Trade, Technology and Wage Inequality in the South African Manufacturing Sectors*

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Abstract

This paper advances on previous work on the effects of trade and technical change on labour markets within the framework of Heckscher-Ohlin trade theory. *First*, we employ dynamic heterogeneous panel estimation techniques not previously used in this context, which separate Heckscher-Ohlin-based long run relationships from short run dynamics that are heterogeneous across sectors. *Second*, we provide evidence for an unskilled labor abundant developing country that allows comparison of the results against developed country evidence. *Third*, we consider the appropriateness of alternative approaches and examine endogeneity issues in the impact of technology and price changes on factor returns. For South African manufacturing we find that output prices increase most strongly in sectors that are labor intensive. Our results further suggest that trade-mandated earnings increases are positive for labor, and negative for capital. By contrast technology has mandated negative earnings increases for both factors. We also find that separation of different demand side factors collectively constituting globalization is useful in understanding the impact of trade, and taking account of endogeneity is important in isolating factor and sector bias of technological change.

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Key Words: Trade, Total Factor Productivity, Stolper-Samuelson Theorem, Mandated Factor Earnings Changes, Dynamic Heterogeneous Panel Data, Pooled Mean Group Estimation.

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1 Introduction

Recent experience in many industrialized countries has seen a large fall in employment amongst the unskilled at the same time as employment of skilled labor has risen. Wage levels for skilled workers have also risen in relation to those of the unskilled. Both factors have resulted in rising wage inequality. Two explanations have been given: skill-biased technological improvement and increased international competition. Trade with less developed countries endowed with an abundance of unskilled labor has been advanced as one possible explanation for rising wage inequality, consistent with the Stolper-Samuelson theorem.

To date examinations of the impact of trade on labor markets in terms of Heckscher-Ohlin theory has focused predominantly on developed country contexts. One expectation of Heckscher-Ohlin trade theory is that strongest product price changes should occur in sectors using the abundant factor of production. Empirical validity of this impact would potentially carry important welfare implications for the developing world since in terms of the Stolper-Samuelson theorem output price changes come to be translated into changes in the earnings of abundant factors of production. At the same time, the developing country experience can provide independent corroboration of the impact of trade for developed countries. A notable feature of the debate is that few studies have examined evidence from developing country contexts. Though there are exceptions, where developing countries are considered, this often takes the form of factor content studies, or labor usage equations. We find only one study, Hanson and Harrison (1999), which employs Heckscher-Ohlin theory in a manner directly comparable to developed country studies for a middle income country (Mexico). Thus the opportunity to provide independent verification of Heckscher-Ohlin theory by examining developing country evidence directly has been neglected. If globalization is responsible for growing wage inequality in developed countries by Stolper-Samuelson mechanisms, developing countries should report the mirror image effect of narrowing wage inequality. This paper takes advantage of the opportunity to deepen understanding of the effects of globalization on labor markets by considering evidence from a middle income country, South Africa.

A number of qualifications apply to empirical applications of the Stolper-Samuelson theorem. *First*, Stolper-Samuelson effects explicitly hold in long run equilibrium. Noting that real world processes seldom reflect pure equilibrium states, any empirical application of the Heckscher-Ohlin framework has to account not only for the nature of the equilibrium relationship predicted by theory, but for the fact that dynamic adjustments to equilibrium may be as important a feature of the modeling of the impact of globalization on labor markets.

A *second* consideration is that theory implicitly presumes the impact of trade liberalization to be uniform across all sectors in an economy. Yet there are many reasons why sectors differ substantially - from the degree of liberalization, the presence of non-tariff barriers, developments within labor market institutions, and the composition of trade between developed and developing trading partners, all of which may come to materially affect the extent to which the impacts of globalization predicted by the Heckscher-Ohlin theory may come to be realized. The point is that homogeneity across economic sectors is a presumption that is worthy of explicit attention. While some earlier studies employed panel data techniques [*e.g.*, Sachs and Shatz (1994), Hine and Wright (1998), Feenstra and Hanson (1999), Haskel and Slaughter (2001)], estimation allowed neither for dynamics nor for the possibility of panel heterogeneity beyond fixed effects. In the present paper we use dynamic heterogeneous panel estimation techniques proposed by Pesaran *et al.* (1999) that allow for both dynamics across time periods and a reasonable amount of heterogeneity across cross-sectional units. This approach allows us to simultaneously investigate both a homogenous long-run relationship and heterogenous short-run dynamic adjustment towards equilibrium. Since the Stolper-Samuelson theorem would hold in the long-run but is likely to deviate from its equilibrium path over the short-run, our suggested approach is likely to address the theoretical underpinning more clearly than earlier approaches based on static models. The only study we find to employ dynamic panel techniques is Milner and Wright (1998). However, they employ a framework that generates a labor demand equation, not the Heckscher-Ohlin framework as employed in the developed country literature.

A *third* consideration arises since while trade liberalization can be plausibly linked to a labor market, it is not the only possible reason for price and demand changes in labor markets. Within the broad Heckscher-Ohlin framework, three distinct approaches have come to emerge over time. The first relies on a factor proportions regression, controlling for technology in an *ad hoc* manner. The second takes care to separate the impacts of globalization effects and of technology on factor usage. The third allows for the endogeneity of price and technological change. This paper allows for a comparison of all three approaches to Heckscher-Ohlin theory. In particular, we examine potential endogeneity surrounding the impact of technological change on price and factor usage changes in the South African economy and extend the treatment of endogeneity in estimation beyond earlier approaches in the literature. We also employ a modified labor usage estimation as employed in Hine and Wright (1998) to provide a check of the implications drawn from the three approaches.

One concern is that the Stolper-Samuelson theorem is less conclusive about the effect of increased trade openness on middle income countries, which are likely to share characteristics with both developed and less developed countries. The composition of trade between developed and developing countries is likely to be crucial in determining results. This is precisely the problem encountered in Hanson and Harrison (1999), where for the middle income context of Mexico trade liberalization appears to have spurred growing wage inequality through a promotion of imports from countries less developed than itself.[1] Fortunately, South Africa is able to combine the ready data availability over a large number of sectors and over a protracted period of time, with what relative to its trading partners are properly developing country characteristics. Its international isolation meant trade with the North dominated any trade with other developing countries. Although we might expect trade effects on middle income countries to be ambiguous, in the case of South Africa we are offered a natural experiment allowing us to establish the effect of trade liberalization on a country with a relative abundance of unskilled labor relative to its trading partners. In addition, the Krug-

[1] A number of other studies have found evidence contradictory to SST for developing countries, see for example Hanson and Harrison (1995), Robbins (1996), Harrison and Hanson (1999) and Görg and Strobl (2002). In particular, Wood (1997) points out that this may be the result of the integration of China and India into world trade, rendering all other economies skills abundant. However, as Edwards and Schör (2002) report, 85% of South African imports in 1990 were sourced from the 25 richest OECD countries, declining to 72% in 1999. The comparable figures were 57% and 53% for exports. South African trade is thus heavily biased toward developed countries over the sample period of this study, though it is true to say that developing countries have begun to feature more prominently in South African trade during the 1990's.

man (1995) critique of the US studies denying the US economy the status of a small open economy does not apply here. The South African economy is certainly small, and the manufacturing sector in particular is very open. Finally, the small size of the informal sector in the South African economy avoids the problem associated with many developing countries that a substantial proportion of labor market activity is simply not reflected in official data.

For South African manufacturing over 1972-1997 we find that output prices increase most strongly in sectors that are labor intensive and unskilled labor intensive, consistent with the prediction of the Stolper-Samuelson theorem. Therefore, our results are consistent with those reported for developed countries which have suggested that trade has contributed toward widening wage inequality in the North. But in the South African context, consistent with its developing country status relative to the North, the implication is of narrowing wage and factor return inequality. Our results further suggest that trade-mandated earnings increases are positive for labor and negative for capital. By contrast technology has mandated negative earnings increases for both factors.

The evidence further suggests that accounting for potential endogeneity of price and technological changes is also important even in developing country contexts. Providing a more detailed account of structural variables determining product market developments and technological progress identifies the presence of factor-biased technological change as well as upward pressure on labor earnings from openness to trade, rising capacity utilization, increased industry concentration levels, and downward pressure from research and development expenditure and a rising skills composition of the labor force. Even where we take into account endogeneity, results continue to support the central finding that demand and globalization effects appear to have a positive impact on labor-earnings. To this extent therefore the current study provides support to developed country studies suggesting that the impact of trade has been to shift labor intensive production to the developing world.

The layout of the paper is as follows. Section 2 provides an overview of previous studies into the link between trade, technology and labor markets. Section 3 provides the dynamic panel data methodology used in the paper. Section 4 presents empirical results using annual South African manufacturing data over 1970-1997. Section 5 concludes.

2 Overview of the Trade and Labor Debate

In Europe and the US, growing unemployment amongst the unskilled and rising wage inequality between the skilled and the unskilled led some to attribute the phenomenon to increased trade liberalization. The fear was that unskilled jobs were going to low-wage economies as a result of the lifting of trade barriers. Such an argument is plausible in terms of Heckscher-Ohlin (henceforth HO) trade theory. In the simplest case, skilled and unskilled labor are two factors of production, with developed countries showing a comparative advantage in skills-intensive goods due to greater relative supplies of skilled labor, while developing countries have a comparative advantage in labor-intensive goods due to greater relative supply of unskilled labor. Removal of trade barriers would strengthen the impact of comparative advantage, with developed countries experiencing contraction in unskilled labor intensive sectors, and expansion in skilled labor intensive sectors, leading to widening inequality in the labor market. This migration of jobs thesis would have quite different implications for a less developed country.[2] For poorer countries, the situation for unskilled labor should be reversed, with the position of the unskilled laborer improving with liberalization. By contrast, for skilled labor the premium extracted by their scarcity is put at risk as developing countries increasingly import skilled labor intensive products from the developed countries, thus lowering wage inequality. A useful summary of the state of the debate within developed countries can be found in Collins (1998) and Slaughter (2000).

Testing these implications of HO theory is not a trivial task. As a consequence empirical modeling has provided checks on whether changes in labor markets are *consistent* with the predictions of trade theory, rather than proof that the changes in labor markets are the consequence of trade liberalization. At the heart of the HO story lies an interaction of the HO and the Stolper-Samuelson theorems (hereafter SST), providing the comparative advantage induced relative shift in demand and the change in relative factor price components of the tale respectively. Yet as Deardorff (1994) has pointed out the SST has assumed at least six different formulations. Only two of these mention international trade at all, which Deardorff terms the *general* and the *restrictive* versions. The reason for this is that the essence of the SST is the existence of a link between product and factor price changes. This makes clear the difficulty of directly testing HO theory, since domestic product price changes can be brought about by many factors, and cannot be exclusively attributed to international trade. Isolating the impact of trade is difficult, particularly since trade is likely to be an endogenous outcome of differences in tastes, technology, endowments and barriers to trade.

A further difficulty in testing the validity of HO theory concerns dimensionality. The predicted impact of trade liberalization on skilled and unskilled labor is couched in a two-factor-two-product world. While an instructive simplification, the result does not generalize to multi-factor and multi-product contexts [Jones and Schenkman (1977) and Ethier (1984)]. For this reason the most prevalent test of the trade impact on labor markets has adopted what Deardorff terms the *correlation version* of the SST, which relates product price changes relative to factor price changes. It predicts that *on average* factors used intensively in rising (falling) price industries will experience relative price increases (declines).

But again, the correlation version of the SST provides no more than a consistency check of the trade theory since the source of product price changes remains difficult to unambiguously associate with trade effects. Moreover, empirical application has frequently linked product price changes to factor proportions rather than relative factor price changes. Thus for industrialized countries, a common check is whether observed price changes of unskilled labor intensive goods after liberalization are consistent with factor scarcity, *i.e.* whether unskilled labor intensive product prices fell. A typical regression specification is given by:

$$\widehat{p}_i = \alpha_i + \theta_i \left(\frac{NPW_i}{PW_i}\right) + \varepsilon_i,\ i = 1, 2, ..., N, \tag{2.1}$$

where $\widehat{p}_i$ denotes percentage change in product prices of sector i, NPW non-production workers (a proxy for skilled workers), PW production workers (a proxy for unskilled workers), α_i intercepts and ε_i errors.[3] For example, Lawrence and Slaughter (1993) find and interpret

[2] An alternative HO story would not rely on the lowering of protection, but instead posit a strong expansion of world production of unskilled-labour intensive goods, driving down world prices in unskilled labour intensive sectors and hence the factor reward for unskilled labour.

[3] Throughout this section we employ the notation, $\widehat{x} = \frac{dx}{x}$.

negative estimates of θ_i as evidence against the prediction of SST for developed countries.

The first difficulty with this simple consistency check is that it must assume all domestic prices to be exogenously set internationally. Only by arguing that for a small economy domestic industries are international price takers can all domestic price changes be argued to be the outcome of trade-induced changes. This is legitimate only if tariff changes are not altering the wedge between domestic and international prices, and only as long as we ignore the impact of technological progress, particularly its industry and factor specific impacts.[4] Yet there is no *a priori* reason to suppose that technological progress will be factor-neutral. Where technological progress is not so neutral, the prior expectation must be that relative factor productivity and factor prices would reflect its shift.

One response to the ambiguity introduced by technological change has been to control directly for some identifiable technological changes.[5] (2.1) is readily extended by controlling for total factor productivity growth. A more informative method would allow for the impact of technological change on theoretical foundations, as proposed by Leamer (1998). Typically the Stolper-Samuelson result is founded on the set of sectoral zero profit conditions:

$$\mathbf{p} = \mathbf{A}\mathbf{w}, \tag{2.2}$$

where $\mathbf{p}$ is the $N \times 1$ vector of (domestic) product prices, $\mathbf{w}$ the $J \times 1$ vector of (domestic) factor prices, and $\mathbf{A} = \{A_{ij}\}_{i=1,...,N;j=1,...,J}$ the $N \times J$ matrix of input intensities.[6] The input intensity of factor j in sector i is given by $A_{ij} = v_{ij}/Q_i$, where v_{ij} denotes j-th factor input quantity in sector i and Q_i output in sector i. Then, we have the following relationship:

$$\widehat{p}_i = \mathbf{s}_i'\widehat{\mathbf{w}}, \ i = 1, 2, ..., N, \tag{2.3}$$

where $\mathbf{s}_i = (s_{i1}, ..., s_{iJ})'$ is the $J \times 1$ vector of factor cost shares of sector i and $s_{ij} = \frac{A_{ij}w_j}{p_i}$ is the share of factor j in the average unit cost of product i. (2.3) allows for estimation of changes in factor prices $\widehat{\mathbf{w}}$ that are deemed *mandated* (*viz.* required to maintain the zero profit condition) as the factor share coefficient. This allows for a comparison of mandated with actual factor price changes.[7]

Leamer (1998) demonstrates the importance of explicitly introducing technological improvements. Differentiation of the zero profit condition (2.2) combined with the standard

[4] HO theory is only one of a number of alternative frameworks available. The most often deployed are the Ricardian [Feenstra and Hanson (1995) and Eaton and Kortum (2002)], and the factor content approaches [Wood (1994), and Borjas *et al.* (1996)]. Others extend the HO framework to incorporate technological know-how, see Wood (1997), Wood and Ridao-Cano (1999) and Tang and Wood (2000).

[5] For example, Sachs and Shatz (1994) find the factor usage changes predicted by the SST once the impact of technological change is controlled for. But, they simply add a dummy for computer technology to (2.1).

[6] The zero profit conditions imply a systematic relationship between the set of product prices facing producers, and the set of factor prices paid by producers. One means of ensuring this is by assuming perfectly competitive product markets. Under these conditions, price would be equal to average cost. A systematic link is also possible under imperfect competition, as long as a fixed positive price-cost markup applies. A third option is monopolistic competition, in which sufficient entry ensures zero equilibrium profits.

[7] This approach is called the mandated regression or the price regression, and has been used by Baldwin and Hilton (1984), Baldwin and Cain (1997), Krueger (1997) and Leamer (1998). In general, this mandated regression is odd in the sense that the explanatory variable serves as the regressand. This is since the dimensionality of the data prevents inversion of the $N \times J$ matrix of factor cost shares, $\mathbf{S} = \{\mathbf{s}_1, ..., \mathbf{s}_N\}'$.

measurement of growth in total factor productivity (hereafter TFP) results in:[8]

$$\widehat{p}_i = \mathbf{s}_i'\widehat{\mathbf{w}} - \widehat{TFP}_i,\ i = 1, 2, ..., N. \tag{2.4}$$

Notice, however, that (2.4) implicitly contains two potentially serious limitations. *First*, it carries the implication that factor-biased technological change is entirely irrelevant, and that instead only the sectoral distribution of $\widehat{TFP}_i$ matters.[9] *Second*, it entails an underidentification problem, because it does not allow for the separation of factor price changes due to trade (and other) factors, and those due to TFP growth. In effect we have:

$$\widehat{p}_i\,(t) = \mathbf{s}_i'\widehat{\mathbf{w}}(t) - \widehat{TFP}_i \ \text{ and } \widehat{p}_i(g) = \mathbf{s}_i'\widehat{\mathbf{w}}(g), \tag{2.5}$$

where $\widehat{p}_i\,(t)$ captures the technology effect and $\widehat{p}_i(g)$, which Leamer termed the *globalization* (trade) effect. Globalization-related changes should be seen as the endogenous outcome of international differences in tastes, endowments, and barriers to trade amongst others. Thus trade and product price changes are simultaneously brought about, and hence:

$$\widehat{p}_i = \widehat{p}_i\,(t) + \widehat{p}_i(g) = \mathbf{s}_i'\widehat{\mathbf{w}}(t) + \mathbf{s}_i'\widehat{\mathbf{w}}(g) - \widehat{TFP}_i,\ i = 1, 2, ..., N, \tag{2.6}$$

The underidentification problem arises due to the fact that many possible trade effects are consistent with (2.6). Its complete resolution requires the provision of a model of demand and supply conditions for the world. A more manageable alternative would be to assume that all sectors have a single common pass-through rate of technological progress to product prices, such that $\widehat{p}_i\,(t) = -\lambda\widehat{TFP}_i$, with λ the common pass-through rate. This implies that factor biased technological change does not induce sectorally biased factor price changes.[10]

Another complication is that output price reduction would be particularly strong in sectors using the technology-improving sectors' outputs as inputs, which requires the separation of pass-through to final goods prices and the indirect effect on intermediate inputs - hence a consideration of the full input-output linkages in a strict sense. An alternative is once again to invoke a simplifying assumption that TFP improvements not only have a common pass-through, but that they apply to value-added prices. Then we have:

$$\widehat{p}_i\,(t) - \boldsymbol{\gamma}'\widehat{\mathbf{p}}\,(t) = -\lambda\widehat{TFP}_i, \tag{2.7}$$

with $\boldsymbol{\gamma}$ and $\widehat{\mathbf{p}}\,(t)$ denoting respectively a vector of intermediate input shares and a vector of product price changes (due to the technology effect), such that $\widehat{p}_i\,(t) - \boldsymbol{\gamma}'\widehat{\mathbf{p}}\,(t)$ denotes value-added product price change of sector i. Factor price changes can now be separated into those due to technology and those due to trade liberalization, respectively:

$$(1-\lambda)\,\widehat{TFP}_i = \mathbf{s}_i'\widehat{\mathbf{w}}(t), \tag{2.8}$$

[8]Though the assumption of HO theory that technology is an international public good is contestable for many developing countries, this assumption is more reasonable for South Africa with its relatively large stock of know-how. See Wood (2000).

[9]Sector-bias is important since changes in the factor-composition of output may be the result of strong technological change in sectors intensive in specific factors of production. Where factor-bias induces sector-biased price changes, second-order interaction of factor intensity and factor price results in endogeneity of factor intensities.

[10]One circumstance in which this is justified, would be where nontradeable demand is elastic, and capable of absorbing factors released due to technological change without necessitating change in the prices of tradeables.

$$\widehat{p}_i - \boldsymbol{\gamma}'\widehat{\mathbf{p}}\,(t) + \lambda\widehat{TFP}_i = \mathbf{s}_i'\widehat{\mathbf{w}}(g). \tag{2.9}$$

Thus, the identification problem can be resolved under the assumption of common pass-through applying to value-added prices. Note that the changes mandated by trade liberalization are the factor price changes required to maintain the zero-profit condition after accounting for the impact of technology. Hence the identification problem of associating product price changes with trade liberalization effects remains, and the Leamer specification remains a *consistency check* rather than a direct empirical test of the SST.

Recently, some attempts have been made to deal with endogeneity problems. Feenstra and Hanson (1999) (hereafter FH) add an important qualification to the Leamer methodology. First, they show that where the dual Thornqvist measure of TFP growth is employed, based as it is on the log change in industry prices and the cost-share weighted change in factor prices, (2.4) reduces to an identity. Since the limitation attaches to a specific measure of TFP growth, this is not terminal to the Leamer methodology. Instead, the argument that the assumption that technology and prices are exogenous is false. To deal with the endogeneity of technology and output price changes they propose that both price and technological changes have a set of exogenous structural determinants. Thus,

$$\widehat{TFP}_{it} \simeq \boldsymbol{\alpha}'\hat{\mathbf{z}}_{it}, \tag{2.10}$$

$$\widehat{p}_i\,(t) - \boldsymbol{\gamma}'\widehat{\mathbf{p}}\,(t) \simeq -\lambda\widehat{TFP}_{it} + \boldsymbol{\beta}'\hat{\mathbf{z}}_{it}, \tag{2.11}$$

where $\hat{\mathbf{z}}_{it}$ denotes a $K \times 1$ vector of structural variables, and $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ are corresponding column vectors of coefficients, which allow us to state what amounts to a reduced form:

$$\widehat{p}_i\,(t) - \boldsymbol{\gamma}'\widehat{\mathbf{p}}\,(t) + \widehat{TFP}_{it} \simeq \boldsymbol{\delta}'\hat{\mathbf{z}}_{it}, \tag{2.12}$$

where $\boldsymbol{\delta} = (1-\lambda)\,\boldsymbol{\alpha}+\boldsymbol{\beta}$. This now allows the decomposition of value added price changes and technological change into those due to each k'th structural variable, *viz.* $\delta_k\widehat{z}_{kt}$. Estimation of (2.12) for all k elements of $\boldsymbol{\delta}$ allows the second stage estimation:

$$\delta_k\widehat{z}_{kt} = \mathbf{s}_i'\widehat{\mathbf{w}}_k\,(t) + error,\ k = 1, ..., K. \tag{2.13}$$

Important is the interpretation of the $\widehat{\mathbf{w}}_k\,(t)$ coefficients, which provide the *factor price changes* explained by the k'th structural variable. Thus, (2.13) is a modified price regression in which we attempt to estimate the contribution of each structural variable to the average change in primary factor prices.

FH argue that crucial to the approach is the correct measure of technological change. The Leamer decompositions employ the standard primal measure of TFP, thereby consigning the average deviation of industry-specific factor price changes from their mean levels to the residual, $e_{it} = \frac{1}{2}\left(s_{it-1} + s_{it}\right)'\left(\widehat{w}_{it} - \omega_t\right)$, where $\frac{1}{2}\left(s_{it-1} + s_{it}\right)$ is the average factor cost share, $\widehat{w}_{it}$ the percentage change in factor prices, and ω_t the sector mean of factor prices. FH use *effective* TFP, where $ETFP_{it} \equiv TFP_{it} - e_{it}$. Thus in (2.10) through (2.12) TFP should be read as $ETFP$. Since the use of $ETFP$ renders the Leamer approach an identity, they argue that results prove very sensitive to the definition of technological change employed.

The FH methodology is intended to address the large closed economy case of the USA, in which endogeneity of prices and productivity change and factor bias of technological change is potentially important. [See also Krugman (2000).] While Leamer (2000) argues this to be irrelevant for small open economy contexts, Haskel and Slaughter (2001) nevertheless address the endogeneity issue in their study of the UK. Considerations arising out of multi-sectoral models, the possibility that trade liberalization may impact on technological innovation, and the possibility of imperfectly competitive output markets all point to the importance of these concerns. The advantage of the FH method is that the extent of technological pass-through is left open for empirical determination. In addition, it can accommodate factor-biased technological change. Since only factor-biased changes will influence wages and prices over and above their impact on productivity, in (2.11) any structural variables that prove significant provide confirmation of non-neutral technological change.

While many of the empirical results based on the product price effects do not clearly support SST [*e.g.*, Bhagwati (1991), Lawrence and Slaughter (1993)], explicit incorporation of technological progress through TFP improvements lead to some results consistent with SST, though decade and industry effects remain prevalent, *e.g.* Slaughter (2000). However, the findings are mixed depending on the time periods investigated. Baldwin and Cain (1997) and Leamer (1998) find that the SST consistent results for the US were stronger during the 1970's than during the 1980's. Krueger (1997) extends this finding to the 1990's. Haskel and Slaughter (2001) find similar results for the UK in the 1980s. Wood (1994) attempts some degree of completeness in its developing country evidence, finding in favour of the SST by means of a factor content approach. Moreira and Najberg (2000) find negative short run but positive long run impacts on labor markets from trade liberalization in Brazil using a factor content methodology. A number of studies use labour usage equations to examine the impact of trade liberalization on a number of developing countries. Currie and Harrison (1997) for Morocco and Krishna *et al.* (2001) for Turkey find no negative impact of trade liberalization. For Mexico Revenga (1997) finds a negative impact of trade liberalization on employment and wages, while Milner and Wright (1998) find positive impacts on employment and wages in sectors producing exportables and importables in Mauritius. The former result is corroborated by Cragg and Epelbaum (1996) and Feliciano (2001) using alternative methodologies, and Hanson and Harrison (1999) using the HO framework. Görg and Strobl (2002) present evidence consistent with rising wage inequality for Ghana. For further developing country evidence see also Forbes (2001), Khambhampati *et al.* (1997), and Lu (2000).

3 Dynamic Heterogeneous Panel Data Approach

In this section we describe the main econometric tool used in the paper. *First of all*, we note that the Stolper-Samuleson relationship described in the previous section tends to hold in the long-run but may deviate from its equilibrium path over the short-run. Though the underlying economic theory is entirely silent on these issues, there is still a need for a detailed exploration of dynamics. See Slaughter (2000) for the importance of this line of enquiry.

In this regard we express (2.1) or (2.3) as the long-run equilibrium relationship:

$$y_{it} = \boldsymbol{\theta}'\mathbf{x}_{it} + \varepsilon_{it},\ i = 1, 2, ..., N,\ t = 1, 2, ..., T, \tag{3.1}$$

where y_{it} is a scalar dependent variable for sector i at time t, $\mathbf{x}_{it}$ is the $k \times 1$ vector of regressors for sector i at time t, and ε_{it} is the underlying random disturbance. For example,

y_{it} is product price change, and $\mathbf{x}_{it}$ includes the ratio of skilled to unskilled labor or the factor shares for labor and capital or the growth of total factor productivity. It is more likely that the long-run parameter vector $\boldsymbol{\theta}$ is homogenous across sectors in the context of the mandated regression (2.3), because these parameters are interpreted as the economy-wide mandated changes in factor returns. [See Haskel and Slaughter (2001).] The ε_{it} of (3.1) are likely to be subject to serial correlation, but the pattern of serial correlation is not necessarily homogenous across different sectors. The possibility of both serial correlation and heterogeneity raises further econometric issues, which will be dealt with explicitly below.

Most empirical applications in the literature so far have been carried out by using the cross-section regression specification based on:[11]

$$\bar{y}_i = \boldsymbol{\theta}'\bar{\mathbf{x}}_i + \bar{\varepsilon}_i,\ i = 1, 2, ..., N, \tag{3.2}$$

where $\bar{y}_i = T^{-1}\sum y_{it}$ and $\bar{\mathbf{x}}_i = T^{-1}\sum \mathbf{x}_{it}$. Alternatively, the static panel data technique based on either pooling or fixed effects has been applied to (3.1). Both approaches are unsatisfactory in the sense that no attempt has been made to accommodate heterogeneous dynamic adjustment of the long-run equilibrium relationship as described above.

We now provide an estimation approach that deals with these issues explicitly in the context of panel data, with which we hope to address the theoretical underpinnings more clearly than earlier approaches. The approach suggested here has the advantage of being able to accommodate both the long run equilibrium character of the SST results and its possibly heterogeneous dynamic adjustment process due to information and adjustment costs that may allow deviations to persist for some time. Another advantage of the proposed estimation approach is that theoretically congruent results are possible despite the estimation problems that have traditionally beset this literature.[12]

Embodying the long-run equilibrium relationship (3.1) in an otherwise unrestricted autoregressive distributed lag (ARDL) model for y and $\mathbf{x}$, and following Pesaran *et al.* (1999), we base our panel analysis on an error correction ARDL(p, q) representation:

$$\Delta y_{it} = \phi_i y_{i,t-1} + \boldsymbol{\beta}_i'\mathbf{x}_{i,t-1} + \sum_{j=1}^{p-1}\lambda_{ij}\Delta y_{i,t-j} + \sum_{j=0}^{q-1}\boldsymbol{\delta}_{ij}'\Delta\mathbf{x}_{i,t-j} + \mu_i + u_{it}, \tag{3.3}$$

$i = 1, 2, ..., N$, and $t = 1, 2, ..., T$. Here y_{it} is a scalar dependent variable, $\mathbf{x}_{it}$ is the $k \times 1$ vector of (weakly exogenous) regressors for group i, μ_i represent the fixed effects, ϕ_i is a scalar coefficient, $\boldsymbol{\beta}_i$'s is the $k \times 1$ vector of coefficients, λ_{ij}'s are scalar coefficients, and $\boldsymbol{\delta}_{ij}$'s are $k \times 1$ coefficient vectors. We assume that u_{it} are independently distributed across i and t, with zero means and variances $\sigma_i^2 > 0$. Further assuming that $\phi_i < 0$ for all i and thus there exists a long-run relationship between y_{it} and $\mathbf{x}_{it}$:

$$y_{it} = \boldsymbol{\theta}_i'\mathbf{x}_{it} + \eta_{it},\ i = 1, 2, ..., N,\ t = 1, 2, ..., T, \tag{3.4}$$

[11] Alternative specifications are also suggested. For example, Leamer (1998) uses the following cross-section regression: $\bar{y}_i = \boldsymbol{\theta}'\mathbf{x}_{i1} + \bar{\varepsilon}_i$, $i = 1, 2, ..., N$, where $\mathbf{x}_{i1}$'s are beginning-of-period observations.

[12] Economic theory is not informative in modelling short-run dynamics or heterogenous sectoral behavior. Much is left to be done if we are to fully understand the dynamic processes here, but our modelling approach provides a useful compromise and intermediate link between theory and estimation.

where $\boldsymbol{\theta}_i' = -\boldsymbol{\beta}_i'/\phi_i$ is the $k \times 1$ vector of the long-run coefficients, and η_{it}'s are stationary with possibly non-zero means (including fixed effects). Since (3.3) can be rewritten as

$$\Delta y_{it} = \phi_i \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \boldsymbol{\delta}_{ij}' \Delta \mathbf{x}_{i,t-j} + \mu_i + u_{it}, \tag{3.5}$$

where $\eta_{i,t-1}$ is the error correction term given by (3.4), hence ϕ_i is the error correction coefficient measuring the speed of adjustment towards the long-run equilibrium.

Under this general framework Pesaran, Shin and Smith (1999) advance the Pooled Mean Group (PMG) estimator. This allows the intercepts, short-run coefficients and error variances to differ freely across groups, but the long-run coefficients are constrained to be the same; that is, $\boldsymbol{\theta}_i = \boldsymbol{\theta}$ for all i. The group-specific short-run coefficients and the common long-run coefficients are computed by the pooled maximum likelihood estimation, and these estimators are denoted by $\tilde{\phi}_i$, $\tilde{\boldsymbol{\beta}}_i$, $\tilde{\lambda}_{ij}$, $\tilde{\boldsymbol{\delta}}_{ij}$ and $\tilde{\boldsymbol{\theta}}$. We then obtain the PMG estimators by $\hat{\phi}_{PMG} = N^{-1} \sum_{i=1}^{N} \tilde{\phi}_i$, $\hat{\boldsymbol{\beta}}_{PMG} = N^{-1} \sum_{i=1}^{N} \tilde{\boldsymbol{\beta}}_i$, $\hat{\lambda}_{jPMG} = N^{-1} \sum_{i=1}^{N} \tilde{\lambda}_{ij}$, $j = 1, ..., p-1$, $\hat{\boldsymbol{\delta}}_{jPMG} = N^{-1} \sum_{i=1}^{N} \tilde{\boldsymbol{\delta}}_{ij}$, $j = 0, ..., q-1$, $\hat{\boldsymbol{\theta}}_{PMG} = \tilde{\boldsymbol{\theta}}$.

We may also consider the two alternative dynamic panel estimation techniques. *First*, the dynamic fixed effects (DFE) estimation which imposes the homogeneity assumption for all of the parameters except for the fixed effects. The DFE estimates of all the short-run parameters are obtained by pooling and denoted by $\hat{\phi}_{DFE}$, $\hat{\boldsymbol{\beta}}_{DFE}$, $\hat{\lambda}_{jDFE}$, $\hat{\boldsymbol{\delta}}_{jDFE}$, and $\hat{\sigma}^2_{DFE}$. The estimate of the long-run coefficient is then obtained by $\hat{\boldsymbol{\theta}}_{DFE} = -(\hat{\boldsymbol{\beta}}_{DFE}/\hat{\phi}_{DFE})$. *Secondly*, the mean group (MG) estimates proposed by Pesaran and Smith (1995), which allows for heterogeneity of all the parameters and gives the following estimates: $\hat{\phi}_{MG} = N^{-1} \sum_{i=1}^{N} \hat{\phi}_i$, $\hat{\boldsymbol{\beta}}_{MG} = N^{-1} \sum_{i=1}^{N} \hat{\boldsymbol{\beta}}_i$, $\hat{\lambda}_{jMG} = N^{-1} \sum_{i=1}^{N} \hat{\lambda}_{ij}$, $j = 1, ..., p-1$, $\hat{\boldsymbol{\delta}}_{jMG} = N^{-1} \sum_{i=1}^{N} \hat{\boldsymbol{\delta}}_{ij}$, $j = 0, ..., q-1$, $\hat{\boldsymbol{\theta}}_{MG} = N^{-1} \sum_{i=1}^{N} -(\hat{\boldsymbol{\beta}}_i/\hat{\phi}_i)$, where $\hat{\phi}_i$, $\hat{\boldsymbol{\beta}}_i$, $\hat{\lambda}_{ij}$ and $\hat{\boldsymbol{\delta}}_{ij}$ are the OLS estimates obtained individually from (3.3). We note that the PMG estimation provides an intermediate case between the above two extreme cases, but also its modelling approach matches precisely with the underlying nature of the long-run equilibrium relationship described above.

We briefly discuss one additional important modelling issue. In principle, we need to choose between the alternative specifications. Tests of homogeneity of error variances and/or short- or long-run slope coefficients can be easily carried out using the Log-Likelihood Ratio tests, since the PMG and DFE estimators are restricted versions of all heterogeneous individual group equations. It is worth noting, however, that for most cross-country studies the Likelihood Ratio tests usually reject equality of error variances and/or slopes at conventional significance levels, though the finite sample performance of such tests are generally unknown and thus unreliable. An alternative would be to use Hausman (1978) type tests. The MG estimator provides consistent estimates of the mean of the long-run coefficients, though these will be inefficient if slope homogeneity holds. Under long-run slope homogeneity the PMG estimators are consistent and efficient. Therefore, the effect of both long-run and short-run heterogeneity on the means of the coefficients can be determined by the Hausman test applied to the difference between MG and PMG or DFE estimators. In this paper we will examine the extent of panel heterogeneity mainly in terms of the difference between MG and PMG estimates of long-run coefficients using the Hausman test.

4 Empirical Results

To analyze trade effects on labor markets in developing countries contexts, some reframing of the model specification is required. In a middle income or developing country, we argue that the skilled labor and unskilled labor dichotomy, while relevant, may be complemented by the capital-labor divide. In fact this is a minor adjustment. Usually we might argue that the mobility of capital would preclude anything but the world price of capital from applying. However, in South Africa the presence of capital controls has meant that this is unlikely to have been the case.

One practical issue is that the theory is silent on the timing over which the long-run equilibrium relationship is likely to hold. Mandated changes in factor returns may not be constant over time such that product price changes favor labor in some periods and capital in others. This has been handled in the cross-section regression approach by splitting the samples into sub-time periods. For example, Leamer (1998) applies it to the sub-period samples of 1960's, 1970's and 1980's, and finds qualitatively different estimation results. Although empirically plausible, the selection of sub-period samples is always potentially *ad hoc*. We take the stance that we are primarily interested in exploring the long-run equilibrium relationship specified by the HO and SS mechanisms, allowing for the associated short-run dynamics. Hence, our suggestion here is that we require consideration of as long a time run as is feasible instead of using only the arbitrary decade-long time runs employed by other studies.[13] Nevertheless, where appropriate we also note the impact of "decade-effects" in the empirical results reported below by means of time dummies, in order to capture any possible differential effects of trade on labor markets in South African manufacturing.

4.1 Data and Exploratory Data Analysis

The data set used in this paper is composed of a panel of 22 three-digit SIC version 5 manufacturing sectors in the South African economy observed annually over the period 1970-97. This provides a macro-type panel where both $T = 28$ and $N = 22$ are sufficiently large to allow the use of dynamic panel techniques to estimate a long-run equilibrium relationship while at the same time modeling the short-run dynamics.[14]

Focus on the manufacturing sector rather than all South African industrial sectors (48 three-digit SIC version 5 sectors) is for three reasons. *Firstly*, manufacturing sectors are

[13]Bell *et al.* (1999) note the potential importance of different time periods for the structure of South African trade, due to the impact of primary commodity prices. For the reasons noted, we leave this line of enquiry for future work.

[14]WEFA South Africa provided data. The panel includes 28 sectors over 1970-1997, of which 6 sectors on which the data is generally available were excluded due to an absence of skills and/or concentration ratio. The sectors included in the panel are: Food, Beverages, Textiles & Knitting, Wearing Apparel, Leather & Tanning, Wood, Paper, Publishing & Printing, Basic Chemicals, Other Chemicals & Fibres, Rubber, Glass and Glass Products, Other Non-metallic Minerals, Basic Iron & Steel, Basic Non-ferrous Metals, Fabricated metals, Machinery & Equipment, Electrical Machinery, Motor Vehicles & Accessories, Furniture and Other Manufacturing & Recycling. WEFA have brought data from a number of sources published by Statistics South Africa and South Africa Reserve Bank. The full dataset is available from the Trade and Industry Policy Strategies (http://www.tips.org.za/). Effective protection rates are sourced from Fedderke and Vaze, (2001), total factor productivity measures from Fedderke (2002a), and R&D measures from Fedderke (2002b).

more likely to be appropriately understood as engaged in the production of tradeables. This is evident from Table 1 since on average over the 1970-97 period over 50% of output in South African manufacturing was traded, compared with 30% of output in the South African economy as a whole. The assumption of a small open economy on which HO theory is based is thus justified for South African manufacturing industry.[15]

Table 1 about *here*

Secondly, evidence on the extent of trade liberalization in South Africa as a whole is mixed. Trade liberalization over the past three decades was most pronounced during the 1990's. Fedderke and Vaze (2001) demonstrate that while nominal tariff structures point to substantial liberalization of the economy, the evidence from effective protection rates is more ambiguous, with effective protection rates increasing for about 50% of GDP, decreasing for only 15% of GDP. For manufacturing the evidence is more positive. Figure 1 reports the average effective protection rate for the 28 manufacturing industries, demonstrating the liberalization of the sector as a whole over the 1990's. While there is evidence for trade liberalization in manufacturing over the 1990's, the 1980's were a period of relative closure due to international sanctions and the imposition of import surcharges during the late 1980's, as is evident from the declining proportion of output being traded during the 1980's.[16]

Figure 1 about *here*

Thirdly, reliability of data for manufacturing is more assured, and some data are available only for manufacturing.

Prima facie evidence in favor of the changes predicted by the HO framework comes immediately from a consideration of real per laborer remuneration by skills category defined by occupational category in manufacturing.[17] Figure 2 shows that while real remuneration for skilled and highly skilled workers in manufacturing remained constant or declined over the 1970-97 period, that for unskilled labor rose over the 1970's and 1990's, and stagnated or declined over the 1980's. Since the 1980's are precisely the most closed for the South African economy, the exploratory data analysis shows labor market developments consistent

[15]One should note that mining in South Africa is an important exporter - indeed manufacturing only overtook gold exports during the course of the 1990's as an earner of foreign exchange. The points on data quality and the concentration of trade liberalization remain unaffected.

[16]There is an important qualification on the use of the openness ratio as a proxy for trade liberalization. This arises due to intra-1980's trade movements in South African manufacturing. The early 1980's saw a decline in manufacturing exports perhaps due to the high gold price and its impact on the Rand, while conversely the late 1980's saw a sharp increase in manufacturing exports due to Rand weakness, and perhaps due to declining domestic demand. This was also mirrored in declining imports. The net effect is that the late 1980's reports a relatively high openness ratio, despite intensified sanctions and the imposition of import surcharges. Results using the openness ratio should therefore be interpreted with care. On the other hand, Fedderke and Vaze (2001) show that trade liberalization during the 1990's appears to have been associated with a higher rate of growth in import penetration. In general, this reiterates the potential importance of controlling for the decade effects already referred to above.

[17]Earnings data by skill level is available only for manufacturing sector in aggregate [Fedderke (2002a)]. Use of occupational categories renders the South African skills data comparable to that employed by Leamer (1998).

with SST holding for the developed world. In particular, real remuneration of unskilled labor rose in periods of relative liberalization (the 1970's and 1990's), while unskilled remained stagnant during periods of relative closure. By contrast, countervailing evidence is the closing skilled-unskilled real wage gap during the 1980's. These developments are reflected in the declining ratio of earnings of both highly skilled and skilled workers to unskilled workers over the 1970-97 period reported in Table 1, while the ratio between the earnings of the two skilled occupational categories has remained virtually constant. This narrowing inequality of pay structure is precisely the opposite of that noted for the developed world, and what would be predicted by the SST for a developing country.

Figure 2 about *here*

Potentially confounding evidence is the increasing reliance on skilled labor and capital inputs in manufacturing also reported in Table 1. Both the capital labor ratio and the ratio of skilled and highly skilled to unskilled labor ratios report a steady rise over the 1970-97 period. However, this could also be due to changing relative returns to the factors, or the impact of skill-biased technological change. It must remain for the econometric evidence to establish the consistency of the SST. Certainly the *prima facie* case provided by remuneration by skills category remains compelling motivation to examine the evidence.

An important feature of the South African labor market was the rise of black trade unions during the 1970's, and their sustained bargaining power particularly through the 1980's and early 1990's. Table 1 reports three annual measures reported by the South African Reserve Bank on industrial bargaining activity in aggregate, the total number of recorded strikes, the total number of workers involved in strike activity, and the total number of person days lost due to strike activity. All three measures report a sharp rise from the 1970's to the 1980's, and a further more moderate increase into the 1990's, consistent with a rise in labor militancy. An immediate implication is that the increased militancy of black labor, concentrated as it was in unskilled labor categories, is likely to have been an important contributor to the rising relative real wages of unskilled workers. Ideally we should therefore control for the bargaining power of unions in manufacturing sectors. Unfortunately relevant data is unavailable at sectoral level. What we can control for, however, is an indicator of the pricing power of employers in the form of a concentration ratio in the production of output. This is relevant to the pricing behavior of firms in output markets not only directly, but may also provide indirect evidence of the bargaining power of labor. [See also Haskel and Slaughter (2001).] While one expectation might be that pricing power of employers would reflect bargaining power of employers versus unions, an alternative would be that producers with pricing power could choose to pass on increasing labor cost to consumers instead, avoiding the costs of labor unrest. That unions emerged and proved of sustained strength in sectors that are traditionally concentrated in the South African economy (such as mining), suggests that the second linkage is at least plausible for South Africa. The measure of industry concentration demonstrates rising concentration across the manufacturing sectors over the sample period. Industry concentration ratios were computed based on tables published by StatsSA in the Census of Manufacturing.[18] To maintain consistency with earlier South

[18]For 3 digit SIC manufacturing industries, cumulative percentages of gross output, accounted for by

African studies employing industry concentration measures, we employ a Gini coefficient for industry concentration.[19]

Our TFP measure does not control for a changing skills composition of the labor force, given the unavailability of earnings data by skills category for the three digit manufacturing sectors. Since failure to control for quality dimensions in factor inputs is likely to bias upward any TFP growth measure, Table 1 also reports TFP growth for the aggregate manufacturing sector which controls for factor shares of output by the skills category. Note that the negative impact of TFP on output growth in South African manufacturing is strengthened once the skills composition of labor is accounted for. It will thus be vital that the skills composition of the labor force be controlled for. The importance of controlling for technological change in South Africa is emphasized by the fact that the descriptive evidence suggests that sector-biased technological change has been a consistent feature of the manufacturing. Table 1 reports the capital- and skills-intensity of sectors that lie above and below the mean value of TFP and unskilled labor. Failing to control for TFP growth would come to overstate the impact of demand- and trade-related changes on factor usage, due to strong output growth thanks to technological change in sectors intensive in labor and unskilled labor.

4.2 Product price changes and factor proportions

We now investigate the link between product price changes and factor intensity with reference to two factor ratios, using specifications based on (2.1). The first is the capital-labor ratio (KL) defined in terms of the machinery and equipment capital stock per employment. Labor usage can be further analyzed by using the breakdown of labor by skill level. A skills ratio (SR) is calculated as the sum of highly skilled and skilled workers divided by the number of unskilled workers in a sector. Using dynamic panel data techniques we thus attempt to estimate the following long-run relationship:[20]

$$\Delta p_{it} = \theta_{FR} FR_{it} + \theta_{TFP} \Delta TFP_{it} + \eta_{it},\ i = 1, ..., N,\ t = 1, ..., T, \tag{4.1}$$

where Δp_{it} and FR_{it} denote the percentage change in output price and the natural logarithm of the factor ratio (KL, SR) for sector i. $\Delta TFP_{it} = \Delta \log (Y_{it}) - \ell_{it} \Delta \log (L_{it}) - k_{it} \Delta \log (K_{it})$ is by the primal measure, where Y_{it} is sectoral value-added, L_{it} the sectoral labor employed, K_{it} the constant prices value of sectoral machinery and equipment, and ℓ_{it} and k_{it} denote the labor and capital value-added factor shares for sector i. We proceed both under a $\theta_{TFP} = 0$ restriction, and in the absence of such a restriction. The prior is that under the consistency check of the SST, for South Africa we should expect $\theta_{FR} < 0$. $\theta_{TFP} < 0$ implies that technological progress is passed on to consumers in the form of falling prices, though the small open economy prior is of zero pass-through.

cumulative percentages of firms were available in the 1976, 1979 and 1985 manufacturing censuses. The tables for the 1988, 1991, 1993 and 1996 censuses were not published in the original censuses, but were compiled on request by StatsSA. The required data for the 1972 census was taken from Leach (1992).

[19] Our preference was for the Herfindahl index. The format of the raw data makes computation of the Gini coefficient more feasible. We employ Simpson's one third rule of numerical integration to approximate the Lorenz curve.

[20] η_{it} are decomposed as $\eta_{it} = \alpha_i + \varepsilon_{it}$, where α_i's are fixed effects and ε_{it}'s are zero-mean stationary processes. Without loss of generality we use the common notation in the long-run relationships that follow.

For this and all remaining subsections we report only PMG estimation results. The main justifications are: *First*, the PMG approach is consistent both with the underlying theory of an homogenous long-run relationship and the heterogeneous dynamic time series nature of the data (see subsection 4.1). *Second*, it offers an intermediate option in which the opportunities offered by panel estimation continue to be realized in terms of long-run homogeneity, while short-run heterogeneity is admitted into estimation.

The PMG estimation results are reported in Table 2. A consistent feature of all results is that the Hausman test suggests homogeneity in long-run coefficients. In addition, the speed of adjustment toward the implied long-run equilibrium is relatively high, as indicated by the ϕ-coefficients which uniformly imply at least a 76% adjustment toward equilibrium occurring within a year.

Table 2 about *here*

Estimates of the factor proportions coefficients are consistently statistically significantly negative, regardless of which specification is being considered, and regardless of whether the impact of technological progress is being controlled for. The implication is that results for South African manufacturing sectors are consistent with the implication derived from the SST, *viz.* that the strongest price increases have occurred in labor- and unskilled labor-intensive sectors. Thus to the extent that trade effects are responsible for product price changes the findings are consistent with strengthening demand for labor relative to capital, and unskilled labor relative to skilled labor in South Africa.

The impact of technological progress proves insignificant, suggesting that technological change does not appear to be passed through into product price reductions. This is a plausible finding for a small open economy such as South Africa, since such economies are effectively world price takers, such that the impact of technological progress would be absorbed by producers and not translated into price changes.[21] However, as the theoretical discussion above demonstrated, the treatment of technology in the factor-proportions estimations is *ad hoc*, failing to account for either identification or potential endogeneity issues.

Finally, the question that remains is the extent to which the results of the factor proportions estimations are sensitive to a failure to control for the changing labor market institutions and the period of relative isolation experienced during the 1980's. For this we have also estimated the specifications incorporating the sectoral concentration ratio and a time dummy for the 1980's, to control for changing labor market institutions and the 1980's period of isolation, respectively. Irrespective of whether these additional variables were included singly or jointly, the significance or the magnitude of the θ_{FR} and θ_{TFP} coefficients do not alter significantly.[22] Despite these qualifications, estimation results reported in the present section indicate the strongest product price changes in sectors intensive in the abundant factor of production and thus conform to the expectation generated by the SST. To the extent that output price changes are due to trade effects, therefore, the implication of these findings is

[21]The impact of sanctions and any protection applied to South Africa's markets would merely impose a mark-up over world prices, with any price changes continuing to track changes in world prices. See Krugman (2000) for issues involved in technology pass-through. He argues that productivity improvements are reflected in prices in large economies, or where technology shocks are common across countries.

[22]Full results are available from the authors. While the coefficients on the concentration ratio and the time dummy are not immediately structurally interpretable, both prove consistently significant and positive.

that any trade impact on factor employment favored labor rather than capital, and unskilled rather than skilled labor.

4.3 The Leamer mandated regression specification

To investigate the impact of technological progress in terms of a more explicit theoretical foundation, we examine the impact of product price changes on factor earnings, now explicitly decomposing the change in factor earnings into those mandated by globalization effects and those mandated by technology, using specifications based on (2.7) through (2.9).[23]

First, the price change equation under the common technology pass-through is given by:

$$\Delta p_{it} + \lambda \Delta TFP_{it} = \theta_l \ell_{it} + \theta_k k^*_{it} + \eta_{it},\ i = 1, ..., N,\ t = 1, ..., T, \tag{4.2}$$

where $\ell \equiv (W/P)\, L/Y$ is the share of labor in value added with W/P the real wage, L labor input, and Y real value added, while the share of capital is given by $k^* = NOS/Y$ where NOS is net operating surplus.[24] Here we employ only the zero pass-through specification ($\lambda = 0$) on the small open economy argument (see also next subsection on the Feenstra-Hanson methodology which confirms an estimation of the zero pass-through). *Second*, we estimate the technology equation (see (2.8)):

$$\Delta TFP_{it} = \theta_l \ell_{it} + \theta_k k^*_{it} + \eta_{it},\ i = 1, ..., N,\ t = 1, ..., T. \tag{4.3}$$

Results from the estimation of (4.2)-(4.3) are reported in Table 3. Homogeneity of long run coefficients across sectors is confirmed by the Hausman test, and rapid adjustment to long run equilibrium is once again a consistent feature of the PMG estimation results. We further carry out the t-tests whether the difference between θ_l and θ_k is significantly different from 0, and find that the corresponding t-statistics are 6.06 and 2.60 respectively for (4.2) with $\lambda = 0$ and (4.3). This clearly indicates that both product price changes and technology mandated rising returns to labour relative to capital for South African manufacturing.

Table 3 about *here*

These results allow us to identify factor earnings growth mandated by globalization, and those mandated by technological change. The top panel of Table 4 contains the information given by the preceding regression results. Thus the price change equation estimated on

[23]Note that all empirical specifications are in terms of price changes for output in value added terms. Thus we may ignore the $\boldsymbol{\gamma}'\hat{\mathbf{p}}$ term in estimation. We follow Leamer (1998) in weighting factor proportions by average employment over the full sample period. Use of weights based on a smaller sub-sample did not materially affect results.

[24]Strictly, the share of capital in value added is given by $k = GOS/Y$ with GOS gross operating surplus. Given the accounting identity $\ell_{it} + k_{it} = 1$, this results in a perfect multicollinearity problem in estimation. Since GOS is the sum of NOS and *Depreciation*, use of k^* constitutes an errors in variables problem. But, this bias (*Depreciation*$/Y$) is known, and thus computable. For the correction method see Griliches (1974). An alternative approach is to replace k_{it} by $1 - \ell_{it}$ and estimate, $\Delta p_{it} = \theta_k + (\theta_\ell - \theta_k)\, \ell_{it} + \eta_{it}$. For SST-consistent results to hold for labor abundant economies, what is required is that $\theta_\ell > \theta_k$. Estimation consistently found $\theta_\ell - \theta_k > 0$. Use of the share of factor payments in the paper rather than factor costs in total costs was dictated by data availability.

a zero pass-through assumption implies an annualized earnings increase of 18.1%. Given the aggregate output price inflation of 12% per annum, this provides the mandated annual earnings growth unrelated to technology of 6.1%. Technology by contrast mandates a 5.6% decrease in labor earnings, suggesting that the total mandated change in labor earnings is 0.5% per annum. For capital, mandated earnings increases unrelated to technology were $11\% - 12\% = -1\%$, while technology related earnings increases were -6.5%, thus providing a net mandated earnings change for capital of -7.5%.

Table 4 about *here*

Note that the results are consistent with the SST. In particular, labor demonstrates the predicted positive, and capital a negative average annual growth rate in earnings due to the impact of "globalization" (more accurately understood as total demand factors), with the impact on the abundant factor of production labor stronger than that on capital stock. Potentially one source of surprise is that the impact of technology on mandated factor earnings is negative for both factors of production, with the impact marginally stronger on capital than on labor, though conventional expectations might have anticipated capital deepening technological change. The overall results confirm the positive impact of "globalization" on mandated labor earnings, with the magnitude of the impact exceeding that on capital as is consistent with the prediction of the SST.

A new piece of evidence serves to shed light on the weak employment growth in manufacturing in South Africa. Figure 3 illustrates that aggregate employment in manufacturing has been essentially stagnant since 1980 - indeed, employment actually declined by approximately 47,000 over the same period. Moreover, the average increase in real per laborer remuneration has been 1% per annum over the 1972-97 period. Contrast with the mandated average increase suggested by the Leamer estimations of 0.5%, suggests that one problem in South African labor markets may have been a mispricing of labor.

Figures 3 about *here*

The seriousness of these findings is compounded when considering the aggregate manufacturing sector evidence on real remuneration by skills category. As Figure 2 reported, the strongest increase in real remuneration has occurred for unskilled labor, while real per employee remuneration for skilled and highly skilled workers actually declined. While of course providing corroboration for the findings above consistent with the SST, it also suggests growth rates in unskilled labor remuneration much above the 1% industry average. Thus during the 1970's, unskilled real wages grew at 3.56% per annum, at 0.1% per annum during th 1980's, and at 2.48% during the 1990's, in the manufacturing sector as a whole. At least potentially this may begin to account for the heavy cost in unemployment borne by unskilled labor in South Africa.

A remaining concern with the Leamer methodology is that the mandated factor earnings changes do not fully decompose demand effects into those due to trade, and those due to other demand and institutional factors. It remains to be seen whether the FH methodology which is able to more fully account for the impact of distinct demand factors is able to resolve this remaining puzzle.

4.4 Labor usage estimation

In determining the price effect of trade liberalization on the demand for labor, we observed that the estimations were unable to identify determinants of labor usage directly. In short, while results indicate that trade liberalization is an unlikely explanation of falling labor usage in South Africa, we have not yet been able to account for the source of declining labor use in South Africa beyond the possibility of mispricing.

Here we employ a modified methodology as reported in Hine and Wright (1998). The advantage of the methodology is that it can include a direct isolation of the labor usage effect of trade liberalization. Consider the production function given by:

$$Y_i = F\left(\mathbf{B}_i, K_i, L_i\right),\ i = 1, ..., N, \tag{4.4}$$

where Y_i denotes real output by sector i, K_i real capital stock by sector i, L_i labor inputs (as measured by the total number of employees) by sector i and $\mathbf{B}_i$ a vector of variables that may impact on output independently. Standard assumptions governing the technology of production would allow us to solve for the labor requirements equation:[25]

$$L_i = G\left(\mathbf{B}_i, Y_i, K_i\right),\ i = 1, ..., N. \tag{4.5}$$

Subsuming technological progress in a "Solow-residual," we here include five variables in $\mathbf{B}_i$. Openness, denoted OP, and defined as the ratio of imports and exports to output, reflects the extent to which a sector is exposed to international markets. Given the descriptive evidence presented above, which suggests that both import penetration and export propensity can be linked to the degree of trade liberalization of a sector, the OP variable could also be thought of as a proxy for the degree of trade liberalization. A relative price ratio, denoted RP, is defined as the ratio of the user cost of capital to real per laborer remuneration, where the user cost of capital is composed of the risk rate of return on government paper, the sector specific depreciation rate, and the corporate tax rate. We anticipate a positive sign on RP. Since the real price of skilled labor has fallen relative to unskilled labor (recall the evidence of Table 1), the skills composition of the labor force, denoted SR, controls for the changing incentives to hire different forms of labor in manufacturing production. Labor demand may be switching to skilled rather than unskilled labor. Capacity utilization denoted UT, controls for the impact of cyclical variation in demand in output markets. We anticipate a positive impact of the UT variable on labor usage, on the grounds that expanding demand for output can most readily be met by expansion of the variable factor of production. Finally, industry concentration denoted CC is included in order to control for the bargaining power of employers in labor markets. In the presence of pricing power by employers, increased wage demands by labor may be met and passed on to consumers, but bargaining power of employers may come to be evidenced in a reduced demand for labor in the long run. We thus have no firm priors on the sign of CC.

Hence, we distinguish determinants of labor usage in the South African manufacturing sector using the following labor requirements long-run relationship equation:

$$L_{it} = \theta_y Y_{it} + \theta_{rp} RP_{it} + \theta_{sr} SR_{it} + \theta_{op} OP_{it} + \theta_{ut} UT_{it} + \theta_{cc} CC_{it} + \eta_{it}, \tag{4.6}$$

[25] We require $F_K > 0$, and $F_{KK} < 0$, and monotonicity of the function.

where all variables but CC are in natural logarithmic transforms.

Table 5 presents estimation results for (4.6). One feature of the findings is the slow correction of short-run deviations from the long-run equilibrium. This is indicated by the estimate of the error correction coefficient ϕ which is significantly less negative than for the Leamer or factor proportions equations. This finding is consistent with the general principle of price changes being more rapid than quantity adjustments. Estimation results confirm a positive impact of output, the relative factor price ratio, the skills ratio, openness and capacity utilization on labor usage, while industry concentration proves to have a statistically significant negative impact. In particular, to the extent that OP is a valid proxy for trade liberalization, the implication is that trade liberalization has a positive impact on employment.[26] More importantly, the relative factor price result may provide confirmation of the finding to emerge from the Leamer estimations, that mispricing of labor can account for the poor demand for labor in the South African manufacturing sector, but also transpires to be the single strongest determinant of labor usage.

Table 5 about *here*

The labor usage estimation findings are thus consistent with those from the Leamer equations. While Leamer equations differentiated between technology and trade effects, the latter reflects the endogenous outcome of domestic and international demand conditions. The labor usage equation suggests that the dominant influences on labor usage in the South African manufacturing sector were the requirements on labor inputs generated by output supply levels, the relative factor price of labor to capital, and industry concentration.

4.5 Modified price regressions allowing for endogeneity

While results from estimation thus far have yielded consistent evidence in favor of a positive effect of globalization on labor usage in South African manufacturing industry, a final issue remains to be settled: the sensitivity of the findings to the potential endogeneity of price changes and technological progress. In terms of the choice of structural variables, Feenstra and Hanson (1999) employ high-technology capital and foreign outsourcing. Their justification is that high-technology capital may have a non-neutral impact on relative factor demand. Outsourcing can be thought of as new intermediate inputs which shift the production function in the home market, generating a change in TFP. Where outsourcing is concentrated in unskilled activity, the impact will be non-neutral. For South Africa capital stock data does not distinguish between high- and low-technology capital, and foreign outsourcing is not a significant feature of manufacturing over the time frame of this study. Moreover, Haskel and Slaughter (2001) use a far larger set of structural variables. We follow their lead, and employ private sector research & development expenditure by economic sector, the openness ratio given by the ratio of exports and imports to total sales, the skills ratio of highly skilled and skilled to unskilled workers, capacity utilization, and an industry concentration measure.

Inclusion of research and development costs finds ready support in the Schumpeterian growth tradition, with efficiency gains being directly linked to the intentional innovative

[26] Recall the relevant caveat noted in the data section and the footnote 16.

activity of firms.[27] R&D expenditure by manufacturing sector is compiled from published survey data. Data is collected for private sector R&D expenditure, public sector R&D expenditure, and expenditure by tertiary educational institutions earmarked for each manufacturing sector.[28] Since in South Africa both exports and imports have responded to trade liberalization, the openness ratio provides an indicator of the orientation of the trade regime. Moreover, export performance and productivity growth may be related because export-activity selects in productive firms, export activity may increase the exposure of firms to more productive firms and other learning opportunities to exploit more efficient scales of production. [See Tybout (2000).] The need to control for the skills ratio arises since the computation of TFP in South Africa does not allow for correction due to the changing skills composition of the labor force. The capacity utilization measure allows us to control for the impact of the business cycle, while the industry concentration measure controls for the product market pricing power of producers.

Since the FH approach does not allow an explicit determination of the pass-through coefficient and the small open economy context of South Africa is quite different from that of the large relatively closed economy context of the US, we begin by considering:

$$\Delta p_{it} = -\lambda \Delta TFP_{it} + \theta_{r\&d} \Delta RD_{it} + \theta_{sk} \Delta SK_{it} + \theta_{op} \Delta OP_{it} + \theta_{ut} \Delta UT_{it} + \theta_{cc} \Delta CC_{it} + \nu_{it}, \quad (4.7)$$

in order to obtain an (inconsistent) indication of the magnitude of technological pass-through to final prices, λ. ΔTFP is given by the effective TFP measure correcting for sectoral changes in factor prices. Column 1 of Table 6 reports results. Notably the small economy assumption of zero technological pass-through is confirmed by the result with $\widehat{\lambda} = 0.02$ proving statistically insignificant, a finding consistent with our preferred Leamer results. The result is quite distinct from the $\lambda = -1$ implying full pass-through reported by FH for the US, with the impact of technological change falling on factor usage rather than output prices.[29] The significance of three out of five structural regressors suggests that technological change appears to have been factor- as well as sector-biased in South African manufacturing. This carries the immediate implication that the FH methodology is of relevance in South Africa even though the full technological pass-through condition that justified its use in the FH study does not apply. The Leamer methodology based on the assumption that technological change is devoid of factor bias may be inappropriate in at least some developing countries, and testing for factor bias in technological change is of some importance.

Core of the FH approach is the two-step estimation of specifications corresponding to

[27] The literature is broad. See Romer (1990), and Grossman and Helpman (1991) for the increasing varieties of capital goods approach, and Grossman and Helpman (1991) and Aghion and Howitt (1992) for the quality ladders approach. Barro (1998) contains an overview of empirical issues that arise from endogenous growth theory in the context of obtaining estimates of TFP. For empirical applications see Hall and Mairesse (1995).

[28] The R&D expenditure data is collected from the CSIR and Scientific Adviser to the Prime Minister/President survey results on R&D activity in South Africa by economic sector. Expenditure figures are real. Details on the data compilation are available in Fedderke (2002b).

[29] To assess the FH claim of sensitivity of results to the specification of the TFP measure, we employed both standard primal TFP and effective TFP measures. The zero technology pass-through conclusion remained unaffected when using the primal rather than the effective TFP measure, though the $R\&D$ and SK variable coefficients came to assume statistical significance.

(2.12) and (2.13). For the empirical implementation of (2.12), we consider:

$$\Delta p_{it} + \Delta TFP_{it} = \theta_{r\&d}\Delta RD_{it} + \theta_{sk}\Delta SK_{it} + \theta_{op}\Delta OP_{it} + \theta_{ut}\Delta UT_{it} + \theta_{cc}\Delta CC_{it} + \nu_{it}, \quad (4.8)$$

in which the technology pass-through coefficient is subsumed in the coefficient matrix, and no longer requires explicit estimation. While in our case it appears that $\lambda \rightarrow 0$, we remain open to the possibility that $\lambda < 0$, though the small economy context is likely to ensure that it remains small. This raises a final modelling issue since (4.8) is again likely to suffer from endogeneity, with efficiency gains triggering further expenditure on R&D. The problem is generic to the FH methodology. As long as they are correct in pointing to the existence of a range of structural variables that drive technological progress, and any of these structural variables are able to be influenced by the actions of producers (as are both of the structural variables employed by FH in their study), endogeneity will follow if producers attempt to generate further efficiency gains through the structural dimensions. Thus the reduced form of (4.8) faces renewed endogeneity problems precisely because it contains the TFP term on the left hand side. Sensitivity to this additional source of potential bias will be important in empirical implementation of the FH methodology. In order to deal with this possibility, we instrument the private sector R&D variable on government institutions' R&D expenditure, and sector-relevant R&D expenditure by tertiary educational institutions. While public and tertiary educational sector R&D is publicly available for use in sectoral production, it is not driven by decision-making processes within the private sector that could respond to realized efficiency gains. Thus we have the prospect of sound instruments, which should be correlated with the private sector R&D variable, but not the TFP term. This is confirmed by the correlations of 0.01 and 0.02 between TFP and government institutions' and tertiary educational institutions' R&D expenditure respectively, as opposed to the correlations of 0.44 and 0.31 between private sector R&D and the two instruments. We employ SURE in order to instrument the private sector R&D expenditure ratio on public sector R&D activity and tertiary educational institutions' R&D activity within each manufacturing sector.[30]

In Column 2 of Table 6 we report the results of estimating (4.8). Note the significance of four out of the five regressors at the 5%, and all five regressors at the 10% level. Significance of the regressors identifies a range of structural determinants of returns to labor and capital, that previously in the Leamer methodology were subsumed into the two general categories of technical change and demand factors.

Tables 6 about *here*

Isolation of the precise impact requires a second stage estimation, based on (2.13). In our case, this requires estimation of [31]

$$\hat{\theta}_j z_{jit} = \theta_l \ell_{it} + \theta_k k^*_{it} + \eta_{it}, \quad (4.9)$$

[30]SURE estimation is appropriate due to non-zero contemporaneous correlation of disturbances attaching to growth in total factor productivity across manufacturing sectors. χ^2 test statistic confirms the presence of non-diagonal error covariance matrix. Full details of the procedure followed is available in Fedderke (2002b).

[31]FH and Haskel and Slaughter (2001) re-estimate the standard errors of the estimates in the second stage regression, (4.9), using the modified formula that takes into account the fact that we do not observe the "true contribution" of structural variables to the weighted changes in primary factor prices. But, we are able to prove that this modification is unnecessary in the current context, under certain regularity

where $z_{jit} = \Delta RD_{it},\ \Delta SK_{it},\ \Delta OP_{it},\ \Delta UT_{it},\ \Delta CC_{it}$ and the corresponding estimates $\hat{\theta}_j$ are obtained from (4.8).

Results are reported in Table 7. Recall that the correct interpretation of the θ_l, θ_k, coefficients is as the factor price changes implied by the structural variables. The implication is that labor prices were subject to downward pressure from R&D and the rising skills composition of the labor force, and upward pressure from increasing openness, rising capacity utilization, and rising industry concentration levels. A number of features of these findings deserve comment. First, the downward pressure of a rising skills composition on real labor prices may seem counterintuitive. But recall that for South African manufacturing the real remuneration of skilled workers over our sample period was either constant or falling, while that of unskilled labor was increasing. A rising skills ratio is thus consistent with falling labor prices. Second, the finding on the impact of rising industry concentration ratios suggests that organized labor has been successful in bidding up wages in sectors in which producers have the pricing power to pass on rising production costs to consumers. This suggests that industry concentration in South African manufacturing may serve as an indirect proxy for union bargaining power, as well as an indication of producer pricing power. This inference needs to be tempered by the realization that the labor usage equation above showed that higher wages in concentrated industries would also have been accompanied by labor shedding. Finally, the positive impact of rising capacity utilization on the variable factor is expected, while the negative impact of technology and positive impact of openness on labor prices is consistent with the findings to emerge under the Leamer methodology.

For capital, prices were under upward pressure from R&D and openness, while the rising skills ratio, capacity utilization and the industry concentration ratio measure appear to have been neutral. While the finding on technology reverses that obtained under the Leamer methodology, we also notice that the finding for the positive impact of openness is not consistent with negative mandated earnings by capital due to trade-related changes as found earlier. In the present context, the most likely explanation is that openness ratios still do not adequately isolate trade liberalization, and instead include a range of domestic and international demand factors that are unrelated to liberalization. At least one piece of evidence suggests that this is the most likely explanation for South Africa. [See also the footnote 16.]

While we excluded the use of effective protection rates from this study due to the short time period over which data is available (1988-98), estimation of (4.9) using effective protection rates returns results that are fully consistent with SST, *viz.* a positive and statistically significant impact on labor prices, and a negative and statistically significant impact on capital prices. Strictly the results are not comparable to those for other variables, given the short time run of estimation. Nevertheless, we report the results in Table 7 under $\widehat{\theta}_{erp}\Delta ERP$. Concentrated in the period of maximal trade liberalization, and focussed most closely on a direct measure of liberalization, results are strictly consistent with SST.

Table 7 about *here*

conditions that have been implicitly imposed in both our and their regression analyses. This follows the well-established result in econometrics literature that the error in measuring the dependent variable can be basically indistinguishable form the underlying regression disturbance, see Schmidt (1976, Section 3.4). The detailed proof will be available upon request.

With the possible exception of a remaining puzzle concerning the precise impact of trade on capital prices, we note that even taking into account the existence of numerous forms of endogeneity in estimation, and a more extensive set of structural determinants of price and technology changes, the implication of the empirical results remains the same as before: demand side factors, and trade-related demand side factors in particular serve to raise labor earnings, while we continue to find that the impact of technology has been to decrease them.

5 Conclusion

We have investigated the impact of trade on labor markets by examining four operational consistency-check versions of the Stolper-Samuelson theorem. The paper innovates both by obtaining estimation results by means of dynamic heterogeneous panel estimation, and by employing developing country data. Estimation results suggest that technological progress appears to have had negative consequences for both labor relative to capital, and unskilled labor relative to skilled labor in South African manufacturing. By contrast, results are consistent with a positive impact of trade on the use of labor relative to capital stock, and unskilled relative to skilled labor. We find that while globalization effects have mandated positive growth in labor earnings, the impact of technological progress has mandated considerably smaller growth in labor earnings - approximately half of that actually realized in South African labor markets. One important implication is that factor prices are likely to be crucial in determining factor demand in labor markets. This mispricing of labor is likely to play a significant role in the determination of labor unemployment patterns in South Africa.

The findings of this paper also carry implications for the methodologies conventionally employed in assessing the impact of trade on labor markets, particularly in developing country contexts. While the Leamer (1998) methodology provides the same conclusions as the Feenstra-Hanson (1999) methodology, *viz.* that "globalization" is not associated with a negative impact on manufacturing labor markets in South Africa, it does not provide a full separation of the demand side factors that enter into "globalization." The Feenstra-Hanson approach is useful in the case of South Africa not because it can take account of the possibility that technology pass through is complete (we continue to find zero or near-zero technology pass through), but because it allows for factor bias in technological progress in addition to sectoral bias. This was found to be a significant feature of the South African experience. Moreover, the ability to account for demand-side determinants sheds additional light on different sources of upward and downward pressure on labor and capital earnings. We also find that correction for potential endogeneity of technological change and prices is important even in a small open developing economy setting such as South Africa.

Finally, notable in the reported results is the consistency of the findings. Regardless of the methodology employed, the implication was consistently that demand factors, and trade liberalization related factors in particular did not prove to carry a negative impact on labor in South African manufacturing industry.

Table 1. Summary Statistics: Figures are Manufacturing Sector Averages			
	1970's	1980's	1990's
Change in natural log of output price	0.09	0.15	0.10
Openness (Exports + Imports)/Output	0.50	0.43	0.58
Highly Skilled : Unskilled real per worker remuneration	9.55	6.14	4.03
Highly Skilled : Skilled real per worker remuneration	3.14	2.91	2.71
Skilled : Unskilled real per worker remuneration	3.04	2.10	1.48
(Highly Skilled + Skilled) : Unskilled employment (Skills Ratio)	0.45	0.59	0.74
Capital : Labor	0.06	0.10	0.11
Total No. of Strikes (Aggregate Economy)	199	605	797
Total No. of Workers Engaged in Strikes (Aggregate Economy)	25474	215742	216902
Total No. of Person Days Lost in Strikes (Aggregate Economy)	43930	1150915	1393841
Concentration Ratio of Manufacturing Output	0.80	0.84	0.85
TFP without skills correction	0.49	-0.52	-0.79
TFP with skills correction	-0.26	-1.37	-1.00
Capital : Labor for sectors with TFP growth above the mean	0.04	0.14	0.07
Capital : Labor for sectors with TFP growth below the mean	0.07	0.07	0.16
Skills Ratio for sectors with TFP growth above the mean	0.39	0.60	0.63
Skills Ratio for sectors with TFP growth below the mean	0.47	0.55	0.82
Total Real R&D Expenditure (Private + Public + Tertiary)	0.13	0.24	0.26

Notes: TFP is here reported as the percentage growth in output that results from efficiency gains. Thus 0.49 denotes a 0.49% growth in output resulting from TFP. In estimation we employed TFP growth in the scale of the relevant dependent variable.

Table 2. PMG Estimates for Factor Intensity Equations using the Capital-Labor and Skills Ratios for SA Manufacturing Sectors over 1972-97				
ARDL Specification	ARDL(2,2) on (4.1)	ARDL(2,2,2) on (4.1)	ARDL(2,2) on (4.1)	ARDL-AIC(2) on (4.1)
θ_{KL}	-.05* (.01)	-.05* (.01)		
θ_{TFP}		.02 (.04)		.04 (.03)
θ_{SR}			-.03* (.01)	-.02* (.01)
Speed of Adjustment, ϕ	-.84* (.07)	-.79* (.07)	-.76* (.06)	-.77* (.05)
Hausman Test	.23 [.63]	1.02 [.60]	.93 [.33]	3.85 [.15]

Notes: Standard errors are given in (.). "*" and "**" indicate significance at the 5% and the 10% level. The Hausman test tests for the validity of the long-run homogeneity with its p-value given in [.].

Table 3. PMG Estimates for Leamer Product Price Change and Technology Equations for SA Manufacturing Sectors over 1972-97		
Specification	Zero Pass-Through (4.2) ARDL (4,3,2)	Technology Equation (4.3) ARDL (4,3,2)
Long-run Coefficient, θ_l	.181* (.028)	-.056* (.013)
Long-run Coefficient, θ_k	.11* (.021)	-.065* (.013)
Speed of Adjustment, ϕ	-.45* (.057)	-1.02* (.108)
h Test for Long-run Homogeneity	5.06 [.08]	6.31 [.04]

Notes: See notes to Table 2.

Table 4. Mandated Price Changes for SA Manufacturing Sectors over 1972-97		
	Δp	ΔTFP
θ_l	0.181	-0.056
θ_k	0.11	-0.065
Mean Dependent Variable	0.12	0.005
Mandated Earning Growth Unrelated to Technology in Percent per Annum		
Labour	6.1	
Capital	-1.0	
Mandated Earning Growth Related to Technology in Percent per Annum		
Labour	-5.6	
Capital	-6.5	
Total Mandated Earnings Growth in Percent per Annum		
Labour	0.5	
Capital	-7.5	

Table 5. PMG Estimates for Labor Usage Equation (4.6) based on ARDL(3,1,1,2,2,2,2) for SA Manufacturing Sectors over 1972-97	
θ_y	.28* (.03)
θ_{rp}	1.97* (.15)
θ_{sr}	.19* (.03)
θ_{op}	.09* (.01)
θ_{ut}	1.93* (.24)
θ_{cc}	-1.26* (.28)
Speed of Adjustment, ϕ	-.18* (.06)
Hausman Test	9.41 [0.15]

Notes: See notes to Table 2.

Table 6. PMG Estimates for the Feenstra-Hanson Product Price Change and Technology Equations for SA Manufacturing Sectors over 1972-97		
Regressand Specification ARDL	Δp (4.7) (1,1,1,2,2,2,2)	$\Delta p + \Delta TFP$ (4.8) (3,3,0,2,1,2)
θ_{tfp}	.02 (.01)	
$\theta_{r\&d}$	.002 (.002)	.02* (.00)
θ_{sk}	.07 (.06)	.11** (.06)
θ_{op}	.23* (.05)	.46* (.11)
θ_{ut}	1.51* (.14)	1.31* (.26)
θ_{cc}	1.22* (.33)	1.57* (.52)
Speed of Adjustment, ϕ	-.58* (.07)	-.84* (.07)
Hausman Test	6.27 [.39]	7.78 [.17]

Notes: See notes to Table 2.

Table 7. PMG Estimates for the Feenstra-Hanson Structural Variable Equations (4.9) for SA Manufacturing Sectors over 1972-97						
Regressand ARDL Specification	$\widehat{\theta}_{rd}\Delta RD$ (4,3,3)	$\widehat{\theta}_{sk}\Delta SK$ (4,3,2)	$\widehat{\theta}_{op}\Delta OP$ AIC(3)	$\widehat{\theta}_{ut}\Delta UT$ AIC(2)	$\widehat{\theta}_{cc}\Delta CC$ (4,3,2)	$\widehat{\theta}_{erp}\Delta ERP$ (1,2,1)
θ_l	-.06* (.02)	-.05** (.03)	.32* (.09)	.08* (.04)	.03* (.01)	.16* (.01)
θ_k	.05* (.02)	-.04 (.02)	.48* (.09)	.06 (.04)	-.02 (.01)	-.04* (.004)
Speed of Adjustment, ϕ	-.83* (.15)	-1.79* (.19)	-.99* (.25)	-1.19* (.09)	-1.48* (.18)	-1.42* (.14)
Hausman Test	2.07 [.35]	0.85 [.66]	3.20 [.20]	0.73 [.70]	1.45 [.48]	1.56 [.46]

Notes: See notes to Table 2.

Figure 1. Average Effective Proctection Rates: South African Aggregate Manufacuring

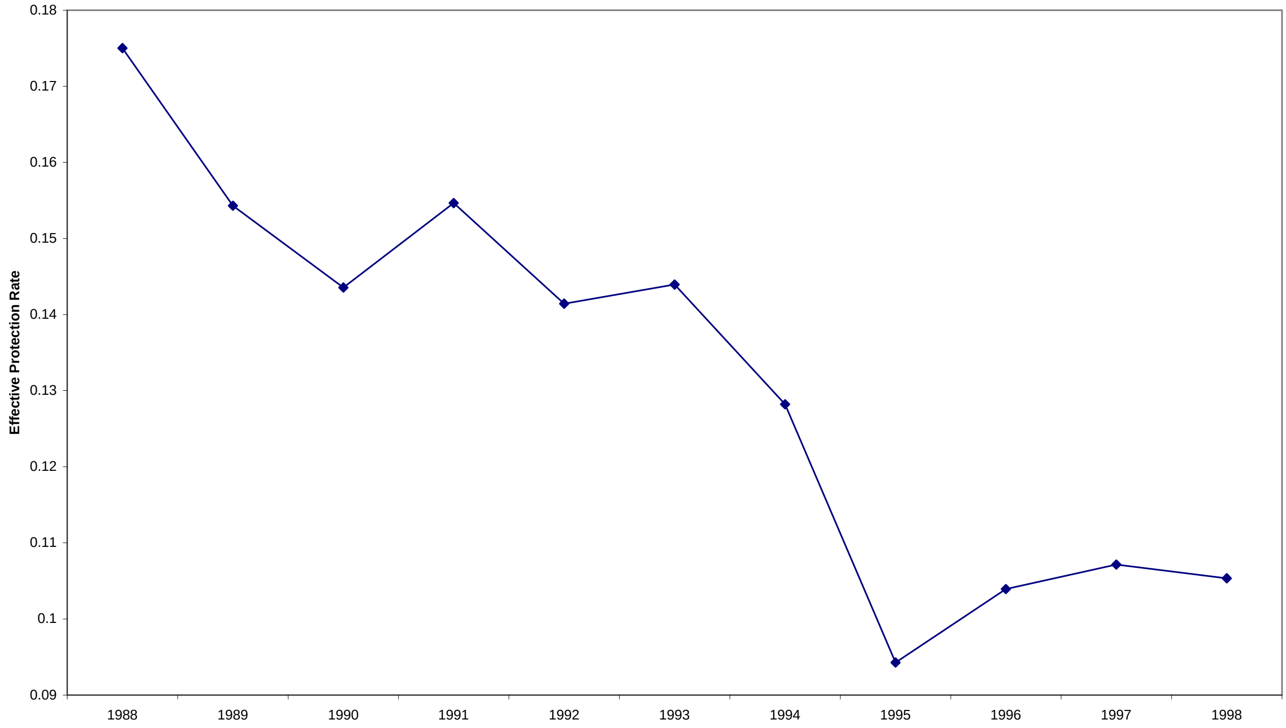


Figure 2. Real Remuneration per Employee by Skill Level: South African Aggregate Manufacturing

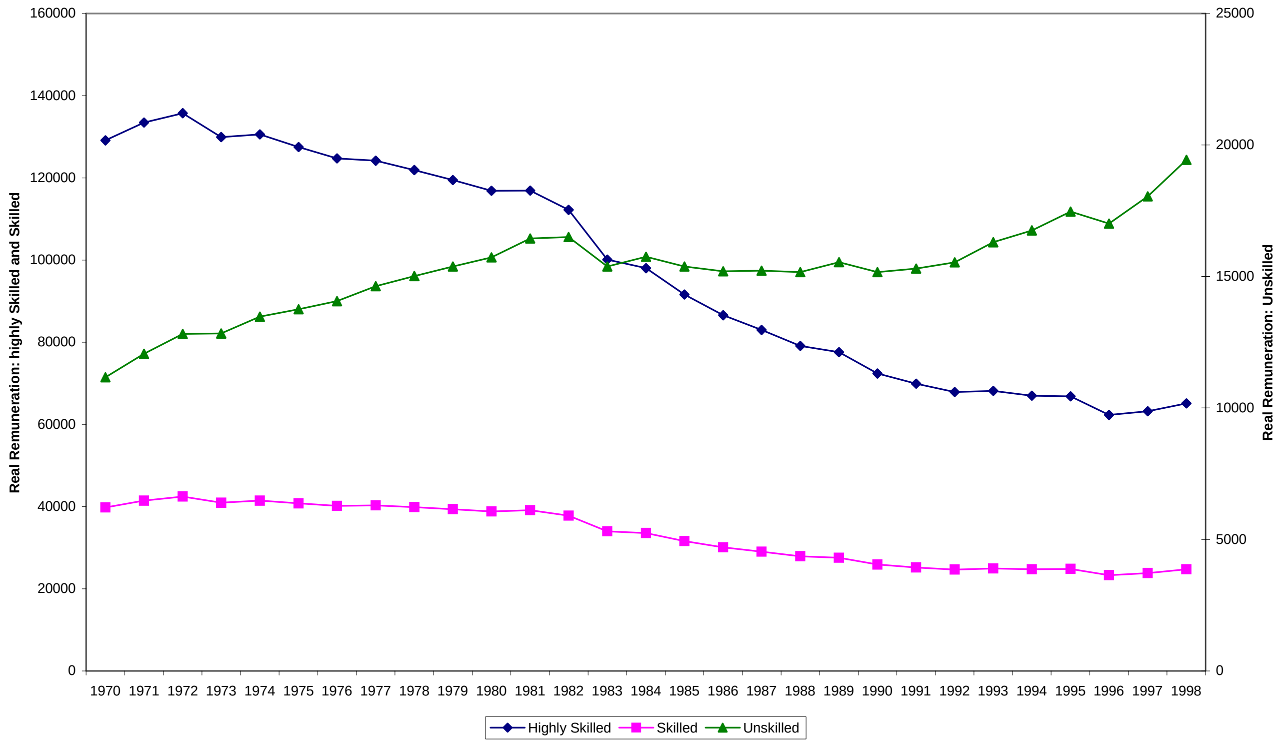
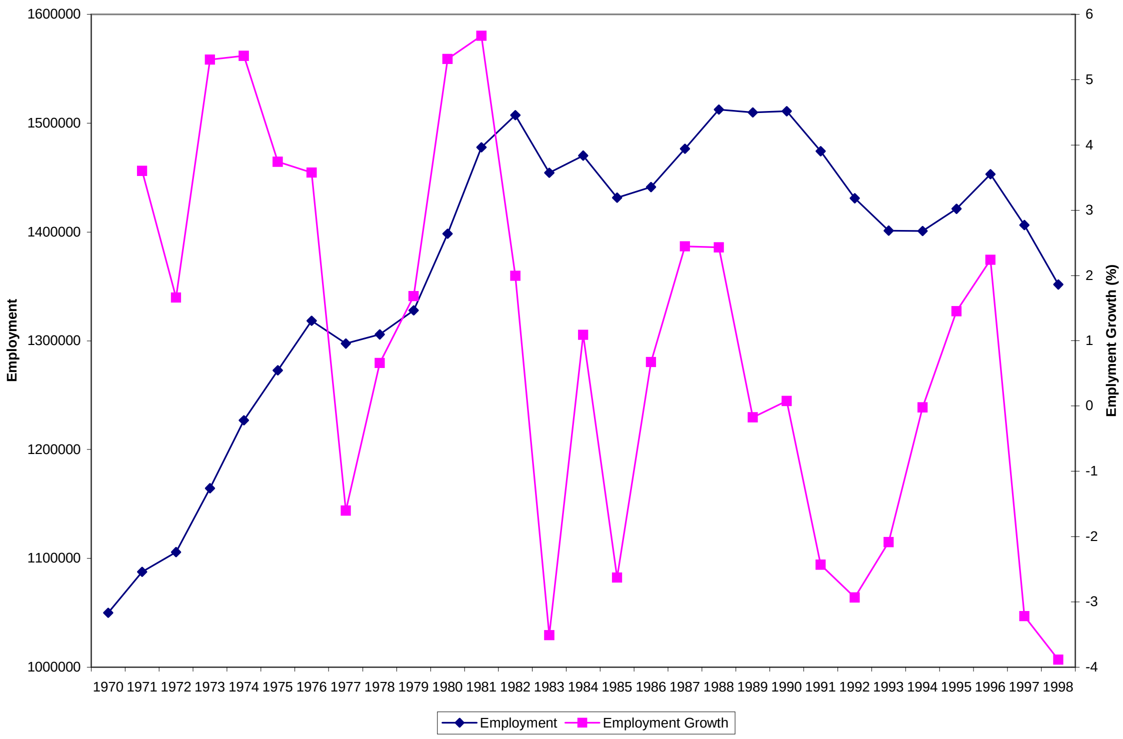


Figure 3. Labor Market Developments: South African Aggregate Manufacturing



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