reproducing the trade and relative wage path in South Africa

Our strategy of quantification is to establish a reference path based on data for South Africa and then study a counterfactual shock to sort out the relationship between trade openness and wage inequality. The reference path captures the broad economic development in the country during 1960-2005. The parameters are set based on a 1998 Social Accounting Matrix, as well as available econometric estimates and stylized facts. The parameters are made consistent with long run equilibrium, where the growth rate is assumed to equal 2% (1.3% technological progress rate and 0.7% labor growth).² Long run technical progress follows the growth rate of the world technology frontier. To reproduce actual GDP growth, the initial levels of productivity, foreign capital and domestic capital 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 transitional economic growth is driven by endogenous adjustment back to equilibrium growth.

² The assumption of 0.7% labor growth is consistent with data on average annual employment growth in South Africa during 1971-2005 (Quantec Research, 2007).

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. The empirical literature addressing foreign trade and trade policy faces the problem that sanctions cannot be measured directly. We capture the protectionist effect of international isolation by calibrating export and import taxes necessary to reproduce the observed trade path 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. Total trade taxes as share of trade represents our measure of openness, as illustrated in Fig. 1. While the tariff equivalent decreases during the 1960s, the slow growth of exports and imports in the 1970s and 1980s 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 gradual liberalization of the trade policy increased trade rapidly, reflected in the model by decreasing tariffs. The calibrated openness indicator is consistent with existing measures of openness in South Africa, represented by Aron and Muellbauer (2002) and Edwards and Lawrence (2008).

Figure 1 about here.

We track the actual growth rate as a steady decline in the model growth rate during 1961-90, followed by more stable growth post Apartheid. While the initial high growth was driven by investment and profitability, sanctions and protectionism increase the cost of foreign capital and the associated change in the composition of the capital stock gives a drop in productivity growth, with further consequences for overall investment profitability. Post Apartheid, the elimination of sanctions and trade liberalization stimulate economic growth through less expensive foreign capital goods and more technology adoption. But overall, the economy is unable to catch up with the frontier.

Starting out with a standard trade theory perspective, the development of the South African relative wage path has been puzzling. Wage inequality decreased during international isolation and increased with trade liberalization post Apartheid. We concentrate the wage story to the period 1970-98 when we have real wage data as used by Fedderke, Shin and Vaze (2004). The wage gap decreases from an average of 4.5 in the 1970s, via 3.2 in the 1980s, to

about 2.2 in the 1990s.³ A recent analysis of South African inequality by Leibbrandt et al. (2006) indicates a structural break in the mid 1990s, where the improvement in distribution since 1970 is turned into increased inequality post Apartheid (measured by the relative income between Whites and Africans). Ardington et al. (2006) address the robustness of this result and confirm the main finding. Our simulations give a similar pattern and indicate that the declining trend ends in the mid 1990s.

In the model simulations, the relative wage path is affected by both supply-side and demand-side factors. The relative supply of labor is set according to Quantec Research (2007) data on employment shares by skill level.⁴ The share of skilled labor in the total labor force increases from 22% to 54% during 1960-2005, and contributes to decreasing wage gap. Demand for different labor types is affected by the direction of comparative advantage and the development in technological bias. The substitution possibilities between domestic sales and exports are set relatively higher in the unskilled-intensive sector. This implies that the economy has a comparative advantage in unskilled labor and the traditional sector is relatively more able to take advantage of an open economy by expanding sales into world markets.

Given the labor market conditions and the development of relative labor supply and openness, the degree of skill bias is calibrated to reproduce the development of the wage gap. The b -parameter in equation (5) is set to 3 in both sectors to give reasonable values of the technological bias. Given the steady state value of the foreign capital share, the degree of skill bias equals about 0.3. This implies that 1% productivity growth generates an increase in the relative marginal productivity between skilled and unskilled workers (which equals the wage gap in this model) of 0.3%. The assumed effect is modest. With annual productivity growth of 1%, skill biased technical change increases the wage gap by 3% during 10 years. The elasticity of technological bias with respect to the foreign capital share [η in equation (5)] is set equal to 2, which implies that an increase in the foreign capital share of 5% points leads to an increase in the degree of technological bias slightly lower than 0.1.⁵ An increase in the degree of skill bias from 0.3 to 0.4 means that the effect of 1% annual productivity growth on

³ Fedderke, Shin and Vaze (2004) offer data on relative wages between unskilled, skilled and highly skilled labor. Our measure of skilled labor consists of highly skilled and skilled workers, and we use average employment shares from Quantec Research (2007) as weights to calculate the aggregate skill wage.

⁴ The supplies of skilled and unskilled labor are extended backwards to 1960 based on average growth rates during 1970-2005.

⁵ The calculation is based on foreign capital shares in the range 0.22-0.33, which is consistent with the values in the model simulations.

the wage gap over a 10-year period increases from 3% to 4.1%. Based on this, the elasticity of technological bias with respect to the foreign capital share applied in our model can be seen as conservative.

Given this calibration, the degree of skill bias is endogenously determined by the relative importance of technology adoption in productivity growth, measured by the foreign capital share. The more dependent the economy is on foreign technology, the higher is the degree of skill bias in technical change. Along the South African reference path foreign capital initially accounts for 33% of aggregate capital, but the share decreases gradually to about 22% in the early 1990s. The economy is forced to rely more on own improvements of technology, and the degree of skill bias in technical change declines. This applies to both the traditional and the modern sector. In the post Apartheid period trade liberalization and removal of sanctions give cheaper foreign capital goods (the foreign capital share increases to 24% in 2005), and gradually increase the degree of skill bias.

The development in the skilled-unskilled wage ratio along the calibrated South African reference path is illustrated in Fig. 2 below. The wage gap decreases until the mid 1990s, mainly driven from the supply side with increasing skill share. The size of the wage gap broadly follows the observed data as given by Fedderke, Shin and Vaze (2004). In the post Apartheid period the higher demand for skilled labor from increasing skill bias puts an end to the declining relative wage path, consistent with the structural break identified by Leibbrandt et al. (2006). Increasing skill intensity during the 1990s is supported by empirical evidence. Edwards (2001) argues that skill bias has contributed to increased skill employment in South Africa, and based on two firm level surveys Edwards (2003) relates skill biased technical change to trade liberalization.

Figure 2 about here.

The relative wage path generated by the model is broadly consistent with the observed pattern in South Africa, and follows from the development in relative labor supply and from skill bias in technical change related to the dependence on foreign technology. Figure 2 compares the South African reference path with an alternative reference path where the skill bias effect on relative wages is not taken into account. As seen from the figure, the interaction between openness and skill biased technical change is necessary to capture the distributional break in

the mid 1990s. When the skill bias effect is ignored, the wage gap decreases during the whole period 1960-2005.

4. Quantification of the relationship between trade openness and wage inequality

The model allows a counterfactual analysis of the role of international trade and thereby a quantification of the effect of trade openness for wage inequality. As explained in section 3, we have calibrated a tariff-equivalent growing from the late 1960s 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 tariff-equivalent decreases gradually, as illustrated in Fig. 1.⁶ The average tariff rate during 1960-2005 equals 16%, down from 38% along the reference path reproducing the actual growth in South Africa.

With lower tariffs the cost of foreign investment goods is kept low, and the average foreign capital share during 1980-2005 is 5% points higher than along the reference path. The modern skill-intensive sector is more capable of utilizing the new technology, and catches up relative to the world frontier. During 1960-2005 relative productivity increases from 32% to 38%, and generates a long-run productivity gap of about 7%-points compared with the South African reference path. Due to the economy's comparative advantage in unskilled labor, trade liberalization implies a structural shift towards the unskilled-intensive sector. Along the reference path the traditional sector expands during the 1960s and in the post Apartheid period, while the output expansion is held back during sanctions and international isolation. Over the period 1960-2005 the sector increases its value added share from 18% to 22%. With a more open economy, the output expansion is larger, and the 2005 value added share equals 28%. However, while the modern sector gains from trade liberalization in terms of higher productivity, the volume expansion in the traditional sector has limited effects on productivity. The sector avoids technological divergence, but is not able to catch-up with the frontier and relative productivity is about constant over time.

⁶ 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.

With a more open economy, the relative importance of technology adoption is higher than along the reference path. The new technology favors skilled workers and the degree of skill bias in technical change increases over time. This generates an increase in the relative demand for skilled labor, and increases the wage inequality compared with the reference path. The wage gap is almost 12% higher on average during the period after 1980 compared with the scenario with sanctions and protectionism (Fig. 2). The result is consistent with the empirical analysis of Edwards (2006), where he finds that the South African tariff liberalization during the 1990s has contributed to an increase in the skilled-unskilled wage gap. The implied relationship between trade as share of GDP and relative wages is of interest. Given our parameterization, the tariff liberalization increases the trade share by 22% points on average for the ‘effect period’ after 1980. Our quantitative results thus imply that an increase in the trade share of 10% points generates an increase in the wage gap of 5.3%. We investigate the robustness of this relationship by imposing large changes in parameter values, and find that the effect on the wage gap lies in the range 3-10%.

The quantitative effects are comparable to econometric studies. Based on mandated wage regressions, Esquivel and Rodriguez-Lopez (2003) try to separate out the effects of technical change and trade on wage inequality in Mexico. However, trade-induced technical change implies that the identified trade effect on the wage gap is likely to be underestimated. The combined effect on wage inequality of trade and technical change estimated by Esquivel and Rodriguez-Lopez can be seen as an upper limit for the true trade effect (when the indirect effect via technical change is taken into account). Based on their results for the 1994-2000 period the increase in the wage gap following 10% points higher trade share is at most 14.5%.⁷ This is the trade effect when all of the technical change effect is assigned to increased trade, and therefore represents the upper limit. Our calibrated quantitative effect is well below the calculated upper limit.

Interestingly, the degree and direction of comparative advantage has only minor impacts on the relative wage path. When the skill bias channel is ignored, a more open economy decreases the wage inequality, consistent with the predictions of standard trade theory. But the effect is marginal; since 1980 the wage gap decreases with 1.8% on average. The

⁷ The total effect on the wage gap during 1994-2000 is estimated to 37.8% (given in Table 6 in Esquivel and Rodriguez-Lopez, 2003). In the same period, Mexican trade as share of GDP increased by 26% points (World Bank, 2008).

understanding is that the structural change following comparative advantage is not large enough to generate significant relative wage effects. Even with more extreme parameter assumptions, the role of comparative advantage for the distributive effects of openness is limited.

Given our model specification, there is a trade-off between economic growth and wage equality. Openness stimulates growth through cheaper foreign capital goods, more technology adoption and positive productivity-investment interaction, but increases the wage gap because foreign technology is skill biased. The average GDP growth rate during 1960-2005 increases by 0.7% point, and generates a permanent income gap between the two scenarios. The model predicts that the 2005 level of real GDP is 37% higher when the rise in the tariff equivalent during the period of sanctions and protectionism is eliminated. Wage inequality increases with trade liberalization, but overall the income level is higher with more openness due to higher growth, also for unskilled workers. The 2005 real wage of unskilled and skilled workers increases with 42% and 51%, respectively.

5. Concluding remarks

The analysis contributes to the quantification of the relationship between international trade and wage inequality in middle income countries. These countries are characterized by a sizable advanced industrial sector and technological development driven by technology adoption. Given the econometric challenges related to the handling of endogenous trade and technology, we suggest quantification based on the calibration of a general equilibrium model. The calibration is based on the growth path of South Africa, which reflects large changes in trade openness of the economy. Standard trade theory predicts worsened wage inequality during international isolation in a country with comparative advantage in unskilled labor. In South Africa the wage gap decreased during the period of international sanctions and protectionism, while it increased with trade liberalization post Apartheid. This ‘puzzle’, which is well known from many country experiences, can be understood as a result of interaction between openness and skill biased technical change. International isolation reduces the inflow of skill biased technology and allows more room for domestic innovation taking advantage of the unskilled labor surplus. Similarly, the opening of the economy post Apartheid increases the dependence on foreign technology and thus the degree of skill bias in technical change.

Our methodological contribution is the construction and calibration of a general equilibrium model and counterfactual analysis of openness. The starting point is the standard open economy Ramsey model and it has been extended to include endogenous technology adoption and skill biased technical change dependent on the trade openness. The composition of investment between foreign and domestic capital goods is assumed to be the main channel of effect, and trade openness consequently is related to the investment decision of the firm. The model is disaggregated to capture comparative advantage. The strategy of quantification is to establish a reference path and do counterfactual analysis of openness. The calibrated reference path captures the main elements of the South African experience during 1960-2005. International sanctions and protectionism are represented by a calibrated tariff equivalent that reproduces the actual trade and growth path. Eliminating the rise in the tariff equivalent during the period of sanctions and protectionism the model predicts an increase in technological skill bias as the economy becomes more dependent on foreign technology. Interestingly, the degree and direction of comparative advantage has only minor impacts on the relative wage path. The quantitative results imply that an increase in trade as share of GDP of 10% points generates an increase in the wage gap in the order of 3-10%. The result is well below econometric estimates where all the technology effect is assigned to trade, which can be interpreted as upper limits of the trade effect on the wage gap. The range indicated is robust to large changes in parameter values.

We have applied a standard open economy growth model that includes both comparative advantage and technology adoption. The model has offered a quantification of the relationship between endogenous trade openness comparing the direct effect (comparative advantage) and the indirect effect (via technology). We acknowledge that the literature offers a range of other theories of trade and technological development and that linkages between trade and wages are more complex. It is of interest in future research to expand this methodology of quantification into other model alternatives and a few papers relevant for developed countries are already available as discussed in the introduction.

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Fig. 1. 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.

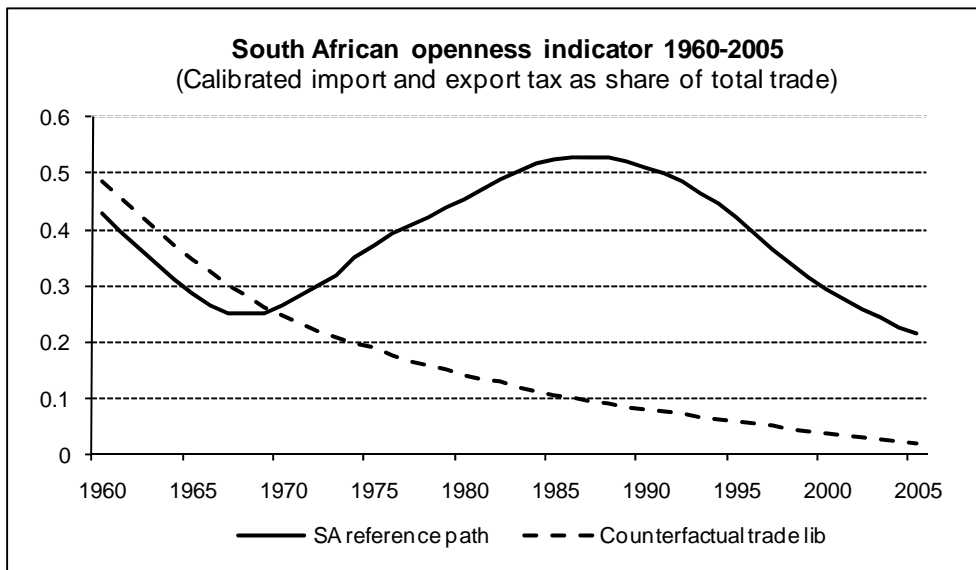


Fig. 2. Skilled-unskilled wage gap: Calibrated South African reference path, reference path in model without skill bias effect, and counterfactual trade liberalization path.

