PEDL Research Papers

This research was partly or entirely supported by funding from the research initiative Private Enterprise Development in Low-Income Countries (PEDL), a Department for International Development funded programme run by the Centre for Economic Policy Research (CEPR).

Does Technical Efficiency Dominate Resource Reallocation in Aggregate Productivity Growth? Evidence from Swazi Manufacturing

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Abstract

Is the effect of input reallocation on aggregate productivity growth (APG) *less* than that of technical efficiency? A robust finding in two influential meta-analyses by Bartelsman *et al*. (2004) and Paǵes *et al.* (2008) is that within-plant productivity dominates input reallocation across plants in the 25 countries studied. The method used to derive these patterns of growth is based on the Baily *et al*. (1992) and Foster *et al*. (2001) approaches which decompose aggregate labour productivity into real productivity and reallocation. This paper applies the Baily *et al*. (1992)/Foster *et al*. (2001) and Nishida *et al*. (2014) approaches to answer this question using the Swaziland manufacturing plant-level dataset covering a trade liberalization period of 1994-2003. In terms of the traditional approach, growth from within-firm activity (-4.88%) is subordinate to the Baily *et al*. (1992) reallocation growth (0.38%) and to the Foster *et al*. (2001) reallocation growth (3.53%). The Nishida *et al*. (2014) method generates similar results. For instance, the component of APG associated with technical efficiency/within-firm growth (-3.61%) compares with input reallocation growth (0.15%). The results from both approaches remain unchanged regardless of deflation criterion applied to value-added, capital and material input quantities. Therefore, the Swaziland manufacturing sector experienced robust contribution of input reallocation to APG relative to technical efficiency during the trade reform period. This suggests that firms were not investing more on improving production efficiency through innovation and adoption of new technologies than they moved inputs to higher activity producers.

JEL Classification: J24, L6, O47

Keywords: Firm-Level, Aggregate Productivity, Reallocation, Technical Efficiency, Swaziland.

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1. Introduction

Recent research spurred by the increasing availability of longitudinal plant-level data, links microeconomic dynamics to aggregate outcomes. One area of focus for this research is the identification of establishment-level drivers and relative dominance of sources of aggregate productivity growth. A robust finding is that structural change effects of resource reallocation across plants are subordinate to within-plant productivity arising from learning-by-doing and learning-by-watching. For example, in nine of the 25 countries studied by Bartelsman, Haltiwanger and Scarpetta (2004) (or BHS) and Paģes, Pierre and Scarpetta (2008) (or PPS), resource reallocation between plants was negative and weakly positive in only four countries. Similarly, in the analysis of job creation and productivity growth for the Slovenian manufacturing sector, De Loecker and Konings (2006) find dominance of technical efficiency over the reallocation of market-share of labour from low- to high-productivity incumbents as well as over firm turnover in driving aggregate productivity. In a comprehensive survey of the literature, Isaksson (2010) confirms for several countries at different stages of development that within-firm effects contribute more than inter-sectoral reallocation effects to aggregate labour productivity growth.

Another strand of the literature using enterprise-level micro-data also finds overwhelming evidence that within-industry reallocation of resources shape changes in industry aggregates; see Foster *et al*. (2008). This churning process and its effects on aggregate productivity have received special theoretical and empirical attention. As observed by Foster *et al*. (2008), models of selection mechanisms depict industries as assortments of producers characterized by heterogeneous productivity which link a firm's productivity level to its performance and survival in the industry. Key contributions in this area include Jovanovic (1982), Ericson and Pakes (1995), Melitz (2003), and Asplund and Nocke (2006). The main mechanism that causes change in these models is the reallocation of market-shares from either inefficient to efficient incumbent producers or from entry and exit of firms. Low-productivity establishments are less likely to survive and prosper relative to high-productivity incumbents which create selection-driven increases in industry productivity (Foster *et al*., 2008).

The common approach used to generate these results is largely based on the work of Baily, Hulton and Campbell (1992) and its derivatives such as Foster *et al.* (2001), Griliches and Regev (1995) and Olley and Pakes (1996). The Baily *et al.* (1992) method defines industry productivity growth as resource-share weighted changes in the distribution of the Solow-type technical efficiency (Solow, 1957). It derives its foundations from the decomposition and aggregation of plant-level residuals into productivity growth components. The sources of this growth include changes in a plant's continuous innovation and adaptation to technological advances in the sense of learning-by-doing/watching as in Jovanovic (1982) and Pakes and Ericson (1998), movement in resource-share changes from low- to high-activity plants and turnover of firms. One question this method seeks to answer relates to the height of barriers to input reallocation in an economy, as in Bartelsman *et al.* (2004) and Paǵes *et al.* (2008).

The Petrin and Levinsohn (2012) method presents an alternative framework which introduces an environment with imperfect competition that creates a wedge in the marginal product−reward mix of inputs. It also creates a friction that induces heterogeneity in production technology and productivity levels, entry and exit of goods, costs of adjusting outputs and inputs, sunk and fixed costs, and markup-pricing. This is consistent with the recent work by Hsieh and Klenow (2009) and Petrin and Sivadasan (2013), who find significant heterogeneity between inputs' marginal products across establishments suggesting the presence of prohibitive distortions in input reallocation. Restuccia and Rogerson (2008) also calibrate a growth model with establishment-level heterogeneity arising from idiosyncratic policies and regulations, and institutional behaviour. This allows them to analyse the distortionary effects of such idiosyncrasies on the reallocation of resources across producers. Policies creating price heterogeneity among producers are found to reduce output and aggregate productivity by a range of 30 to 50 percent (see Restuccia and Rogerson, 2008).

The proposition by Petrin and Levinsohn (2012) has been applied by Nishida *et al*. (2014) to Chile, Colombia, and Slovenia; Ho, Huynh, Jacho-Ch´avez and Cubas (2014) to Ecuador, Petrin *et al.* (2011) to the U.S., and Kwon, Narita and Narita (2009) to Japan. This measurement approach defines aggregate productivity growth (hereafter referred to as APG) "as the change in aggregate final demand *minus* the change in aggregate expenditure on capital and labour" in the presence of imperfect competition and other distortions or frictions. Crucially, the APG decomposition has a term per establishment linked to technical efficiency and one for each primary input at each plant.[2] The term associated with either capital or labour is a function of the wedge between the value of the marginal product (VMP) and the relevant input price.

The purpose of this chapter is two-fold. *First*, it seeks to compare the individual drivers of aggregate labour productivity for the Swazi manufacturing sector with similar drivers for other countries. This exercise has never been done before for a Southern African country using a relatively long panel dataset compiled by a state agency.[3] *Second*, it estimates the components of industry productivity over time using both the Baily *et al.* (1992)/Foster *et al.* (2001) and Petrin and Levinsohn (2012) methods. In essence, the chapter examines the robustness of the overwhelming findings of the meta-analyses that productivity arising from learning-by-doing and learning-by-watching *dominates*

[2] The phrase 'primary inputs' is used interchangeably with 'factor inputs'.

[3] Van Biesebroeck (2005) undertakes a similar analysis but has access only to RPED surveys, which have a short time dimension.

productivity from market-share reallocation across incumbent firms and from net-entry of firms?[4,5] This question is examined across several dimensions using a rich and unique dataset for the manufacturing sector in a small developing African country- Swaziland.

This chapter makes three contributions to the literature. *First*, it applies the Baily *et al.* (1992)/Foster *et al.* (2001) approach to compare the drivers of industry productivity in Swazi manufacturing with similar growth drivers in Sub-Saharan economies, economies in transition and developed countries. *Second*, it uses the traditional approach and Petrin and Levinsohn (2012)/Nishida *et al*. (2014) to estimate ALP and APG over time. *Third*, it estimates the impact of confounding effects of plant turnover on the Baily *et al*. (1992) reallocation in the Swazi manufacturing data.

In the next section, we present an overview of the manufacturing sector in Swaziland for a period which coincides with trade liberalization and the political transition in South Africa. Section 3 undertakes descriptive analyses of key indicators and the behaviour of aggregate productivity for capital and labour. This is followed by a formal presentation of the research methodology for ALP measurement and decomposition in Section 4. Section 5 discusses the results while Section 6 presents a summary and conclusion of the paper.

2. Overview of the Manufacturing Sector in Swaziland

The latter part of the 1980s was a period of unprecedented economic growth in the Swazi manufacturing sector. This was in response to economic sanctions on South Africa imposed by influential world economies (Edward *et al*. (2013)) and the relocation of some South African firms to neighbouring countries like Swaziland to circumvent these sanctions. The relocation decision enabled them to access foreign markets and/or to export intermediate inputs back to the home country. These foreign affiliates gained access to relatively cheap labour and material inputs in Swaziland, which reduced production costs. The domestic effect of this foreign presence in the sector came in the form of transfer of technical knowledge to local labour and to upstream suppliers. The resulting learning-by-doing increased both the efficiency of primary inputs and the quality of intermediate inputs from suppliers. Consequently, Hammouda, Karingi, Njuguna and Jallab (2010) found that Swaziland experienced 11.15 percent growth in real gross domestic product during the period 1985−1990 in which capital and total factor productivity accounted for 3.13 percent and 6.34 percent, respectively.

However, the period spanning the 1990s and 2000s was characterized by a marked deterioration in economic growth. This was due largely to the lifting of sanctions and re-integration of South Africa

[4] Resource reallocation refers to reallocation of resources across incumbent firms and reallocation of resources in response to firm turnover, where firms/plants/establishments are used interchangeably.

[5] Levinsohn and Petrin (1999) refer to the learning-by-doing and learning-by-watching effects as the real productivity case.

into the world economy (Hammouda *et al.*, 2010). In particular, trade liberalization that took place in the second half of the 1990s made South Africa appear as a more attractive investment destination. The response of South African multinational enterprises was to recall their foreign affiliates to improve their own scale economies, see Jonsson and Subramanian (2001). As international competition intensified, domestic industries that were characterized by oligopolistic markup pricing behaviour were forced to behave competitively. According to Jonsson and Subramanian (2001), the consequence of a freer market environment was the exit of some of the inefficient firms which, in turn, reallocated market shares to continuing ones and also to industry entrants. They also argue that, despite the presence of such import discipline mechanism, the limited domestic market size still enabled a portion of inefficient plants to survive and also allowed new low-productivity manufacturers to enter the market.

During this period the Swaziland Government responded with an attempt to address the issue of missing markets in the economy. One critical area for industrial policy intervention involved institutional reforms and infrastructure development to attract FDI, see Masuku and Dlamini (2009). As a result, the Swaziland Industrial Development Corporation (SIDC) was commissioned to design and implement a factory shell development programme to reduce sunk investment costs for producers, particularly in the textile and apparel industries. The Swaziland Investment Promotion Authority (SIPA) was also established in 1998 as a one-stop shop to serve mainly foreign investors. The objective of SIPA's existence was to market the country abroad as an investment destination and also to serve as an information desk when the foreign firm was ready to invest in Swaziland. In addition to these efforts to lure foreign investment, the state was also an active participant in the domestic economy. Direct state presence through Tibiyo TakaNgwane sought, *inter alia*, to increase formal sector employment and earn foreign exchange.[6] The presence of this state-owned enterprise is found in key sectors of the economy, and is perceived by the Federation of Swaziland Employers and Chamber of Commerce as having undesirable crowding-out effects on private investment, see Tibiyo TakaNgwane's Annual Report (2010).

3. Descriptive Analysis of the Panel Data Series

3.1. Data Description and Summary Statistics

Although a detailed account of the source and structure of the dataset is presented in the overview chapter, the investigation of aggregate productivity growth requires a more direct description of relevant data series. Firm dynamics in the 1990s and early 2000s were driven by an average entry rate of 9.72 percent and exit rate of 8.03 percent per year. In the same period, the aggregate labour series oscillated around an average of 21 500 employees as shown in Table 3.1. In particular, aggregate

[6] Tibiyo TakaNgwane is a state-owned enterprise whose purpose is to actively pursue commercially viable projects in all sectors of the economy.

labour changes exhibit relatively erratic patterns of weakening over the entire period. At the same time, the real value-added series in column four was largely static, except for a sharp drop in 1997.

Table 3.1: Summary Statistics

Year	No. of Firms	Employment	Total Amount in E' Million*		
			Real Value-Added	Real Capital	Real Wages
1994	100	17 260	1 241.28	2 221.8	2 267.2
1995	109	18 216	1 033.25	1 445.7	2 144.4
1996	117	17 837	1 132.92	1 085.7	2 271.0
1997	130	18 513	1 164.43	1 287.2	1 433.3
1998	150	20 296	1 087.23	2 928.2	1 605.6
1999	153	19 760	2 568.00	5 344.3	2 042.5
2000	164	19 036	2 291.59	5 477.6	2 705.8
2001	177	28 861	2 697.51	5 482.2	2 685.7
2002	188	32 219	2 143.96	6 879.5	2 830.7
2003	160	23 499	1 919.77	6 557.2	2 852.9
Mean	144.8	21 550	1 727.99	3 871.9	2 283.9

Note: * These figures were transformed using double-deflation of value-added, capital and the wage series as required by Bruno (1978) and applied by Nishida *et al*. (2014) for the case of Chile, Colombia and Slovenia.

The events that characterize the churning process of firms included the deepening pressure for higher wage increases by unions, and the resulting worker unrest necessitated restructuring of businesses through retrenchments.[7] Industrial action was however more visible in some sectors than in others. Moreover, the increase in aggregate capital was rather rapid from 1996 and levelled off somewhat in 1999. Since capital measurement is based on the plant, machinery and equipment (PME) series, which excludes the cost of repairs and replacement, its years of upward trend is a reflection of generally lumpy investment in fixed capital by a few large firms.[8]

3.2. Aggregate Input Productivity Movements

Aggregate input productivity changes in manufacturing during the trade liberalization period show a general decline as shown in Figure 3.1. The aggregate labour productivity index mimics aggregate labour input trends examined above. This suggests a high level of co-movement between value-added output and aggregate labour productivity. It is therefore not surprising to see a rapid decline in aggregate capital productivity from a point in time when the capital series begins an increase. Furthermore, the capital-labour ratio shows an increase after the first three years. This reflects a general increase in capital-intensity in production during the period under analysis without corresponding growth in real value added.

[7] See the Central Bank of Swaziland Reports (1995-2003) on industrial unrests and IMF Staff Report (2000:13) on the need to review the Industrial Relations Act.

[8] The intermittence and lumpiness of capital projects as well as indivisibility contribute to the non-smoothness in the adjustment path of capital stock; see Nielsen and Schiantarelli (2003). Indivisibility ensures that investment occurs only in discrete increments.

Figure 3.1: Output-Input and Capital-Labour Ratios by Year

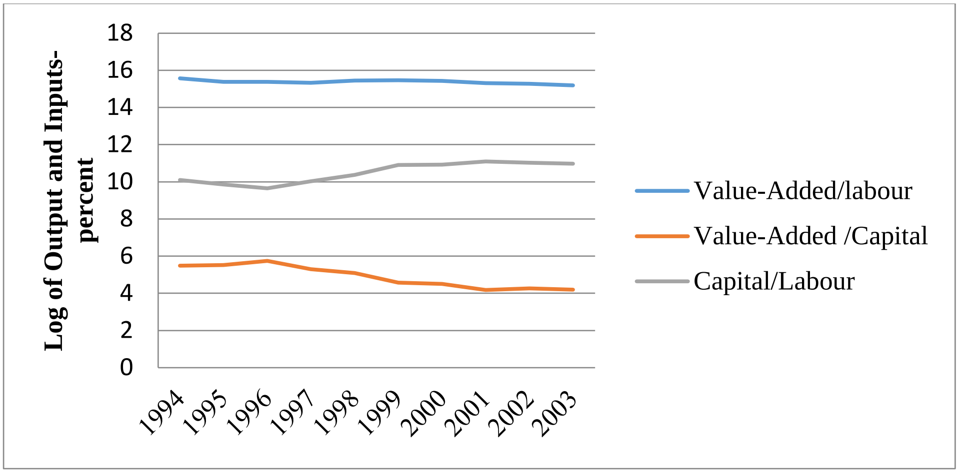
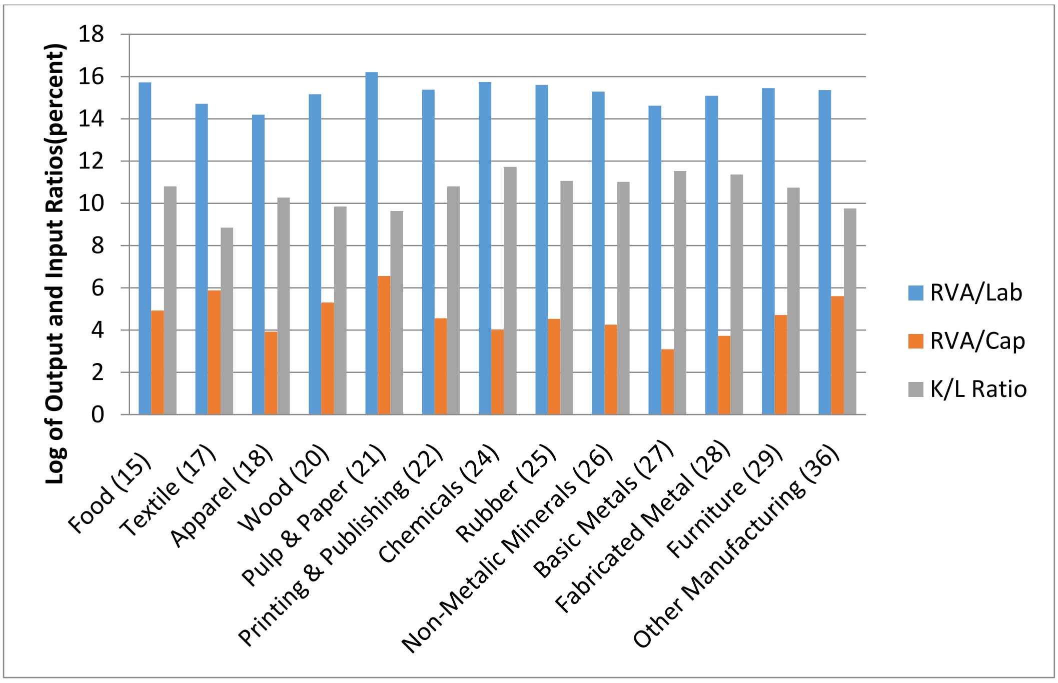


Figure 3.2: Output-Input and Capital-Labour Ratios by Industry (1994-2003)

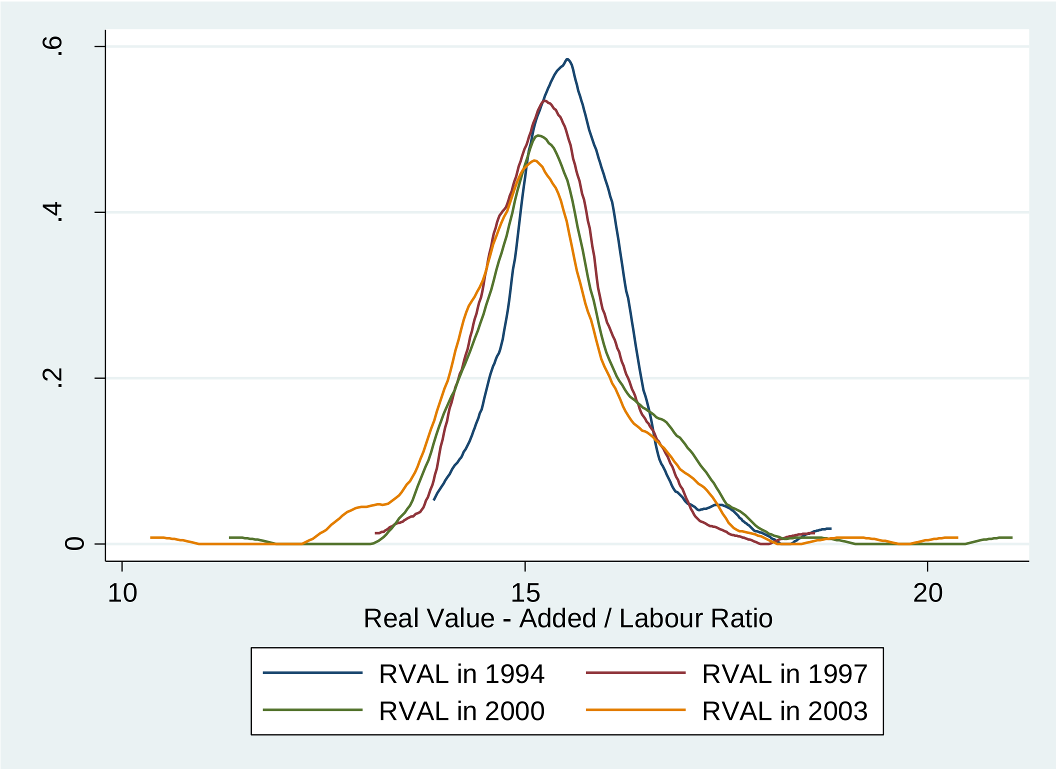


In general, the descriptive analysis is consistent with an explanation where a significant proportion of larger firms shed labour and keeps capital adjustment levels largely unchanged. This pattern of firm behaviour aligns with an economic environment which favours shifting most of the production by South African affiliates in Swaziland back to South Africa. Given that capital is mostly irreversible in nature, these firms could not recoup the fixed costs of capital but simply operated to cover their variable costs to remain in business.

This evidence sheds light on average patterns of aggregate factor input productivity across time and industry but cannot reveal much, if anything at all, about its cross-sectional distribution at a given point in time. Looking at aggregate labour productivity (ALP), Figure 3.3 shows a persistent shift of

ALP towards the left with growing fat-tails in both directions. These patterns remain unaltered even when the value-added series is subject just to single deflation, except that the whole distribution moves more to the left, see Appendix A3.2. This is in sharp contrast to conventional wisdom, which holds that market reforms increase productivity within and across firms to drive aggregate growth.[9] Normally, trade liberalization has been shown to increase firms' incentives to invest in innovative technologies, and weak firms to lose market share to efficient ones, thereby boosting productivity, see Lileeva (2008).

Figure 3.3: ALP Distribution for Selected Years (1994, 1997, 2000, 2003)



Note: ALP is measured as a ratio of double-deflated value added to aggregate employment in a year; see Appendix A3.2 for a single-deflated ratio of real value added to annual total employment.

In Table 3.2, we report patterns of productivity index movements by industry, and measure their central tendencies and dispersion. This allows us to document the relative performance of industries in relation to the chosen base year. Our first year of the sample period −1994− is normalized to one and the productivity index for the subsequent years is measured relative to this base year. On average, there is at best stagnation in 1998-1999 and at worst a loss of about 3 percent in productivity by 2003. This is contrary to De Loecker and Konings (2006) who use Olley and Pakes (1996) to find an average increase of 63 percent in the productivity index for Slovenia covering the period 1994-2000. The presence of heterogeneity is starkly reflected by a 2 percent growth in the 'Wearing Apparel'

[9] See; for example, Lileeva (2008, Fig.1) for the case of Canada within NAFTA where the evolution of growth generated from the 'Between' and 'Within' terms continuously shift towards the right. Escribano and Stucchi (2014, Fig.1) find productivity improvement for Spanish manufacturing firms during a recession.

industry, while the 'Basic Metals' industry declines by 9 percent in the final year. Again, De Loecker and Konings (2006) found increases of 7 and 77 percent in the respective industries. However, the Pulp and Paper industry remains the dominant driver of ALP growth in the trade reform period in Swaziland.

Table 3.2: Evolution of the Average ALP by Industry (1994-2003)

Industry	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Food and Food Products	1.00	0.97	0.97	0.98	0.99	0.98	0.98	0.98	0.97	0.96
Textile	1.00	0.98	0.98	0.98	1.00	1.00	0.97	1.00	0.97	0.96
Wearing Apparel	1.00	0.99	1.03	1.01	1.03	1.01	1.01	0.88	1.00	1.02
Wood and Wood Products	1.00	0.97	0.96	0.96	0.99	0.98	1.00	0.97	0.98	0.95
Pulp and Paper Products	1.00	1.01	1.03	1.05	1.05	1.05	1.05	1.01	1.02	0.97
Printing, Publishing	1.00	0.99	0.99	0.99	0.99	0.99	1.00	1.00	0.99	0.99
Chemicals Products	1.00	0.99	1.00	1.01	0.98	0.99	1.00	1.01	1.00	0.98
Rubber and Plastic Products	1.00	0.99	0.99	0.97	0.99	0.98	0.97	0.98	0.96	0.94
Other non-metallic Minerals	1.00	0.99	0.96	0.94	0.96	0.97	0.98	0.96	0.98	0.97
Basic Metals	1.00	0.99	1.01	1.02	1.01	1.02	0.98	0.98	0.99	0.91
Fabricated Metal Products	1.00	0.99	1.01	0.98	0.99	0.99	0.97	0.97	0.98	0.99
Machinery and Equipment	1.00	0.99	0.99	0.99	0.99	0.99	0.97	0.99	1.00	0.99
Furniture	1.00	1.02	1.00	0.98	0.98	1.02	0.98	0.99	0.98	0.98
Sector Mean	**1.00**	**0.99**	**0.99**	**0.99**	**1.00**	**1.00**	**0.99**	**0.98**	**0.99**	**0.97**
Sector Median	**1.00**	**0.99**	**0.99**	**0.98**	**0.99**	**0.99**	**0.98**	**0.98**	**0.98**	**0.97**
Std Dev ($\boldsymbol{\sigma}_{ALP}$)	**0.00**	**0.01**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.03**	**0.02**	**0.03**

Source: Author's calculations.

It also seems natural to perform an analysis of ALP behavioural patterns at the tails of its distribution. For example, the 25th percentile in the ALP distribution shows more volatility than either the average situation or the upper 75th tail. That is, the standard deviation of the 25th percentile was $\boldsymbol{\sigma}_{ALP} \in [1.05, 6.68]$ whereas the 75th percentile was characterized by $\boldsymbol{\sigma}_{ALP} \in [0.11,\ 0.26]$ as shown in Appendices A3.3 and A3.4, respectively. This suggests that a firm in the 25th percentile ALP distribution was more sensitive to productivity shocks than either an average or a third-quartile firm. As a result of these industrial productivity swings, the bottom and 75th percentile firms experienced an ALP decline of 8 and 5 percent, respectively.

The emerging ALP trends and heterogeneity suggest the need for a deeper understanding of microeconomic causes and foundations for productivity growth, or in Swaziland's case stagnation and decline. It is therefore necessary to disentangle the roles of real productivity, intensive margins of share-shift effects, and extensive margins of turnover in productivity growth across industries. We achieve this in the next section by formally presenting a framework that outlines the relationship between resource shares and the productivity index in calculating each component of the ALP decomposition.

4. Measurement and Decomposition of Aggregate Labour Productivity

4.1. Definition and Measurement of ALP Growth

The quantity of labour (L_{it}) as a primary input in production at firm i is measured by the head-count of paid workers and working proprietors.[10] Nominal value-added output is measured as gross output *minus* intermediate inputs; that is, material and energy. Following Nishida *et al*. (2014) and Petrin *et al.* (2011), the quantity index of real value added (VA) is then constructed by using the double-deflation approach to nominal value added proposed by Bruno (1978) as

$$VA_{it} = \frac{P_{it}Q_{it}}{P_t^Q} - \frac{P_{iMt}M_{it}}{P_t^M} - \frac{P_{iEt}E_{it}}{P_t^E} \qquad \text{Double Deflation} \qquad (1)$$

$$\cong \frac{P_{it}Q_{it} - P_{iMt}M_{it} - P_{iEt}E_{it}}{P_t} \qquad \text{Single Deflation}$$

where Q_{it}, M_{it} and E_{it} are nominal gross output and inputs of material and energy with their respective price indices. The double-deflation expression in the first line of Eq.1 represents the relevant price index for gross output and intermediate input quantities, see Petrin *et al*. (2014, Appendix 3) for Chile. The second line of Eq.1 presents the expression of a single-deflation method approximated with a common industry price deflator for both the output quantity and intermediate inputs, see Petrin *et al*. (2014, Appendix 3) for Colombia and Slovenia. The single-deflation approach is useful whenever intermediate deflators are not available.

Armed with information on VA_{it} and L_{it}, it is straightforward to calculate the ALP growth index. Thus, plant *i*'s labour productivity at time *t* is represented by $\boldsymbol{\varphi}_{it}=\frac{VA_{it}}{L_{it}}$ and aggregate labour productivity $(\boldsymbol{\varphi}_t)$ at time *t* can then be expressed as $\boldsymbol{\varphi}_t=\frac{\sum_i VA_{it}}{\sum_i L_{it}} = \frac{VA_t}{L_t}$ while the employment share of plant *i* at time *t* is $s_{it} = \frac{L_{it}}{L_t}$. Movements in $\boldsymbol{\varphi}_t$ may reflect changes in embodied and disembodied technology as well as changes in technical efficiency.[11] These changes may also reflect shifts in scale economies and degrees of capacity utilization. For the decomposition of aggregate labour productivity

[10] The best measure of labour input according to OECD (2001) is hours worked. Although the legal length of a work-day is 8 hours and public holidays are known for the Swazi manufacturing sector, there is no information on worker absenteeism, variation in overtime, evolution of part-time work, sick leave and employee slack time due to ill-health. Furthermore, in the absence of the total number of hours worked that can be divided by the average annual number of hours actually worked in full-time jobs, the use of full-time equivalent employment is not feasible for the labour input definition contained in Doraszelski and Jaumandreu (2013, Appendix A) and OECD (2001).

[11] Embodied technology refers to advances in the design and quality of new vintages of capital goods and intermediate inputs, and disembodied technology refers to new blueprints, scientific results and new organizational techniques, see OECD (2001).

growth, $\Delta\boldsymbol{\varphi}_t$, the literature relies largely on the tradition of Baily *et al.* (1992)/Foster *et al.* (2001) in defining the effects of its sources. Specifically,

$$\Delta\boldsymbol{\varphi}_t = \text{Within Effects} + \text{Between Effects} + \text{Cross Effects} + \text{Net Entry Effects}$$

$$= \Delta\boldsymbol{\varphi}_{WEt} + \Delta\boldsymbol{\varphi}_{BEt} + \Delta\boldsymbol{\varphi}_{Cross} + \Delta\boldsymbol{\varphi}_{Net-Entry}. \qquad (2)$$

Eq. 2 means that aggregate labour productivity growth, $\Delta\boldsymbol{\varphi}_t$, increases when firms use innovative production methods to produce more output through the 'Within-Firm' effects term $\Delta\boldsymbol{\varphi}_{WEt}$, holding factor inputs constant. The $\Delta\boldsymbol{\varphi}_t$ index can also increase when inefficient incumbent firms reallocate resources to more efficient ones through the term $\Delta\boldsymbol{\varphi}_{BEt}$. Haltiwanger (1997) adds a component that allows for the interaction between the change in resources and the change in ALP growth, and calls it the 'cross' or the 'covariance' term. The cross term increases when the changes in both components move in the same direction; that is, when the market share and ALP growth jointly increase and vice versa. Lastly, if new business methods including capital deepening that lead to improvements in industry productivity can only be adopted by new plants, then the net-entry term, $\Delta\boldsymbol{\varphi}_{Net-Entry}$, should dominate.

Motivated by PPS and BHS, Nishida *et al*. (2014) perform a theoretical and empirical analysis of ALP growth and APG using traditional methods and Petrin and Levinsohn (2012), respectively. We replicate Nishida *et al*. (2014) for the case of the manufacturing sector in Swaziland by decomposing ALP on the basis of Baily *et al*. (1992)/Foster *et al*. (2001) and APG using the marginal product of factor inputs.

4.2. The ALP Growth Decomposition Using the Baily *et al.* (1992) Method

The traditional method of $\Delta\boldsymbol{\varphi}_t$ decomposition is associated with the Baily *et al.* (1992) approach and its derivatives such as Griliches and Regev (1995), Foster *et al.* (2001) and Olley and Pakes (1996). In this context, $\Delta\boldsymbol{\varphi}_t$ is traditionally defined as input-share weighted changes in the distribution of plant-level technical efficiency, covariance and resource reallocation by incumbents and net entrants into the market. The Baily *et al.* (1992) decomposition additively isolates $\Delta\boldsymbol{\varphi}_t$ gains arising only from technical efficiency and resource reallocation. The Baily *et al.* (1992) (or BHC_{ALP}) procedure decomposes $\Delta\boldsymbol{\varphi}_t$ as

$$BHC_{ALP} = \left(\overbrace{\textstyle\sum_{i\in C_t} s_{it-1}\Delta\boldsymbol{\varphi}_{it}}^{Within}\right) + \left(\overbrace{\textstyle\sum_{i\in C_t} \Delta s_{it} * \boldsymbol{\varphi}_{it-1}}^{Between}\right) + \left(\overbrace{\textstyle\sum_{i\in C_t} \Delta s_{it} * \Delta\boldsymbol{\varphi}_{it}}^{Covariance}\right) +$$

$$\left(\overbrace{\textstyle\sum_{i\in EN_t} s_{it} * \boldsymbol{\varphi}_{it} - \sum_{i\in EX_t} s_{it-1} * \boldsymbol{\varphi}_{it-1}}^{Net\ Entry}\right) \qquad (3)$$

where $\Delta\boldsymbol{\varphi}_{it} = \boldsymbol{\varphi}_{it} - \boldsymbol{\varphi}_{it-1}$ and $\Delta s_{it} = s_{it} - s_{it-1}$, and EN_t and EX_t represent firm entry and exit at time *t*, respectively. The different sources of $\Delta\boldsymbol{\varphi}_t$ are defined as

Within-plant effects: $\sum_{i\in C_t} s_{it-1}\Delta\boldsymbol{\varphi}_{it}$ is the sum of changes in plant-level labour productivity weighted by $t-1$ base-period labour share for continuing plants. It measures a plant's gains in productivity induced by continuous improvement in production methods without an increase in its labour share. This growth component is referred to as real-productivity effects in Levinsohn and Petrin (1999).

Between-plant effects: $\sum_{i\in C_t} \Delta s_{it} * \boldsymbol{\varphi}_{it-1}$ in Baily *et al.* (1992) is the sum of changes in plant-level employment shares multiplied by the $t-1$ labour productivity for continuing plants. This growth effect measures the extent of labour share reshuffling across plants where the labour input is reallocated to more efficient plants. This term is also viewed as 'clean' because it holds real productivity constant; see Nishida *et al*. (2014).

Covariance effects: $\sum_{i\in C_t} \Delta s_{it} * \Delta\boldsymbol{\varphi}_{it}$ is the sum of plant-level contemporaneous changes in the labour share and labour productivity. As Nishida *et al*. (2014) point out, this term increases when plants with increasing labour productivity are also plants with increasing labour shares.

Net-entry effects: An entering plant is identified when it first appears at time *t*, and an exiting plant is identified when it last appeared at time $t-1$. Thus, for $\sum_{i\in EN_t} s_{it} * \boldsymbol{\varphi}_{it} - \sum_{i\in EX_t} s_{it-1} * \boldsymbol{\varphi}_{it-1}$, where $\boldsymbol{\varphi}_{it}$ enters the equation as raw data for firm i at time t, positive contributions to ALP growth arise from the entry of high productivity firms and exit of inefficient ones. Net-entry effects therefore refer to the difference between productivity growth contributions by entering and exiting plants.

In the BHC_{ALP} formulation of resource movement between plants in Eq. 2, as Forster *et al*. (2001) and Nishida *et al*. (2014) point out, even if all plants have the same level of productivity for both the beginning and end period, the between component and net-entry component will in general be nonzero. Moreover, previous studies such as Syverson (2004) have estimated high dispersion in measured productivity, which translates to large and volatile (Baily *et al*, 1992) 'Between' effects. The standard remedy for this is to 'normalize' each industry's 'Between' and 'Within' terms by the industry's ALP and use the industry's revenue shares as weights to aggregate across industries, see Petrin and Levinsohn (2012). As in Petrin and Levinsohn (2012) and Nishida *et al*. (2014), no normalization is carried out here in order to avoid losing the potential link between the actual ALP and BHC_{ALP}, although the nature of such a link prior to normalization is unknown[12].

[12] King and Nielson (2016) argue in the context of propensity score matching that standardization of variables makes the analysis invariant to the substance.

4.3. The ALP Growth Decomposition Using the Foster *et al.* (2001) Method

The decomposition of ALP using Foster *et al.* (2001) (or FHK_{ALP}) is given as

$$FHK_{ALP} = \left(\overbrace{\sum_{i \in C_t} s_{it-1} \Delta \boldsymbol{\varphi}_{it}}^{Within}\right) + \left(\overbrace{\sum_{i \in C_t} \Delta s_{it} * (\boldsymbol{\varphi}_{it-1} - \boldsymbol{\varphi}_{t-1})}^{Between}\right) + \left(\overbrace{\sum_{i \in C_t} \Delta s_{it} * \Delta \boldsymbol{\varphi}_{it}}^{Covariance}\right) +$$

$$\left(\overbrace{\sum_{i \in EN_t} s_{it} * (\boldsymbol{\varphi}_{it} - \boldsymbol{\varphi}_{t-1}) - \sum_{i \in EX_t} s_{it} * (\boldsymbol{\varphi}_{it-1} - \boldsymbol{\varphi}_{t-1})}^{Net\ Entry}\right), \quad (4)$$

where the 'Within' and 'Covariance' terms are identical to those calculated using the Baily *et al*. (1992) method. The rest of the other ALP growth components calculated using Foster *et al*. (2001) are described as

Between-plant effects: $\sum_{i \in C_t} \Delta s_{it} * (\boldsymbol{\varphi}_{it-1} - \boldsymbol{\varphi}_{t-1})$ is the sum of the changing labour shares weighted by the deviation of initial plant-level productivity from initial industry productivity index. An increase in a continuing plant's labour share makes a positive contribution to the 'Between' component only if its initial productivity exceeds the average initial industry productivity.

Net-entry effects: The 'Entry' term, $\{s_{it}(\boldsymbol{\varphi}_{it} - \boldsymbol{\varphi}_{t-1})\}$, reflects the deviation of current firm-level productivity from average initial industry productivity index weighted by current labour shares. First, a new firm contributes positively to growth if its productivity level exceeds the average initial industry productivity index; i.e., $\boldsymbol{\varphi}_{it} > \boldsymbol{\varphi}_{t-1}$. Second, the 'Exit' component is calculated similarly to the 'Between' term, except that it is weighted by the un-differenced labour shares. Thus, a shutting down plant contributes positively to ALP growth only if it has lower productivity than the average initial industry productivity index; i.e., $(\boldsymbol{\varphi}_{it-1} < \boldsymbol{\varphi}_{t-1})$.

4.4. The Relationship Between the Baily *et al*. (1992) and Forster *et al*. (2001) Methods

The last two sections have outlined and discussed methods of decomposing the ALP index based on Baily *et al*. (1992) and Forster *et al*. (2001) but do not address their differences in calculating and interpreting the 'Between' and 'Net-Entry' components. In the examination of these methods, the scrutiny of the first and third terms in Eqs.3-4 is not undertaken because these terms are not model dependent. That is, these components are identical regardless of the model used to compute productivity gains. Therefore this sub-section considers the relationship between these methods and offers an explanation of the meaning of results thus generated.

The discussion of how the Baily *et al*. (1992) and Forster *et al*. (2001) approaches are related is best expressed mathematically as

$$FHK_{Bet} - BHC_{Bet} = BHC_{Net-Entry} - FHK_{Net-Entry}$$

The left-hand side of the expression relates the FHK_{Bet} to the BHC_{Bet} quantity for continuing plants. The latter is just a change in labour shares, weighted by an initial firm-level productivity that is always positive. This is a between-firm index measuring the productivity-weighted share shifting effects of a change in labour. The between-effects of the Baily *et al*. (1992) method can in principle either be positive due to labour growth, zero due to firm size stagnation or negative due to a producer scaling down operations. However, as noted by Haltiwanger (1997), the absence of a relationship between the initial firm-level productivity and initial industry average productivity does not guarantee a zero outcome in the between-firm effects index, even if all plants have the same productivity levels across the $t-1$ and t periods. In the case of the first term on the left-hand side, the weighting is based on deviations between the initial firm-level and average initial industry-level productivities. Unlike the Baily *et al*. (1992), the Forster *et al*. (2001) method therefore allows the weighting index to be positive if the initial firm-level productivity is lower than the industry average, zero if the initial firm-level and initial industry average are equal or negative if the initial firm-level productivity is lower than the industry average product.

Since the labour change across methods can take any sign while the productivity weight in BHC_{Bet} is always positive, FHK_{Bet} and BHC_{Bet} can have opposite signs and differing orders of magnitude for at least two reasons. First, assume a firm is hit by a negative exogenous shock and is forced to scale down operations by reducing its industry share of employment; i.e., $\frac{L_{it-1}}{L_t} \rightarrow \frac{L_{it}}{L_t}$, holding L_t constant in both periods. Since $L_{it-1} > L_{it}$, then the change in the firm's labour share at time t is $\Delta s_{it} = \frac{L_{it}}{L_t} - \frac{L_{it-1}}{L_t} < 0$. Given that the ratio of real value-added to labour, $\boldsymbol{\varphi}_{it-1}$, is always positive, then firm i's $BHC_{Bet} = \Delta s_{it} * \boldsymbol{\varphi}_{it-1}$ is negative, suggesting a movement of labour from the downsizing firm to other producers. If the same firm operated at lower efficiency levels than the initial average industry productivity index; that is, $\boldsymbol{\varphi}_{it-1} < \boldsymbol{\varphi}_{t-1}$, then the firm's $FHK_{Bet} = \Delta s_{it}(\boldsymbol{\varphi}_{it-1} - \boldsymbol{\varphi}_{t-1})$ is positive. Only if $\boldsymbol{\varphi}_{it-1} > \boldsymbol{\varphi}_{t-1}$ does FHK_{Bet} become negative for this type of firm. Both measures of 'Between' effects jointly suggest that labour resources in inefficient downsizing firms reallocate to initially more productive firms relative to the initial industry average productivity.

Second, firm i may experience a large positive demand shock and raise its employment at time t by drawing workers (i.e., $\Delta s_{it} > 0$) from firm i' to increase its production. Although the Baily *et al*. (1992) 'Between' effects will be positive, the Forster *et al*. (2001) 'Between' effects will either be positive, zero or negative, depending on whether $\boldsymbol{\varphi}_{it-1} > \boldsymbol{\varphi}_{t-1}$, $\boldsymbol{\varphi}_{it-1} = \boldsymbol{\varphi}_{t-1}$ or $\boldsymbol{\varphi}_{it-1} < \boldsymbol{\varphi}_{t-1}$ which indicates the direction of resource flows. That is, if $\boldsymbol{\varphi}_{it-1} > \boldsymbol{\varphi}_{t-1}$, for example, labour is moving an initially high efficient firm to an initially inefficient industry average of firms. Otherwise, if $\boldsymbol{\varphi}_{it-1} < \boldsymbol{\varphi}_{t-1}$, labour resources reallocate to initially more productive firms.

On the right-hand side, the expression relates net-entry effects computed from $BHC_{Net-Entry}$ and from $FHK_{Net-Entry}$ indices. In the Bailey *et al*. (1992) approach, the net effect of entrants and exiting producers reflects any differences in the levels of productivity between firm birth and death, and any differences in labour shares. In particular, and holding labour shares of the entrant and exiting plants constant, the net-entry productivity index is negative if the existing firm is more productive than the new born. Again, the index can also be negative if the quitting firm has a larger share of labour in the industry than does the entrant, holding firm-level productivity constant. This productivity measure is positive if the existing firm is less productive than the new born, holding labour shares of the entrant and exiting plants constant. It can also be positive if the quitting firm has a lower share of labour in the industry than does the entrant, holding firm-level productivity constant. In the case of the Forster *et al*. (2001), net-entry effects of productivity are driven by weighted deviations of the firm-level productivity from the initial industry average productivity instead of just the firm-level ratio of real value-added to labour. Thus, net-entry is positive if the productivity contribution from entry is greater than the productivity contribution from exit. This can happen only if the entrant is more productive than the initial industry average productivity *and* the exiting plant is less productive than the initial industry average productivity. Otherwise, net-entry is either negative or zero.

4.5. A Quantitative ALP Decomposition for the Swazi Manufacturing Sector

The previous sections have outlined and discussed the two traditional methods of aggregate labour productivity decomposition, highlighting the impact of specific firm-level patterns of resource shares and productivity either in isolation or relative to the industry average. That enquiry does not clarify with precision how the identified micro-factors interact to dominate in a broadly defined industry. This section is concerned with a detailed analysis of the Swazi manufacturing sector to gain insight into the annual patterns of productivity variation represented by cross-plant movement of resources, technical change as well as net-entry dynamics. It achieves this by using an unbalanced dataset of heterogeneous producers across 13 two-digit ISIC industries in the period 1994−2003. The estimation of ALP and its component parts is based on the Baily *et al.* (1992)/Foster *et al.* (2001) decomposition in Eq. 3 and 4 and reported in Table 3.3.

Table 3.3: ALP growth rate in Swazi manufacturing 1994–2003: Baily *et al.* (1992)/Foster *et al.* (2001) Decomposition Using Eq. 3 and Eq. 4 for Columns 3−7.

year	Value-Added Growth	Labour productivity growth (0)	Baily *et al.* (1992) and Foster *et al.* (2001) ALP decomposition: (0) = (1) + (2) + (3) + (4)					
			Within (1)	Between (2)		Cross (3)	Net Entry (4)	
				BHC-RE	FHK-RE		BHC	FHK
1995	7.76	-26.03	-12.34	-27.06	0.67	3.60	9.51	-17.83
1996	23.10	-1.33	-7.93	-6.92	0.08	0.23	13.37	6.28
1997	-44.35	-2.79	2.93	32.90	-8.51	4.09	-42.71	-1.31
1998	265.55	119.30	1.32	-36.46	0.40	-0.90	155.33	118.47
1999	275.57	102.21	9.89	-35.03	5.11	-3.86	134.79	91.46
2000	-16.28	-17.27	-17.10	-1.39	-3.20	0.11	0.05	3.67
2001	37.42	-1.02	31.79	-28.89	-0.42	-8.90	4.97	-23.50
2002	-20.74	-39.18	-25.93	-21.55	-3.62	5.60	2.71	-15.22
2003	-36.71	-3.33	-26.55	73.21	41.25	-29.12	-20.88	11.09
Mean	**54.59**	**14.51**	**-4.88**	**-5.69**	**3.53**	**-3.24**	**28.57**	**19.23**
Median	**7.76**	**-2.79**	**-7.93**	**-21.55**	**0.08**	**0.11**	**4.97**	**3.67**
Std Dev	**125.32**	**56.26**	**18.67**	**36.72**	**14.63**	**10.66**	**68.48**	**50.43**

Notes: The "Labour productivity growth" column depicts the ALP growth with entry and exit, and the "Value-added growth' column represents the aggregate real value added growth rate. The plant-level real value added is summed and annualized across plants. As in Nishida *et al*. (2014), numbers are percentage growth rates. We define labour productivity as the amount of real value added relative to unit labour. $\Delta\boldsymbol{\varphi}_t$ is decomposed into four components: (1) within, (2) between, (3) cross, and (4) net-entry term, using Eq. 1 in text for Baily *et al.* (1992) and Eq. 2 in text for Foster *et al*. (2001). We use employment share for the share weights, and both "within" and "between" terms use the base-period share for the weights.

Source: Author's own calculations.

The second and third columns report annualized growth rates in real value-added and ALP, respectively. The annual average (median) growth rate in real value-added is 54.59 percent (7.76 percent) with the measured standard deviation of 125.32 percent. Although real value-added growth is largely positive, particularly in 1998 and 1999, the incidence of negative growth is non-negligible. ALP, on the other hand, had an annual average (median) growth rate of 14.51 percent (−2.79 percent). Again, the years 1998 and 1999 stand out as outliers.[13] In seven out of nine years, we observe negative ALP values in column three.

In columns four through nine, we present the Baily *et al.* (1992) and Foster *et al.* (2001) decompositions. The annual average 'within-effect' in column four is −4.88 percent compared to the Baily *et al.* (1992) between-plants term of −5.69 percent and Foster *et al.* (2001) between-plants term

[13] We made an attempt to remove any potential outliers as in Nishida et al. (2014) by applying the Stata "**Winsor**" command to the plant-level labour productivity at *p*(0.01), which specifies the proportion of observations to be modified in each tail. This creates too many missing values and therefore we abandoned the procedure. Another approach involves identifying outliers and removing them sequentially, beginning with the largest. When the very first outlier where $\boldsymbol{\varphi}_{it} = 1.6$ is removed, decompositions for both 1998 and 1999 disappear. Again, this procedure is abandoned. However, it is considered not fatal to use the data 'as is' given the large similarities between our results and the results found in the literature, and the fact that the Swazi manufacturing sector is highly concentrated and these are real and important firms.

of 3.53 percent. Clearly, real productivity dominates the Baily *et al.* (1992) share-shift component of aggregate productivity, yet it is subordinate to the Foster *et al.* (2001) between-plants term. However, if the potentially profound confounding effects of entry−exit dynamics in the measured "Between" term calculated using the Baily *et al.* (1992) approach is accounted for, then net-entry and the "Between" effects dominate the measured "Within" effects. Both Baily *et al.* (1992) and Foster *et al.* (2001) decompositions make significant net-entry contributions to ALP growth by contributing 28.57 percent and 19.23 percent, respectively. The entry of more productive firms than the average initial industry productivity and the exit of lower productivity firms than the average initial industry productivity are the main drivers of ALP.

Looking at firm-level production efficiency in isolation, we find evidence of progressive weakening of technical change in manufacturing potentially induced by increasing competition in the Customs Union, save for the 31.79 percent productivity increase in 2001 which was consistent with the start of AGOA. Judging from the size of the standard deviation, there was marked heterogeneity in plant-level technical efficiency around a declining average productivity trend.

In a closer examination of incumbents, entrants and exiting firms, we find evidence of significant heterogeneity as in Liu and Tybout (1996) represented by the standard deviations of 68.48 percent and 50.43 percent in the Baily *et al*. (1992 and the Foster *et al*. (2001) approaches, respectively. We also find that, on average, exiting plants are 28.97 percent and 19.23 percent lower than incumbents in terms of productivity contribution to ALP when using the respective methods. Hence, their disappearance improves sectoral productivity. However, the occasional exit of relatively more efficient firms has the consequence of inducing a negative turnover effect on aggregate labour productivity. In this context, Liu and Tybout (1996) note that while productivity of exiting firms may drop, surviving entrants may raise their productivity such that the snowballing effects of this cleansing process are probably substantial over a longer time horizon. According to Caballero and Hammour (1994), it is this continuous process of creation and destruction of business units resulting from product and process innovation that is essential for understanding growth.

A further isolation of incumbents shows that productivity heterogeneity remains important, regardless of the approach used. Using the Forster *et al*. (2001) approach, we find the portion of change in sectoral productivity that is due to the labour market share reallocation accounts for 3.53 percent, on average. As in Nishida *et al*. (2014), it is instructive to determine the impact of an expanding or shrinking economy on the Baily *et al.* (1992) share-shift component. The direction of change in the number of firms can work to reduce or increase this component of productivity, as shown in the next section.

4.6. Confounding Effects of Firm Turnover on the Baily *et al*. (1992) Reallocation

The Baily *et al.* (1992) reallocation component can be further decomposed into two more constituent parts: one related to reallocation and another related to the number of plants as in Nishida *et al*. (2014). Suppose there are N_t plants in manufacturing at time *t* and the plant-level average share of employment is $s_t = \frac{\sum_i s_{it}}{N_t} = \frac{1}{N_t}$. Then, the relative labour share in the i[th] plant is defined as $\tilde{s}_{it} = s_{it} - s_t$, and the change in the relative labour share from time *t-1* to *t* is $\Delta\tilde{s}_{it} = \tilde{s}_{it} - \tilde{s}_t$. Hence, the "Between" term for incumbent firms can be decomposed as follows:

$$BHC_{RE} = \left(\sum_{i \in C_t} \Delta s_{it} * \boldsymbol{\varphi}_{it-1}\right)$$

$$= \left(\sum_{i \in C_t} \{(s_{it} - s_t) - (s_{it-1} - s_{t-1})\} * \boldsymbol{\varphi}_{it-1}\right) + \left(\sum_{i \in C_t} (s_t - s_{t-1}) \sum_{i \in C_t} \boldsymbol{\varphi}_{it-1}\right)$$

$$= \left(\overbrace{\textstyle\sum_{i \in C_t} \Delta\widetilde{s_{it}} * \boldsymbol{\varphi}_{it-1}}^{First\ Component}\right) + \left(\overbrace{\left(\frac{1}{N_t} - \frac{1}{N_{t-1}}\right)\textstyle\sum_{i \in C_t} \boldsymbol{\varphi}_{it-1}}^{Second\ Component}\right) \tag{5}$$

where C_t refers to continuing plants at time *t*. The first component represents labour reallocation and the second component is related to patterns of creative destruction. An increase in the number of firms over time confounds the first component by $\left(\frac{1}{N_t} - \frac{1}{N_{t-1}}\right)$ in the negative direction, since $\boldsymbol{\varphi}_{it-1}$ can never be negative. The reverse effect obtains in case of a persistent fall in the number of firms. The second component also gets smaller and smaller as the number of firms gets smaller and smaller, which happens if firm exit rate is persistently higher than the entry rate. If there is no change in the number of firms in the adjacent periods, the second component falls away. That is, the entry-exit dynamics have a spurious influence on the Baily *et al*. (1992) labour reallocation effect. Table 3.4 presents a quantitative decomposition of BHC_{RE} for the Swazi manufacturing sector.

Table 3.4: The ALP Growth Rate for the Swazi Manufacturing Sector (1994–2003): Baily *et al*. (1992) Between Term Decomposition.

Year	BHC (0): Between	Baily *et al*. (1992) between term decomposition: (0) = (1) + (2)		Percentage Growth of firms
		(1) First component	(2) Second component	
1995	-27.06	-16.93	-10.13	11.11
1996	-6.92	4.71	-11.63	13.75
1997	32.90	30.89	2.00	-2.20
1998	-36.46	-13.21	-23.25	25.84
1999	-35.03	-24.83	-10.20	23.21
2000	-1.39	4.08	-5.47	7.97
2001	-28.89	-21.39	-7.50	10.07
2002	-21.55	-14.49	-7.06	8.54
2003	73.21	54.59	18.62	-15.17
Mean	**-5.69**	**0.38**	**-6.07**	**9.24**
Median	**-21.55**	**-13.21**	**-7.50**	**10.07**
Std Dev	**36.72**	**26.73**	**11.39**	**12.37**

Notes Percentage growth rates. The Baily *et al*. (1992) 'between' term is decomposed into two terms using Eq. 5 in the text.

Source: Author's own calculations.

The second column is identical to the BHC_{RE} column in Table 3.3 in the previous section. The third and fourth columns are the respective first and second components of Eq. 5, and the last column is the percentage growth of firms per year. In seven out of nine years, the manufacturing sector experienced growth in the number of firms, and in these years the confounding effect of plant expansion was negative on the 'Between' term. The comparison of the first term to the overall average of the Baily *et al*. (1992) 'Between' term shows that on average it is 6.07 percent higher over the sample period due to the downward confounding effects of plant turnover on the labour reallocation component. These results mimic the findings by Nishida *et al*. (2014) for Chile and Slovenia, and they cast doubt on the validity of the share-shifting effects of the Baily *et al.* (1992) approach. This confirms the conclusion by Nishida *et al*. (2014) that the Baily *et al*. (1992) reallocation can be negatively correlated, positively correlated or simply uncorrelated with the actual reallocation of inputs. A crucial argument in that paper, also corroborated by our results, is that the Baily *et al.* (1992) indices can erroneously equate reallocation growth to productivity growth, yet output per labour ratio is neither a perfect proxy for marginal products nor plant-level productivity.

This dilemma opens a door to the application of one of the promising approaches to estimating the decomposition of APG based on parametric aggregation of plant-level productivity. In his study of the robustness of productivity estimates, Van Biesebroeck (2007) demonstrates with Monte Carlo techniques the circumstances in which each of the methodologies works well. Among the six approaches analysed, two parametric methods appear suited to investigating productivity growth; namely, the systems generalized method of moments' estimator (SYS-GMM) and the semiparametric Olley and Pakes (1996)/Levinsohn and Petrin (2003)-type models.

The next sections draw heavily on the theoretical foundations of Petrin and Levinsohn (2012) as applied in Nishida *et al*. (2014) for measuring APG using plant-level data. Our purpose is to estimate and contrast the APG sources with those found when using traditional methods. It begins by determining a suitable proxy for the unobserved firm-level productivity. The actual semiparametric model estimation follows immediately.

4.7. Country Comparison of Evidence on Drivers of ALP Growth

In this section, the empirical decomposition of $\Delta\boldsymbol{\varphi}_t$ into its component sources of growth is reviewed for other countries for comparative examination. Two meta-analyses by BHS and by PPS together analyse 25 countries across Europe, the Americas and East Asia. Isaksson (2010) also surveys sources of $\Delta\boldsymbol{\varphi}_t$ in 33 advanced and developing countries as well as economies in transition, which include many of the countries covered in the BHS/PPS meta-analyses. A number of these countries have undergone economic reforms to facilitate freer movement of inputs across firms in order to trigger productivity growth from resource reallocation. A consistent finding is that there has been significant ALP growth, measured as growth in $\boldsymbol{\varphi}_t=\frac{\sum_i VA_{it}}{\sum_i L_{it}}$, for these economies.

In order to examine the sources of ALP growth, the BHS/PPS meta-studies decompose this index into real productivity and reallocation terms using the Baily *et al*. (1992) and Foster *et al*. (2001) methods. The survey by Isaksson (2010) adds Haltiwanger (1997) in its arsenal of techniques of productivity decomposition.[14] A key finding is that most of the growth in aggregate labour productivity comes from longitudinal firm-level efficiency gains; that is, 'Within' dominate 'Between' effects. Specifically, nine of the 25 countries experienced *negative* growth from resource reallocation and only four had a weak 'Between' term. Furthermore, 23 of the 25 countries had a negative covariance term.

Table 3.5 presents empirical decompositions of $\Delta\boldsymbol{\varphi}_t$ for the manufacturing sector covering a sample of 13 countries from the survey by Isaksson (2010), *plus* Swaziland, based on either the Foster *et al.* (2001) or Haltiwanger (1997) methods. This allows us to compare the results from Swaziland with evidence from market economies, economies in transition and Sub-Saharan Africa (SSA). Following the example of Van Biesebroeck (2005) for the Sub-Saharan results, we estimate a value-added production function which enables comparison of our results with those of other Sub-Saharan economies. Unlike Van Biesebroeck (2005), however, we also calculate productivity contributions

[14] The difference between Baily *et al*. (1992) and Haltiwanger (1997) is that the latter introduces the covariance term.

coming from entry and exit of firms, which now enables comparison with results from advanced nations and economies in transition.[15]

Table 3.5: ALP Growth, $\Delta\varphi_t$, Decomposition for the Manufacturing Sector in Industrialized Countries, Economies in Transition and in Developing Countries (Percentage) using Eq. 4.

Method	Country	Period	Output/Share/ Productivity	Within	Between	Cross	Entry	Exit	Total
FHK (2001)	USA	1992 & 1997	GO/Labour/LP	109.00	-3.00	-24.00	-29.00	49.00	102.00
FHK (2001)	UK	2000-2001	GO/Labour/LP	48.00	19.00	-17.00	35.00	12.00	97.00
FHK (2001)	Germany	1993-2003	GO/Labour/LP	118.60	11.50	-30.10	–	–	100.00
FHK (2001)	Russia	1992-2004	GO/Labour/LP	-590.40	359.60	61.61	-223.70	292.93	-99.96
FHK (2001)	Slovenia	1997-2001	GO/Labour/LP	68.00	18.00	-2.00	15.00	13.00	112.00
FHK (2001)	Chile	1985-1999	GO/Labour/LP	95.00	25.00	-50.00	-35.00	65.00	100.00
FHK (2001)	Colombia	1987-1998	GO/Labour/LP	105.00	20.00	-45.00	-20.00	40.00	100.00
FHK (2001)	**Swaziland**	**1994-2003**	**VA/Labour/LP**	**-33.63**	**24.33**	**-22.33**	**116.20**	**16.33**	**100.90**
Halti (1997)	Cameron	1990-1995	VA/Labour/LP	144.94	-25.84	-13.48	–	–	105.62
Halti (1997)	Ghana	1990-1995	VA/Labour/LP	78.97	66.15	-43.59	–	–	101.53
Halti (1997)	Kenya	1990-1995	VA/Labour/LP	445.45	282.80	-629.09	–	–	99.16
Halti (1997)	Tanzania	1990-1995	VA/Labour/LP	122.00	13.00	-36.00	–	–	99.00
Halti (1997)	Zambia	1990-1995	VA/Labour/LP	357.14	28.57	-278.57	–	–	107.14
Halti (1997)	Zimbabwe	1990-1995	VA/Labour/LP	163.33	33.33	-96.67	–	–	99.99

Notes: Methods are described in the text. LP = Labour Productivity, GO = Gross Output, VA= Value Added, and Halti (1997) = Haltiwanger (1997). Information sources include Isaksson (2010), "Structural Change and Productivity Growth: A Review with Implications for Developing Countries", *United Nations Industrial Development Organization,* Tables 1-3; Van Biesebroeck (2005), "Firm Size Matters: Growth and Productivity Growth in African Manufacturing", *Economic Development and Cultural Change,* Vol. 53(3), pp. 543-83; and the author's calculation of ALP growth components for Swaziland.

The average industry productivity for non-SSA countries, excluding Russia, is 101.83 percent and for SSA excluding Swaziland is 102.07 percent. This compares with 100.90 percent for Swazi manufacturing. The 'Within' effects generate more growth than 'Between' effects across all countries except Swaziland. In 12 of 14 countries, results show dominance of real productivity over both resource reallocation among incumbents and turnover effects. Sub-Saharan 'Within' effects also dominate share-shift effects in the rest of the other economies surveyed in the table. This suggests that the Sub-Saharan manufacturing sectors generate incredibly more productivity growth from innovation and technological progress than do the more technologically advanced economies. The highest beneficiary from technological advancement is, for example, Kenya with 445 percent 'Within' effects followed by Zambia with 357 percent. On the other hand, looking at the 'Between' term alone shows that only the U.S. and Cameroon had negative growth. Contrary to normally functioning market economies, this suggests that the U.S. manufacturing sector reallocated resources from high- to low-productivity plants between 1992 and 1997; and Cameroon did the same in the period 1990 to 1995.

Finally, while all countries reporting on turnover have positive growth from firm exit, only Swaziland, Slovenia and the UK report positive entry contributions to growth. The 16.33 percent for Swaziland

[15] Van Biesebroeck (2005) uses data from the RPED surveys of the World Bank spanning a maximum of five years for each country.

means that the country experienced the exit of lower productivity firms than the average initial industry productivity index. At the same time, Swaziland also experienced firm entry with higher average productivity of 116.2 percent than the average initial industry productivity. It can be shown that an un-normalized entry−exit rationalization effect of firms has a pronounced impact of 19.23 percent on ALP growth in Swaziland.

Moreover, the stylized fact from BHS/PPS and Isaksson (2010) is that real productivity dominates both the share-shift effects and turnover terms in studies that use Baily *et al.* (1992) or its derivatives such as Foster *et al.* (2001) and Haltiwanger (1997).[16] Contrary to conventional wisdom, however, the Swazi results show superiority of resource reallocation among incumbents and firm entry-exit dynamics over real productivity. This suggests that the Swazi manufacturing sector is unique in delivering dominance of reallocation and rationalization effects over innovation and technological advancement during a period of trade reforms.

4.8. The Petrin-Levinsohn (2012) Approach to Aggregate Productivity Growth Decomposition

4.8.1. Production Function Specification

The estimation of production functions in economics has been a fundamental activity in applied economics since the 1800s, and the early econometric problems inhibiting efficient estimation of the coefficients of capital and labour are still a concern even today. Perhaps the most recurring econometric issue is the likelihood of the presence of output determinants that are unobserved to the analyst but observed by the producer. If that is the case, and if capital and labour are chosen as a function of these output determinants, then there exists an endogeneity problem. In such situations, the OLS procedure generates biased parameters for the observed production inputs; see Ackerberg *et al*. (2015).

The semiparametric method of estimating production functions initiated by Olley and Pakes (1996) addresses problems of endogeneity in inputs and the unobserved productivity shocks. Instead of using

[16] What also stands out as a stylized fact from this analysis is that the sources of growth for ALP differ by country, period in a country and methodology applied to the sector in question. For example, in their analysis of the manufacturing sector in 1995−2000 as opposed to 1997−2001 above, De Loecker and Konings (2006) use the Foster *et al.* (2001) decomposition of ALP and find 'within' firm productivity growth of 123.4 percent and reallocation growth of -11.7 percent compared to 68 percent and 18 percent above, respectively. Simply by discarding the first two years and the last year of study, significantly different results are produced; see note 5 in Nishida et al. (2014) for the case of Chile, Colombia and Slovenia.

lumpy investment as a proxy for productivity like Olley and Pakes (1996), the Levinsohn and Petrin (2003) approach uses the intermediate input to estimate the gross output production function [17]

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \nu_{it}, \qquad (6)$$

where all variables are in natural logarithms. The variable y_{it} is real output, β_0 is the constant term, the coefficients (β_l, β_k) are y_{it} elasticities with respect to labour and capital inputs.[18] l_{it} is variable labour input for firm i at time t, k_{it} is fixed and/or quasi-fixed capital input. The last two components are the unobservable productivity, ω_{it}, which is known to the firm but unknown to the econometrician, and ν_{it} is a sequence of independent and identically distributed (i.i.d.) shocks. Demand for intermediate inputs, m_{it}, is a function of state variables k_{it} and ω_{it} and is assumed monotonically increasing in ω_{it}. Therefore, this function is invertible to express ω_{it} as a function of k_{it} and m_{it}. In turn, ω_{it} is governed by a first-order Markov process with an additional innovation that is uncorrelated with k_{it}, but not necessarily with l_{it}.

In the first stage, Levinsohn and Petrin (2003) transform (6) into a function of labour input and an unknown function $g(k_{it}, m_{it})$, where $g(.)$ is approximated with a third-degree polynomial in k_{it} and m_{it}, and β_l is estimated using O.L.S., see Eqs. $1.6 - 1.8$ in Appendix A3.1. Ackerberg *et al.* (2015) (hereafter referred to as ACF) demonstrate how β_l is unidentified because l_{it} is correlated with $g(.)$, and propose an alternative but still two-stage approach. The second stage in Levinsohn and Petrin (2003) involves nonparametric estimation of the value of $\hat{\phi}_{it} = \hat{y}_{it} - \hat{\beta}_l l_{it}$, and estimating the productivity series using $\widehat{\omega}_{it} = \hat{\phi}_{it} - \beta_k^* k_{it}$. A consistent nonparametric approximation to $E(\omega_{it}|\omega_{it-1})$ is then given by predicted values from a nonlinear regression shown by Eq. 1.21 in Appendix A3.1. Given $E(\widehat{\omega_{it}|\omega_{it-1}})$, $\hat{\beta}_l$ and β_k^*, the estimate of β_k, solves the minimization of the squared regression residuals

$$\min_{\beta_k^*} \textstyle\sum_i \left(y_{it} - \hat{\beta}_l l_{it} - \widehat{\beta_k^*} k_{it} - E(\widehat{\omega_{it}|\omega_{it-1}})\right)^2. \qquad (7)$$

Instead of a two-step approach, Wooldridge (2009) proposes to simultaneously estimate (β_l, β_k) by making a Conditional Mean Independence (CMI) assumption about the error term in respect of current and past values of l_{it}, k_{it}, m_{it}. This allows him to express the third-degree polynomial in single-period lags of capital and intermediate inputs as in (8)

[17] Appendix A3.2 shows 100 percent of non-zero intermediate observations compared to an average of only 34 percent for investment. Therefore, choosing investment as a proxy in this case would truncate 66 percent of the observations in the panel dataset.

[18] A detailed exposition of the Wooldridge-Levinsohn-Petrin estimation of the production parameters is found in Appendix A3.1.

$$y_{it} = \varphi_0^* + \beta_l l_{it} \ + \ \beta_k k_{it} + g(k_{it-1}, m_{it-1}) + u_{it} \quad (8)$$

or

$$y_{it} \cong \varphi_0^* + \beta_l l_{it} \ + \ \beta_k k_{it} + \sum_p^3 \sum_q^{3-p} \hat{\delta}_{pq} k_{it-1}^p m_{it-1}^q + u_{it}. \quad (9)$$

Following Petrin and Levinsohn (2012), Petrin *et al*. (2011) and Nishida *et al*. (2014), Eq. 9 can be estimated using a pooled IV, with $k_{it}, k_{it-1}, l_{it-1}, m_{it-1}$ and third-order polynomial approximation of $g(.)$ with k_{it-1}, m_{it-1} as instruments for $l_{it} = f(l_{it}^{WP},\ l_{it}^{PE})$, where l_{it}^{WP} denotes Working Proprietors and l_{it}^{PE} denotes Paid Workers. CMI II in the Appendix renders this approach robust to the ACF critique and it does not require bootstrapping to obtain robust standard errors for (β_l, β_k).

4.8.2. Parametric Estimation of the Production Function

It is essential to show in a practical sense how to efficiently estimate the parameters (β_l, β_k) using firm-level datasets. Eq. 9 can be estimated either by gross output production functions as in Petrin *et al*. (2011) or a value-added production technology as in Nishida *et al*. (2014). The latter is adopted here. Table 3.6 presents the characteristics of the empirical model.

Table 3.6: Specification of the Empirical Model

Panel A: Variables for the Levinsohn and Petrin (2003) or the LP Models	
Dependent variable:	Double-deflated value-added ($\boldsymbol{rva_{it}}$)
Freely variable inputs:	$\boldsymbol{l_{it}^{WP}},\ \boldsymbol{l_{it}^{PE}}$
Proxy: Intermediate Inputs	$\boldsymbol{m_{it}}$
Capital:	$\boldsymbol{k_{it}}$
value-added:	$\boldsymbol{valueadded_{it}}$
Reps (#):	Number of bootstrap replications to be performed
Panel B: Variables for the Wooldridge (2009) and Levinsohn and Petrin (2003) or the WLP Models	
Dependent variable:	Double-deflated real value-added ($\boldsymbol{rva_t}$)
Included Instruments:	$\boldsymbol{k_{it}, k_{it-1}, m_{it-1}, k_{it-1}m_{it-1}, k_{t-1}^2, m_{t-1}^2, k_{t-1}^2 m_{it-1}, k_{it-1}m_{t-1}^2, k_{t-1}^3, m_{t-1}^3}$
Endogenous variables:	$\boldsymbol{l_{it}^{WP}}, \boldsymbol{l_{it}^{PE}}$
Excluded Instruments:	$\boldsymbol{l_{it-1}^{WP}}, \boldsymbol{l_{it-1}^{PE}}$

Notes:

- Consistent with order conditions for identification in Hayashi (2000), the number of predetermined variables excluded from the equation $(\boldsymbol{l_{it-1}^{WP}}, \boldsymbol{l_{it-1}^{PE}})$ = the number of endogenous variables ($\boldsymbol{l_{it}^{WP}},\ \boldsymbol{l_{it}^{PE}}$) or the number of instruments = the number of regressors.
- The test for weak instruments (Z variables) is H_0: Z$\in \mathcal{W}_{bias.TSLS}$ against H_1: Z$\notin \mathcal{W}_{bias.TSLS}$. The test procedure is, Reject H_0 if the Cragg-Donald (1993) g_{min} statistic $\geq d_{bias.TSLS}$(b;K_2, n, δ), where $d_{bias.TSLS}$ denotes the Stock and Yogo (2005) critical value based on the Two Stage Least Squares (TSLS) bias, K_2 the number of instruments, and n is the number of included endogenous regressors.

Panel A is the LP Model which includes freely variable inputs ($\boldsymbol{l_{it}^{WP}},\ \boldsymbol{l_{it}^{PE}}$) and excludes the proxy variable $\boldsymbol{m_{it}}$. ACF have however shown that the LP Model suffers from parametric identification problems arising from firms' optimization of variable labour, yet labour is also a deterministic function of unobservable productivity and capital. In Panel B, Wooldridge (2009) therefore modifies

Levinsohn and Petrin (2003) to correct for this endogeneity problem. In this Model, endogenous variables ($\boldsymbol{l_{it}^{WP}}$, $\boldsymbol{l_{it}^{PE}}$) are instrumented with capital and the polynomial approximation of the unknown expression $g(.)$.[19]

Table 3.7: Estimates of Production Functions with Third Order Polynomial

Variable	WLP	LP	FE[a.]	FE-Int[b.]	O.L.S.	O.L.S.lab
l_t^{WP}	-0.162	-0.118	-0.069	-0.028	-0.070	
l_t^{PE}	0.892***	0.794***	0.796***	0.793***	0.811***	
l_t						0.863***
k_t	0.224***	0.181***	0.216***	0.222***	0.193***	0.158***
m_t			0.325***	0.321***	0.306***	0.356***
k_{t-1}	7.074*					
m_{t-1}	0.663					
$k_{t-1}m_{t-1}$	-0.682**					
k_{t-1}^2	-0.162					
m_{t-1}^2	0.293**					
$k_{t-1}^2 m_{t-1}$	0.010					
$k_{t-1}m_{t-1}^2$	0.014*					
k_{t-1}^3	0.001					
m_{t-1}^3	-0.011***					
cons	-25.021		8.413***	8.397***	8.810***	8.367***
N	757	1021	1021	1021	1021	1257
R^2	0.839		0.811	0.827	0.796	0.824
R^2_a	0.837		0.806	0.803	0.795	0.824

Diagnostic Tests for the WLP Model

Endog Vars[c]	***Shea Partial R^2***	***Partial R^2***	***F(2,744)***	***p-value***
l_t^{WP}	0.3080	0.3219	41.69	0.0000
l_t^{PE}	0.8921	0.9324	3663.48	0.0000

Test		p-value / Statistic
[d.]Anderson-Rubin (AR) Test F(2,744)=172.86		0.0000
Anderson-Rubin (AR) Test $\chi^2 = 351.77$		0.0000
Stock-Write s Statistic $\chi^2 = 57.64$		0.0000
[e.]Cragg-Donald (N-L)*CDEV/L1	F-Statistic =	165.59

Legend: * p<0.05; ** p<0.01; *** p<0.001.

Notes:
a. Represents a fixed effects' model that controls for both time and industry effects.
b. Represents a fixed effects' model that interacts time with industry effects.
c. The Shea (1997) partial R^2 provides evidence for the presence of significant correlation between excluded variables $(\boldsymbol{l_{it-1}^{WP}}, \boldsymbol{l_{it-1}^{PE}})$ and endogenous regressors $(\boldsymbol{l_{it}^{WP}}, \boldsymbol{l_{it}^{PE}})$.
d. H_0: $B1 = 0$ and overidentifying restrictions are valid. The null is strongly rejected by AR F- and χ^2- tests as well as by Stock and Write (2000) χ^2-test, where B1=0 tests the joint significance of coefficients of endogenous variables. See Stock and Yogo (2005) for a detailed and fairly accessible discussion.
e. H_0: instruments are weak, even though parameters are identified. The null is strongly rejected at 95% confidence when the statistic g_{min} =165.59 is compared with the TSLS critical value of 7.03 produced by K_2=13, n=2 and the desired maximum level of bias of the IV estimator relative to OLS bias (b)=10% as in Stock and Yogo (2005, table 5.1).

Table 3.7 presents estimation results from the WLP Model, Levinsohn and Petrin (2003), Fixed Effects and O.L.S. methods with separate and combined labour components. Our preferred production

[19] A full derivation of the empirical LP Model and its transformation into WLP Model is presented in Appendix A3.5.

function specification is the WLP version of Eq.9 as outlined in Appendix A3.5.[20] While $\ln WP$ is negative and insignificant across specifications, $\ln PE$ and $\ln K$ are consistently positive and highly significant. The model is well-behaved and its primary input parameters are comparable to ACF input coefficients in Gandhi *et al.* (2016, table 1) for the cases of Colombia and Chile.

One important finding from our preferred the IV−GMM estimator presented as the WLP Model is that primary inputs in manufacturing deliver increasing returns to scale. This is potentially associated with import-competing industries whose output is likely to decline due to intensified foreign competition during the trade liberalization episode in the Customs Union.[21] The low value of the capital coefficient is typical in the literature and the cited cause for this is measurement error; see Levinsohn and Petrin (2003).[22] The IV−GMM labour coefficient shows an improvement of 10 percent compared to the other estimation methods. This can be attributed to efficiency gains in the GMM routine induced by the removal of selection and simultaneity biases. Industry effects on real value-added movements show a significant degree of heterogeneity whereby five of the 13 industries made insignificant contributions to output and the Apparel industry suffered a marked decline, particularly in 2001. Furthermore, there is no evidence of time effects in the first seven years and a significant decline began persistently in 2000 with marked negative effects in 2001 and 2003. The economic performance in the latter years coincides with heightened firm exit and the near-conclusion of progressive tariff-cuts in SACU.

4.8.3. General Set-Up, APG Decomposition and Estimation

There is already a growing view noted by Banerjee and Moll (2010), among others, that countries' underdevelopment may not only be an outcome of resource inadequacy, such as capital, skilled labour, entrepreneurship, or ideas, but also a result of the misuse or misallocation of available resources. Specifically, Banerjee and Duflo (2005); Jeong and Townsend (2007); Restuccia and Rogerson (2008, 2012); Hsieh and Klenow (2009); Bartelsman *et al.* (2004); and Alfaro, Charlton, and Kanczuk (2008) all argue that the scope of resource misallocation in developing economies is large enough to explain a significant gap in the aggregate productivity growth between advanced and

[20] The **ivreg2** Stata command with the GMM continuously updated estimator (**cue**) and **cluster** for each firm in order to generate efficient IV-GMM parametric estimates of the WLP functional specification was used

[21] The constant returns to scale in the other estimation methods is potentially induced by simultaneity and selection problems explained in detail in Wooldridge (2001).

[22] Galuščák and Lizal (2011) correct for measurement error in the capital series by running an O.L.S. on $k_{it} = \gamma_0 + \gamma_1 z_{1t} + \cdots + \gamma_N z_{Nt} + e_{Nt}$, where e_{Nt} is the i.i.d. measurement error, z_{it} are instruments and the predicted values of capital are $\hat{k}_t = k_t - e_t$. The estimation proceeds with linear approximation of the unknown function for consistency, and coefficient standard errors are derived non-parametrically through bootstrapping that reflects uncertainty in capital adjustment. Improvement in the capital input measurement to investigate industries' scale economies is left for future work.

poor countries. A similar argument is relevant if trade reforms identify industries that still need protection while trade liberalization in other industries deepens, as demonstrated by Edwards (2006) in the case of South Africa and, by extension, the rest of SACU.

Furthermore, there are also factors that move an economy away from the perfect competition setting such as input adjustment costs, hiring, firing and search costs, holdup and other contracting problems, taxes and subsidies, and markups. Examples of empirical evidence include Kambourov (2009) for firing costs in the case of Chile and Mexico, Aghion, Brown and Fedderke (2007) and Fedderke, Kularatne and Mariotti (2005) for markups in South Africa, and Petrin and Sivadasan (2013) for marginal product-marginal cost gaps in Chile. The finding of input misallocation suggests the presence of barriers to the movement of resources across heterogeneous production units. Similarly, firm-level heterogeneity in marginal products of inputs within industries in a country is also pronounced; see, for example Hsieh and Klenow (2009) for the case of India and China, Petrin and Sivadasan (2013) for Chile and Ho *et al.* (2014) for Ecuador. Ho *et al.* (2014), Petrin *et al*. (2011) and Nishida *et al*. (2014) rely on Petrin and Levinsohn (2012) to identify the relative role of technical efficiency improvement, the intensive and extensive margins. In response to the non-neoclassical frictions in developing economies, we also implement the Petrin and Levinsohn (2012) approach to estimate the extent of technical efficiency improvement and both margins of reallocation.

4.8.4. The General Set-Up

In this section we focus on the reallocation of primary inputs across, and the patterns of technical efficiency within, firms. The characterization of aggregate productivity growth in the absence of intermediate inputs takes the form

$$\left\{\sum_i \sum_k \left(P_i \frac{\partial Q_i}{\partial X_k} - W_{ik}\right) dX_{ik}\right\} + \left\{\sum_i P_i \frac{\partial Q_i}{\partial \omega_k} d\omega_i\right\} \quad (10)$$

where $\frac{\partial Q_i}{\partial X_k}$ is the partial derivative of output with respect to capital. We denote the price of output Q_i in establishment i as P_i, and W_i denotes the cost of labour. The change in the use of k^{th} input quantity X_{ik} by firm i is dX_{ik}. The 'net output' remaining after deducting contributions by factor inputs to dQ_i is $d\omega_i$. Therefore, $\sum_i P_i \frac{\partial Q_i}{\partial \omega_k} d\omega_i$ represents gains from total technical efficiency changes, given $d\omega_i$. In Petrin and Levinsohn (2012, Lemma 1) and Petrin *et al*. (2011, Eq. 7), the impact of a change in the k[th] input on a change in output is normalized as $\frac{\partial Q_i}{\partial \omega_k} = 1$ to transform the total technical efficiency changes into $\sum_i P_i d\omega_i$.[23]

Thus, Eq. 12 shows that the primary input reallocation is zero if dX_{ik}=0. This occurs if distortions or adjustment costs are so prohibitively high that inputs do not adjust and consequently do not reallocate across firms. Furthermore, under a perfectly operating factor input market, the VMP of each input is equal to its reward, $P_i \frac{\partial Q_i}{\partial X_k} = W_{ik}$. This means that factor inputs are continuously reallocated across plants in response to changes in economic conditions to maintain the VMP-price equality and no extra output gains can be realized from this reallocation; see Petrin and Levinsohn (2012).

4.8.5. APG Decomposition and Estimation

The decomposition of APG based on a double-deflation procedure for the value-added function, if it exists, is shown by Petrin and Levinsohn (2012) to be

$$\text{APG} = \sum_i D_i^v dln(VA_i) - \sum_i \sum_k s_{ik} dln\, X_{ik} \tag{11}$$

where the Domar-weight $\left(D_i^v = \frac{VA_i}{\sum_i VA_i}\right)$ is plant *i*'s real value-added share. The two classes of labour are defined as $X_{PE} = L^{PE}$ and $X_{WP} = L^{WP}$, where L^{PE} refers to Paid Employees and L^{WP} refers to Working Proprietors (or Nonproduction Workers in Levinsohn and Petrin (2003)). The real value-added production function can then be written as

$$ln(VA_i) = \sum_k \epsilon_{ik}^v X_{ik} + ln\omega_i^v. \tag{12}$$

Eq. 12 can be translated into APG as

[23] The definition of APG allows for the classification of firms into entrants and exits, and exporters and nonexporters. It is also flexible to account for the impact of growth of both firm-level fixed and sunk costs (F_i^v) and input (Capital, Labour, Energy, Material) reallocation contributions, see Bruno (1978, Section 3), Petrin and Levinsohn (2012:706) and Petrin *et al*. (2011, Eq. 10). This means Eq. 9 can be fully decomposed into the expression

$$\left\{\sum_i \sum_k \left(P_i \frac{\partial Q_i}{\partial X_k} - W_{ik}\right) d\, X_{ik}\right\} + \left\{\sum_i \sum_k \left(P_i \frac{\partial Q_i}{\partial M_k} - P_{ik}\right) d\, M_{ik}\right\} + \{\sum_i P_i d\omega_i\} - \{\sum_i P_i dF_i\}$$

where $\frac{\partial Q_i}{\partial \omega_k}$ in the third term is normalized to one and the expression is translated into an augmented version of APG in (12) as

$$\left(\overbrace{\sum_i D_i^v \sum_k (\varepsilon_{ik}^v - s_{ik}^v)\Delta ln X_{ik}}^{Primary\ Input\ Reallocation}\right) + \left(\overbrace{\sum_i D_i^v \sum_j (\varepsilon_{ij}^v - s_{ij}^v)\Delta ln M_{ij}}^{Material\ Input\ Reallocation}\right) + \left(\overbrace{\sum_i D_i^v\, \Delta ln\omega_i^v}^{Technical\ Efficiency}\right) - \left(\overbrace{\sum_i D_i^v\, \Delta ln F_i^v}^{Fixed\ and\ Sunk\ Costs}\right).$$

$$APG = \left(\overbrace{\sum_i D_i^v \sum_k \left(\varepsilon_{ik}^v - s_{ik}^v\right) \Delta ln X_{ik}}^{Primary\ Input\ Reallocation} \right) + \left(\overbrace{\sum_i D_i^v\, \Delta ln\omega_i^v}^{Technical\ Efficiency} \right) \tag{13}$$

where the first-difference operator is $\Delta x_{it} = x_{it} - x_{it-1}$ and $s_{ik}^v = \frac{W_{ik}X_{ik}}{VA_i}$ is the k^{th} input revenue ratio to the plant's real value added. The real value-added elasticity with respect to the k^{th} input is $\varepsilon_{ik}^v = \frac{\varepsilon_{ik}}{1-s_{ik}}$. The gaps in Eq. 13 are measured by the difference between the plant-level value-added elasticities (ε_{ik}^v) and its input revenue share (s_{ik}^v) to value added. The aggregate input reallocation is therefore given by $\sum_i D_i^v \sum_k(\varepsilon_{ik}^v - s_{ik}^v)\Delta ln X_{ik}$ and aggregate technical efficiency is $\sum_i D_i^v\, \Delta ln\omega_i^v$. The APG approach has been applied to the US manufacturing data by Petrin *et al*. (2011), to Chile, Colombia and Slovenia by Nishida *et al*. (2014), to Chile by Petrin and Sivadasan (2013) and to Ecuador by Ho *et al.* (2014).

Using index number theory, it is possible to estimate Eq. 10 directly from the discrete data using the Törnqvist−Divisia methods. As in Nishida *et al*. (2014), the prices in the Domar-weights are annually chain-weighted and updated. The Törnqvist−Divisia method can be used in Eq. 12 for each of the two APG components; namely, the reallocation of primary inputs and technical efficiency – the respective analogues to the 'Between' and 'Within' terms from ALP in the traditional approach. The *estimated* aggregate productivity growth can then be expressed as

$$\overline{APG}_{it} = \sum_i \bar{D}_{it}^v \Delta ln(VA_{it}) - \sum_i \bar{D}_{it}^v \sum_k \bar{s}_{it}^v \Delta ln\, X_{ikt}, \tag{14}$$

which translates to

$$\overline{APG}_{it} = \{\sum_i \bar{D}_{it}^v \sum_k(\varepsilon_{ik}^v - \bar{s}_{it}^v)\Delta ln X_{ikt}\} + \{\sum_i \bar{D}_{it}^v\, \Delta ln\omega_{it}^v\}. \tag{15}$$

The $\bar{D}_{it}^v$ denotes plant *i*'s average value-added share weight from year *t−1* to *t*, Δ the first difference operator as before, and $\bar{s}_{it}^v$ is the two-period average of plant *i*'s expenditure for the k^{th} primary input as a share of firm-level value added. In summary, the definitions of the APG components are

Technical Efficiency: $\sum_i D_i^v\, \Delta ln\omega_i^v$ is the value-added production function sum of the Domar-weighted changes in the Solow residuals, the APG analogue of the ALP "Within" term in Baily *et al*. (1992)/Foster *et al*. (2001). Technical efficiency increases when a plant continuously innovates and adapts to technological advances through learning-by-doing/watching and other means.

Reallocation: $\sum_i \sum_k \left(P_i \frac{\partial Q_i}{\partial X_k} - W_{ik}\right) d\, X_{ik} \xrightarrow{yields} \sum_i D_i^v \sum_k(\varepsilon_{ik}^v - s_{ik}^v)\Delta ln X_{ik}$. According to Petrin and Levinsohn (2012), Petrin *et al*. (2011), Petrin and Sivadasan (2013, p. 288) and Nishida *et al*. (2014, Eqs. 6 and 8), plants produce at the output level where $P_i \frac{\partial Q_i}{\partial X_k} > W_{ik}$, under imperfect factor market conditions. Therefore, there are three potential instances for input reallocation growth. *First*, if dX_{ik} is the change in the k[th] factor input that was previously idle, but now reallocates to plant *i*, then the value of aggregate output changes by $P_i \frac{\partial Q_i}{\partial X_k} - W_k$. *Second*, when a small amount of primary inputs reallocates from *j* to *i* so that $dX_i = -dX_j$, then aggregate output changes by $P_i \frac{\partial Q_i}{\partial X_k} - P_j \frac{\partial Q_i}{\partial X_k}$. *Third*, in the event factor inputs reallocate across firms but the total amount of these inputs is held constant, the change in aggregate output induced by reallocation is given by $P_i \frac{\partial Q_i}{\partial X_k} dX_{ik}$.

Entry and Exit: Entry in this set-up includes the development of a new product, the replication of an existing product by a new firm or a reintroduction of a good back into the market after exiting previously (see Petrin and Levinsohn, 2012: Appendix).

In order to separately estimate firm-level technical efficiency in Eq. 12 for each ISIC2-digit industry code in Swazi manufacturing, Eq. 6 can be re-written as

$$\widehat{ln\omega_{it}^{v}} = \{ln(VA_{it})\} - \{\widehat{\beta^{v}} + \widehat{\epsilon_{jPE}^{v}} lnL_{it}^{PE} + \widehat{\epsilon_{jWP}^{v}} lnL_{it}^{WP} + \widehat{\epsilon_{jWP}^{v}} lnK_{it}\} \quad (16)$$

and estimated using the proxy method of Wooldridge (2009) that modifies Levinsohn and Petrin (2003) to address the simultaneity problem in the determination of inputs and productivity. In Eq. 14, we use three factor inputs as regressors: non-production (Working Proprietors) L_{it}^{WP}, production (Paid Employees) L_{it}^{PE} and capital K_{it}. Unlike Nishida *et al*. (2014), we do not report only aggregate labour reallocation in our results, we also report reallocation of L_{it}^{WP} and L_{it}^{PE} separately.

Table 3.8 quantitatively decomposes APG into technical efficiency, primary input reallocation and net entry estimated using Eq. 14. The relationship between APG and its component sources of growth is that APG(0) *equals* 'Technical Efficiency (1)' *plus* 'Total Reallocation (2)' *plus* 'Net-Entry (3)'. In turn, 'Labour Reallocation (2)' decomposes to 'Working Proprietors Reallocation' *plus* 'Paid Employees Reallocation' while 'Total Reallocation' refers to all primary input reallocation across plants. In considering the results sequentially, the second and third columns show changes in real value added and aggregate productivity, respectively. It is striking to observe such a high correlation between aggregate productivity growth and the growth of value added. This reflects the fact that most of the fluctuations in aggregate productivity are predominantly linked to fluctuations in value added. Similar results are found in the case of Chile, Colombia or Slovenia in Nishida *et al*. (2014) or for the case of Japan in Kwon *et al.* (2009). For example, the Swazi manufacturing sector reports an estimated average real value added of 54.59 percent and average APG of 54.54 percent, or the median real value added of 7.76 percent and the median APG of 7.71 percent per year, respectively.

Table 3.8: Aggregate multifactor productivity growth rate, Swaziland manufacturing 1994–2003: APG decomposition, manufacturing value-added index double-deflator.
Estimates of $\sum_i \bar{D}_{it}^{v} \Delta ln(VA_{it})$ and $\overline{APG} = \sum_i \sum_k \bar{D}_{it}^{v}(\varepsilon_{ik}^{v} - \bar{s}_{it}^{v})\Delta lnX_{ik} + \sum_i \bar{D}_{it}^{v}\, \Delta ln\omega_i^{v}$.

Year	Value-Added Growth	APG (0)	APG Decomposition: (0)= (1) + (2) + (3)					
			Technical Efficiency (1)	Reallocation				Net Entry (3)
				Total Reallocation (2)	Labour Reallocation	Working Proprietors' Reallocation	Paid Employees' Reallocation	
1995	7.76	7.71	-4.43	-4.31	8.76	5.61	3.15	16.45
1996	23.10	23.03	2.27	-6.98	1.21	-0.30	1.51	27.75
1997	-44.35	-44.25	-2.69	18.13	9.84	-0.08	9.92	-59.69
1998	265.55	265.30	2.31	-2.38	0.10	0.02	0.07	265.37
1999	275.57	275.42	0.64	9.81	3.01	-0.01	3.03	264.97
2000	-16.28	-16.27	-15.30	-5.16	0.61	-0.13	0.74	4.18
2001	37.42	37.39	9.03	20.10	-0.08	-0.11	0.03	8.25
2002	-20.74	-20.75	-3.56	-29.01	-1.36	-1.66	0.30	11.82
2003	-36.71	-36.67	-20.74	1.12	7.14	-2.61	9.75	-17.05
Mean	**54.59**	**54.54**	**-3.61**	**0.15**	**3.25**	**0.08**	**3.17**	**58.01**
Median	**7.76**	**7.71**	**-2.69**	**-2.38**	**1.21**	**-0.11**	**1.51**	**11.82**
Std Dev	**125.32**	**125.23**	**9.21**	**14.88**	**4.22**	**2.27**	**3.96**	**120.14**

Notes: As in Nishida *et al*. (2014), numbers are percentage growth rates. The plant-level multifactor productivity is calculated by using production function parameters that vary across 2-digit ISIC. We obtain the estimates by using Wooldridge (2009). APG represents the aggregate productivity growth with entry and exit, which is defined as aggregate change in final demand *minus* aggregate change in expenditure in inputs, holding input constant. We use value-added share (Domar) for weights. APG is decomposed into four components: (1) technical efficiency, (2) reallocation, and (3) net-entry term, using Eq. 17 in text.

These trends are characterized by high firm-level heterogeneity in the change of value added and APG. For example, the measure of dispersion for APG is over twice its average size. One channel explaining this is found in Syverson (2004), which states that trade liberalization creates a competitive market environment and snowballing of product variety. This enables consumers to switch between products and/or producers such that high-cost producers' profitability is diminished. Thus, a high substitutability industry is likely to have less productivity dispersion and a high aggregate productivity level.

The contribution of technical efficiency to APG is on average (median) -3.61 (-2.69) percent per year, compared to an average of 0.95 percent for Chile, 0.25 percent for Colombia and 2.17 percent for Slovenia (see Nishida *et al*. (2014)). This component of APG is positive in only four out of nine years. However, the most interesting case is the combined input reallocation in the fourth column reflecting simultaneous cross-plant movements in capital and components of labour inputs. The average total reallocation is 0.15 percent per year and consists of input reallocation from low to high productivity plants, from idle state to productive uses and reallocation that is not accompanied by changes in input amounts. Clearly, the average reallocation compares with 1.60 percent for Chile, 3.63 percent for Colombia and 3.42 percent for Slovenia as reported in Nishida *et al*. (2014).

However, our ultimate focus is the behaviour of the paid labour resource in response to shifts in economic factors that cause movements in the manufacturing sector. We first isolate labour reallocation from the contribution of all inputs put together. This produces 3.25 percent as the average annual rate of labour reallocation, and we report only two instances of negative reallocation out of the nine years studied. A further decomposition of labour reallocation into that which is accounted for by the reshuffling of working proprietors and paid employees produces sharper results. Paid employment shows positive growth in every year and accounts for an average of about 98 percent [3.17÷3.25] percent of all labour reallocated per year. Again, paid labour reallocated from low to high VMP plants, new paid labour entered the labour market and some paid labour reallocated without increasing the number of workers. This is consistent with the wave of downsizing in the manufacturing sector during the period of trade liberalization. Our results are robust to the use of 'single-deflation' by the manufacturing value-added deflator in Appendix A3.3 and 'double-deflation' by the consumer price index in Appendix A3.4. Another robustness check applied, but not reported here, involved 'single-deflation' by the consumer price index which also sustained the basic results.

Thus, the analysis reveals that the contribution by the labour reallocation growth to APG decisively *dominates* technical efficiency in the manufacturing sector in Swaziland. Firms were not investing more in improving production efficiency through innovation and adoption of new technologies than they were moving labour to higher activity producers. This conclusion remains robust regardless of the deflation procedure used in the estimation of the value-added production function. However, based on our robustness checks, the combined input reallocation *versus* technical efficiency is inconclusive because the outcome depends on whether we use the mean or the median as a standard for comparison.

On the other hand, the extensive margin accounts for most of the change in APG. The annual average of net entry contribution to APG is 58.01 percent and is driven by the dramatic increase of APG in 1998 and 1999. This pattern of high contribution by net entry is consistent with extensive margin effects of trade liberalization which increases opportunities for mergers and acquisitions as well as business restructuring and retrenchments.

5. Discussion of Results

In the previous section, different decomposition approaches for aggregate productivity growth are described, estimated and results compared. It is evident that the joint use of the Bailey *et al*. (1992) *and* Forster *et al*. (2001) methods to measure contributions made by individual determinants of the aggregate labour productivity growth produces significant insights. More specifically, while these methods identically define the longitudinal effects of productivity changes and the covariance effects, their conceptualization of resource-shift effects and the entry-exit dynamics differs only in terms of whether or not firm-level productivity deviations from the initial industry average productivity is considered. That is, the Bailey *et al*. (1992) technique does not consider these deviations while Forster *et al*. (2001) does.

The present study of industrial aggregate productivity growth in Swaziland coincides with a period of progressive trade liberalization and deregulation in the customs union. Trade reforms typically create competitive markets by inducing domestic price reduction, forcing inefficient producers out of business thereby reallocating resources and market shares to more productive plants, see Pavcnik (2002). However, the standard absence of well-functioning markets due to other forms of protection in developing economies may account for the observed poor industrial performance in Swaziland. In table 3.3; for instance, the average year-on-year within-firm effects is negative. In five out of nine instances, within-effects report large negative productivity growth, suggesting that the manufacturing sector in was dominated by continuing low productivity firms. This productivity growth component is only positive in 1997-1999 and in 2001, suggesting the manufacturing sector in Swaziland experienced some productivity growth in these years. That is, the annual orders of magnitude in these specific years indicate that plant-level improvements in production efficiency only marginally dominated industrial activity. In an efficient market environment, the weak performance of the sector in technological advancements would feature prominently in heightened exit rates of poor performers and entry of efficient firms.

The labour share-shift effect computed from the traditional methods produces interesting results. On a year-to-year average basis, the Bailey *et al*. (1992) between-effect is -5.69 percent and the Forster *et al*. (2001) between-effect is 3.53 percent. Such patterns of negative Bailey *et al*. (1992) between-effects and positive Forster *et al*. (2001) between-effects occur in four out of nine instances. Interpreting these results collectively, it means most industrial firms downsized their operations and this affected mostly plants with initial productivity level that exceeded the initial industry average productivity. The observed apparent inefficient reshuffling of resources away from productive to less productive producers can be explained in terms of the newly reforming industrial sector in the customs union. These are likely South African owned subsidiaries that moved to Swaziland during the period of economic sanctions prior to the mid-1990s to access cheaper intermediate and primary inputs as well as foreign markets. The new trade policy regime was incentive enough for these plants to relocate back into the larger South African market to enjoy scale economies in an increasingly competitive market environment.

However, section 3.4.6 demonstrates that the traditional methods suffer from confounding effects of firm turnover. Purging these effects from the producer-level labour share merely reduced the magnitude of the share-shift effect in absolute terms without altering its sign and only converted this effect from negative to positive in 1996. Therefore, our results generally remain robust to the confounding effects of changes in the number of firms over time.

The entry-exit dynamics that characterize the manufacturing sector in Swaziland tell an interesting story about the behavioural patterns of establishments when using the Bailey *et al*. (1992)/Forster *et al*. (2001) techniques during the 10-year period. Although both methods yield large positive net-entry effects of productivity growth on a year-to-year average basis, table 3.3 reports four out of nine instances of positive Bailey *et al*. (1992) net-entry effects associated with positive Forster *et al*. (2001) net-entry effects. Again, a joint interpretation of this result from the two methods is that new firms were generally more productive relative to *both* their exiting counterparts and initial industry average productivity. In turn, exiting plant productivity levels were predominantly lower than the initial industry average productivity. This pattern is more pronounced in 1998-1999, a period of significant shake up in one industry where a large investment asset was sold to another and this was recorded as firm entry. The results also show three out of nine instances of positive Bailey *et al*. (1992) net-entry effects associated with negative Forster *et al*. (2001) net-entry effects. This is evidence of more productive entrants than quitters, and more productive quitters than the initial industry average productivity.

The Bailey *et al*. (1992) approach and its associated derivatives has been fiercely criticised by Levinsohn and Petrin (1999), Petrin and Levinsohn (2012) and Petrin *et al*. (2014) for decomposing aggregate labour productivity growth using firm-level output per labour, $\boldsymbol{\varphi}_{it} = \frac{VA_{it}}{L_{it}}$, as a proxy for the marginal product of labour. This literature also questions the use of changes in output/labour, $\Delta\boldsymbol{\varphi}_{it}$, as a proxy for plant-level changes in productivity. Petrin *et al*. (2014) demonstrate *a priori* and in a firm-level panel data application to the cases of Chile, Colombia and Slovenia how plant specific technical efficiency, input reallocation and turnover effects influence changes in APG. Following this alternative line of enquiry into the behaviour of industrial determinants of APG in Swaziland, two technical activities are carried out. First, an analytical framework for estimating a robust production function for the thirteen two-digit ISIC industries is developed and implemented to understand the behaviour of capital and labour inputs in relation to real value-added. This exercise turned out crucial in the estimation of the Solow-residual for use in the subsequent analysis. Second, a conceptual framework based on Petrin and Levinsohn (2012) for estimating the impact of plant-level technical efficiency and resource reallocation across firms is outlined in full and applied to the manufacturing sector in Swaziland.

Table 3.8 presents results based on the Petrin and Levinsohn (2012)/Nishida *et al*. (2014) procedure for measuring technical efficiency, input reallocation and plant turnover effects on aggregate productivity growth. These results broadly mimic those generated from using the Bailey *et al*.

(1992)/Forster *et al*. (2001) methods. In Swaziland, the manufacturing sector is highly concentrated even within broadly defined industries. Hence, a major movement of resources between a few firms translates into significant output changes as observed in 1998-1999 of the second column. Since aggregate productivity growth is defined here as the change in aggregate final demand less the change in the aggregate expenditure in primary inputs, the measured aggregate productivity growth matches the industrial value-added growth very closely over time.

Technical efficiency is on average negative and annually traces the ALP within-firm effects produced by conventional methods closely, although the APG orders of magnitude are much lower in absolute terms. This confirms the earlier view that the degree of firm-level and industrial innovation and entrepreneurial transformation remains negligible at best in the period under study. The direct effect of the generally negative real productivity in Swaziland reverses any positive impact arising from other sources of AGP despite the unboundedness of learning and ingenuity opportunities available to firms as discussed in Levinhson and Petrin (1999). Such preponderance of poor producer performance in a trade liberalization period associated with intensified import competition is hard to explain without thinking about a possible existence of protective industrial regulations, high costs of adjustment of primary inputs or managerial incapacity. Capital irreversibility and protective policies are a crucial barrier to firm exit. Evidence by Bloom *et al*. (2013) shows that the adoption of appropriate managerial practices in large Indian textile firms raised productivity by 17 percent in the first year.

The most important input of production to national policymakers, Bretton Woods institutions and development organizations in the context of Swaziland is paid labour employment. During the period of trade reforms, there was an average paid labour reallocation productivity growth of 3.17 percent every year. Looking at paid employee productivity that is in excess of one percent, this is observed only in five out of the 10 years. Three of these years experienced paid labour productivity that is *at most* 0.07 percent. Nonetheless, positive industrial paid labour reallocation characterized every single year. There are at least four explanations based on $VMP_{ik} = P_i \frac{\partial Q_i}{\partial X_k}$, value-added elasticities and input shares that shed some light into these patterns of growth. First, the reallocation of paid labour input from plant j to plant i leads to $dL_{iPE} = 1$ and $dL_{jPE} = -1$. This increases the amount of real value-added by

$$P_i \frac{\partial Q_i}{\partial L_{iPE}} - P_j \frac{\partial Q_j}{\partial L_{jPE}},$$

assuming common wages across firms and holding total labour input constant. Hence, when paid labour moves from low to high VMP_{iPE}, aggregate final demand increases without any increase in technical efficiency or aggregate input use, see Petrin and Levinsohn (2012).

Secondly, market distortions arising from markups and taxes, and the impact of adjustment costs of paid labour, find full expression in the resource reallocation component of APG. The markup is by definition the wedge between the price and marginal cost of the product in question, and APG increases when paid labour moves from low to high markup firms. On the other hand, a tax of τ on a product induces a reduction in the marginal revenue of paid employees from $P_i \frac{\partial Q}{\partial L_{iP}}$ to $\frac{1}{1+\tau} P_i \frac{\partial Q}{\partial L_{iPE}}$ such that establishments produce at $P_i \frac{\partial Q}{\partial L_{iPE}} > W_{iPE}$, where W_{iPE} denotes firm i's wage rate for paid workers.

Thirdly, in the presence of adjustment costs of paid employees, the s-S-type modelling becomes suitable. In that case, there exists ranges of product demand or technical efficiency shocks such that the plant does not necessarily adjust paid employees every year. Even when paid employment is adjusted, firms do not use first-order conditions to determine employment. Thus, whether the concerned labour input is adjusted or not, the process does not lead to $P_i \frac{\partial Q}{\partial L_{iPE}} = W_{iPE}$.

Fourthly, since reallocation growth of paid employment is consistently positive every year, then the manufacturing sector is dominated by firms with either $\Delta lnL_{iPEt} > 0$ and $(\varepsilon_{ik}^{v} - s_{ik}^{v}) > 0$ or $\Delta lnL_{iPEt} < 0$ and $(\varepsilon_{ik}^{v} - s_{ik}^{v}) < 0$ in Eq.15. Producers of manufactured goods with value-added elasticity with respect to paid labour greater than the revenue share of paid employment for growing incumbent firms contributes positively to APG. Similarly, producers of goods with value-added elasticity less than the revenue share of paid labour for contracting firms contributes positively to APG as well.

Overall, consideration of resource shuffling across plants based on the microfoundations approach produces results similar to those generated by Bailey *et al*. (1992)/Forster *et al*. (2001).This process led us to separate out the reallocation of total labour, paid workers, and working proprietors from total input reallocation. The finding is that, on a year-to-year basis, all input reallocation has a positive impact on APG. More importantly, the component of labour that is widely used by the IMF in country reports for Swaziland; that is, paid employees, is significantly positive every year. It dominates labour reallocation and accounts for 98 percent of all labour shuffled from low to high VMP producers. However, the annual average productivity for primary input reallocation, though still positive, is much lower due to the inclusion of real capital stock. This is due to high capital irreversibility characterizing the manufacturing sector and is likely to constrain entry-exit dynamics while also promoting coexistence of both efficient and inefficient plants.

In the case of net-entry, mergers and acquisitions involving two large firms had a large effect on APG due to the high level of concentration in most industrial sectors. That is, in 1998 a division of a large company was taken over by another firm in the same sector but this was recorded as entry of a new firm. In the following year the acquiring firm took over the rest of the company and engaged in extensive retrenchments which raised labour productivity in this sector. This behaviour accounted for approximately 265 percent productivity growth in these two years.

6. Summary and Conclusion

This chapter investigates primary input trends, aggregate productivity and factor-intensities in Swazi manufacturing firms over a period of trade liberalisation in the Southern African Customs' Union. It begins with descriptive analyses and then investigates the drivers of aggregate productivity growth over time and across industries. A cross-country comparison of drivers of aggregate labour productivity growth with those of the Swazi manufacturing sector is also undertaken. The chapter then deepens the analysis to focus on Swaziland by decomposing aggregate labour productivity growth over time using traditional methods and also relying on Petrin and Levinsohn (2012) as applied by Nishida *et al*. (2014). It concludes with an analysis of seemingly outlying aggregate labour productivity growth in 1998 and 1999 to determine the characteristics of entrants associated with it.

The descriptive evidence shows a decline in both aggregate labour and capital productivities and an increase in the capital−labour ratio. It also shows a leftward distribution of ALP and increasing heaviness of both tails. There are three potential explanations for this. First, firms shed more labour relative to capital due to capital irreversibility and to South African companies shifting production back to South Africa as a response to the lifting of economic sanctions whilst keeping Swazi plants in operation to cover their variable costs. Second, lower productivity firms are growing faster relative to higher productivity plants. Third, there is entry of lower ALP firms.

An in-depth analysis using the conventional approach found that the ALP growth is driven largely by net entry, then by cross-firm market share shift and negatively by within-firm technical change. This result is robust to controlling for confounding effects of plant turnover in the Baily *et al*. (1992) method. Using the Petrin and Levinsohn (2012) approach also produces the same order of importance for APG components. That is, the net-entry contribution explains most of the changes in APG followed by input reallocation, while technical efficiency remains negative per year.

However, the most interesting case is the combined input reallocation reflecting cross-plant movements. The average reallocation of the input bundle from low- to high-productivity incumbent plants is 0.15 percent per year. However, isolating the average annual rate of labour reallocation from the contribution of all inputs put together produces 3.25 percent. Furthermore, paid employment shows positive growth in every year and accounts for an average of about 98 percent of all labour reallocated per year. These results are robust to 'single-deflation' by the manufacturing value-added deflator and 'double-deflation' by consumer price index. Furthermore, the annual average of net-entry contribution to APG is 58.01 percent and is mainly accounted for by the dramatic increase of APG in 1998 and 1999 due to firm entry.

Finally, the analysis reveals that individual contributions by the extensive and intensive margins of resource reallocation to APG decisively *dominate* technical efficiency in the manufacturing sector in Swaziland. Firms were not investing more in improving production efficiency through innovation and adoption of new technologies than they were moving labour to higher activity producers. This conclusion remained robust regardless of the deflation procedure used in the estimation of the real value-added production function. The novelty of our results lies in the use of micro-foundations to define aggregate productivity growth.

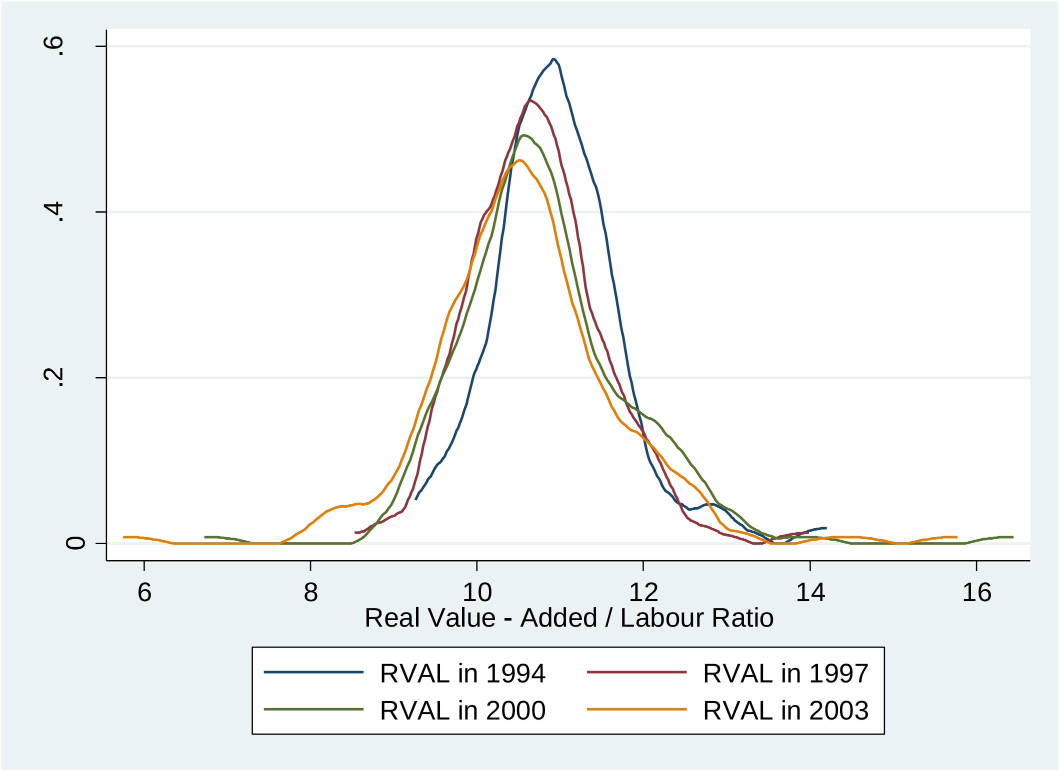
Our future research will focus on separating the contribution of each factor and intermediate input to APG. Given that the APG framework nests many situations around the development and introduction of new goods, this enquiry should also estimate fixed costs and the "gap" terms in Eq. 15 to further understand the productivity dynamics during a period of market reforms. Petrin *et al*. (2011) estimate the impact of primary and intermediate inputs on productivity growth and estimate the orders of magnitude and potential volatility of input gaps. Petrin and Sivadasan (2013) use input gaps to estimate output losses due to allocative inefficiency.

APPENDIX

Appendix A.1: Manufacturing and Survey ALP (1994−2003)

Notes: S-productivity denotes ALP measured by the natural logarithm of real value-added/labour ratio calculated from survey data and the equivalent M-productivity calculated from real value-added sourced from the World Bank Indicators and paid labour sourced from IMF Country Reports for Swaziland (1999, 2000, 2003, and 2008).

Appendix A.2: ALP Distribution for Selected Years (1994, 1997, 2000, 2003)



Notes: Single deflation of the ratio of real value-added to aggregate annual employment.

Appendix A.3: Evolution of the First Quartile of ALP by Industry (1994-2003)

	EVOLUTION OF FIRST QUARTILE ALP BY INDUSTRY									
isic2	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Food (15)	1.00	0.70	0.83	0.88	0.91	0.81	0.73	0.74	0.68	0.52
Textile (17)	1.00	0.61	0.58	0.73	1.37	0.72	0.47	0.65	0.17	0.34
Apparel (18)	1.00	-16.15	16.46	10.99	13.17	9.77	11.50	-23.31	7.47	3.95
Wood (20)	1.00	0.66	0.68	0.64	0.61	0.55	0.81	0.80	0.58	0.25
Pulp & Paper (21)	1.00	1.27	1.55	1.51	1.60	1.63	1.49	0.73	1.55	-0.11
Printing & Publishing (22)	1.00	0.93	0.92	0.83	0.79	0.86	0.93	0.69	0.74	0.62
Chemicals (24)	1.00	1.11	0.82	1.08	0.80	0.99	1.03	0.80	0.89	0.95
Rubber (25)	1.00	1.02	0.93	0.77	0.87	0.81	0.90	0.95	0.70	0.51
Non-Metallic Minerals (26)	1.00	0.96	0.61	0.40	0.43	0.47	0.62	0.22	0.41	0.59
Basic Metals (27)	1.00	-0.05	3.13	3.25	3.13	3.16	1.49	1.18	0.17	2.00
Fabricated Metal (28)	1.00	0.84	1.23	0.92	1.10	1.30	0.94	0.80	0.74	1.02
Furniture (29)	1.00	0.94	0.90	1.10	1.07	0.96	0.86	1.02	1.07	0.27
Other Manufacturing (36)	1.00	1.75	0.95	1.03	0.85	1.24	1.20	0.59	0.82	1.02
Sector Mean	**1.00**	**-0.42**	**2.28**	**1.86**	**2.05**	**1.79**	**1.77**	**-1.09**	**1.23**	**0.92**
Sector Median	**1.00**	**0.93**	**0.92**	**0.92**	**0.91**	**0.96**	**0.93**	**0.74**	**0.74**	**0.59**
Std Dev (σ_{ALP})	**0.00**	**4.75**	**4.31**	**2.83**	**3.41**	**2.50**	**2.94**	**6.68**	**1.91**	**1.05**

Source: Author’s calculations.

Appendix A.4: Evolution of the Third Quartile of ALP by Industry (1994-2003)

	EVOLUTION OF THIRD QUARTILE ALP BY INDUSTRY									
isic2	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Food (15)	1.00	0.88	0.94	0.94	1.05	1.06	1.07	1.00	0.95	0.92
Textile (17)	1.00	0.63	0.81	0.97	0.94	1.13	0.66	0.83	0.50	0.77
Apparel (18)	1.00	1.11	1.12	0.70	1.38	0.92	0.73	0.62	0.64	1.54
Wood (20)	1.00	0.84	0.66	0.79	0.99	1.17	1.06	0.73	0.77	0.69
Pulp & Paper (21)	1.00	1.00	1.01	1.25	1.20	1.22	1.42	1.34	1.14	1.09
Printing & Publishing (22)	1.00	0.82	0.87	0.87	1.00	1.03	1.08	1.08	0.97	1.01
Chemicals (24)	1.00	0.95	0.95	1.29	0.96	1.04	1.13	1.20	1.33	0.95
Rubber (25)	1.00	0.85	0.93	0.70	0.87	0.88	0.76	0.65	0.62	0.58
Non-Metallic Minerals (26)	1.00	0.83	0.80	0.65	0.84	0.91	0.82	0.87	0.98	0.90
Basic Metals (27)	1.00	0.99	0.70	0.73	0.70	0.71	0.55	0.53	1.00	0.96
Fabricated Metal (28)	1.00	0.84	0.92	0.75	0.76	0.89	0.83	0.84	0.90	0.83
Furniture (29)	1.00	0.91	0.87	0.78	0.78	0.78	0.74	0.82	0.87	1.34
Other Manufacturing (36)	1.00	0.86	0.84	0.54	0.71	1.12	0.88	0.85	0.73	0.74
Sector Mean	**1.00**	**0.89**	**0.88**	**0.84**	**0.94**	**0.99**	**0.90**	**0.87**	**0.88**	**0.95**
Sector Median	**1.00**	**0.86**	**0.87**	**0.78**	**0.94**	**1.03**	**0.83**	**0.84**	**0.90**	**0.92**
Std Dev (σ_{ALP})	**0.00**	**0.11**	**0.12**	**0.22**	**0.19**	**0.15**	**0.24**	**0.23**	**0.23**	**0.26**

Source: Author’s calculations.

Appendix A.5: Estimation of the Wooldridge-Petrin-Levinsohn Production Function

This Appendix relies on Petrin, Poi and Levinsohn (2004), Galuščák and Lizal (2011) and Wooldridge (2009). The value-added function is specified as in Levinsohn and Petrin (2003):

$$y_{it} = \beta_0 + \beta_l l_{it} \ + \ \beta_k k_{it} + \omega_{it} + \nu_{it} \ , \qquad (1.1)$$

where all variables are expressed in the natural logarithm. β_0 is a constant term, the coefficients (β_l, β_k) are output elasticities with respect to labour and capital, in that order. The unobserved productivity is ω_{it} and ν_{it} is a sequence of shocks that is assumed to be conditionally mean independent (CMI) of current and past inputs.

The demand for intermediate inputs is assumed to be a function of capital and the unobserved productivity

$$m_{it} = f(k_{it}, \omega_{it}). \qquad (1.2)$$

Levinsohn and Petrin (2003) demonstrate the monotonicity property of the demand function for intermediates under mild assumptions which allow for the inversion of Eq.1.2 as

$$\omega_{it} = g(k_{it}, m_{it}) \qquad (1.3)$$

and productivity adjusts according to a Markov process as

$$\omega_{it} = E(\omega_{it}|\omega_{it-1}) + \xi_{it} \qquad (1.4)$$

where ξ_{it} is productivity innovation.

Then, (1.1) can be expressed as either

$$y_{it} = \beta_0 + \beta_l l_{it} \ + \ \beta_k k_{it} + g(k_{it}, m_{it}) + \nu_{it} \qquad (1.5)$$

or

$$y_{it} = \beta_l l_{it} \ + \ \phi(k_{it}, m_{it}) + \nu_{it} \qquad (1.6)$$

where

$$E(\nu_{it}|l_{it}, k_{it}, m_{it}) = 0 \qquad (1.7)$$

and

$$\phi(k_{it}, m_{it}) = \beta_0 + \ \beta_k k_{it} + g(k_{it}, m_{it}). \qquad (1.8)$$

To complete the first stage, the function ϕ in Eq.1.6 is approximated with a third-degree polynomial in $k_{it} and \ m_{it}$, and β_l is estimated using O.L.S.

The final stage sets out to identify β_k. First, the values of Eq.1.6 are estimated as

$$\hat{\phi}_{it} = \hat{y}_{it} - \hat{\beta}_l l_{it}. \qquad (1.9)$$

Then, using a potential estimate for β_k, say β_k^*, it is possible to estimate the productivity series as

$$\widehat{\omega}_{it} = \hat{\phi}_{it} - \beta_k^* k_{it}. \qquad (1.20)$$

In terms of Levinson and Petrin (2003), a consistent nonparametric approximation to $E(\omega_{it}|\omega_{it-1})$ is given by the predicted values from the nonlinear regression

$$E(\widehat{\omega_{it}|\omega_{it-1}}) = \widehat{\omega}_{it} = \gamma_0 + \gamma_1\omega_{it} + \gamma_2\omega_{it}^2 + \gamma_3\omega_{it}^3 + \vartheta_{it} \qquad (1.21)$$

Thus, given $E(\omega_{it}|\omega_{it-1})$, $\hat{\beta}_l$ and β_k^*, the estimate of β_k solves the minimization of the squared regression residuals

$$\min_{\beta_k^*} \sum_i \left(\hat{y}_{it} - \hat{\beta}_l l_{it} - \widehat{\beta_k^*} k_{it} - E(\omega_{it} \widehat{|\omega_{it-1}})\right)^2. \quad (1.22)$$

This procedure closes with a bootstrap based on random sampling from observations to construct standard errors of the capital and labour coefficient estimates as in Horowitz (2001).

In stark contrast to the two-step approach, Wooldridge (2009) proposes to simultaneously estimate the capital and labour coefficients by assuming CMI of the i.i.d error term with respect to current and past values of l_{it}, k_{it}, m_{it} .

CMI Assumption I:

$E(v_{it}|l_{it}, k_{it}, m_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{1t}, k_{1t}, m_{1t}) = 0$. This means the error term is conditional mean independent of, or uncorrelated with, the present and past production inputs. ■

Wooldridge (2009) restricts the dynamics of the unobserved productivity shocks and writes

$$E(\omega_{it}|l_{it}, k_{it}, m_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{1t}, k_{1t}, m_{1t})$$
$$= E(\omega_{it}|\omega_{it-1})$$
$$= j(g(k_{it-1}, m_{it-1}) \quad (1.23)$$

where $\omega_{it-1} = g(k_{it-1}, m_{it-1})$ and the productivity innovation a_{it} can be written as

$$\omega_{it} = j(\omega_{it-1}) + a_{it}. \quad (1.24)$$

The innovation in (1.24) may reflect heterogeneity and persistence in firm-level managerial ability, labour quality, etc.; see Gebreeyesus (2008).

CMI Assumption II:

$E(a_{it}|k_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{1t}, k_{1t}, m_{1t}) = 0$. Given the quasi-fixed nature of capital in firms due to irreversibility (see, for example, Caballero and Engel, 1999), the productivity innovation a_{it} is uncorrelated with the state variable k_{it} and all past inputs and their functions, but correlated with l_{it} and m_{it} .■

Substitution of Eq.1.23 and Eq.1.24 into Eq.1.1 yields

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + j(g(k_{it-1}, m_{it-1})) + u_{it} \quad (1.25)$$

where $u_{it} = a_{it} + v_{it}$. Notably, the arguments in the j(g(k_{it-1}, m_{it-1})) function are now lagged capital and intermediate inputs which can be approximated with low-order polynomials as in Levinsohn and Petrin (2003).

CMI Assumption III:

$E\left(u_{it}\middle|k_{it}, l_{it-1}, k_{it-1}, m_{it-1}, \ldots, l_{1t}, k_{1t}, m_{1t,}\right) = 0$. The error u_{it} is conditional mean independent of current capital and past values of all production inputs. In the presence of the productivity innovation in u_{it}, this Condition is identical to Conditional Mean Independence Assumption2 above. ■

Therefore, (1.1) becomes

$$y_{it} = \varphi_0^* + \beta_l l_{it} + \beta_k k_{it} + g(k_{it-1}, m_{it-1}) + u_{it} \quad (1.26)$$

or

$$y_{it} = \varphi_0^* + \beta_l l_{it} + \beta_k k_{it} + \sum_p^3 \sum_q^{3-p} \hat{\delta}_{pq} k_{it-1}^p m_{it-1}^q + u_{it}. \text{ ■■■} \quad (1.27)$$

Appendix A.6: Proportion of Non-Zero Input Observations

Industry (ISIC)	Investment	Material	Energy
Food and Food Products(15)	45.39	100.00	94.09
Textile (17)	30.51	100.00	99.44
Apparel (18)	20.31	100.00	100.00
Wood and Wood Products (20)	35.51	100.00	90.65
Paper and Paper Products (21)	61.82	100.00	89.09
Printing, Publishing (22)	23.12	100.00	96.48
Chemicals and Chemical Products (24)	26.36	100.00	90.70
Rubber and Plastic Products (25)	49.09	100.00	98.18
Other non-metallic Minerals (26)	29.45	100.00	93.25
Basic Metals (27)	9.68	100.00	100.00
Fabricated Metal Products (28)	33.16	100.00	91.98
Machinery and Equipment (29)	46.00	100.00	100.00
Furniture and Other Manufacturing (36)	32.32	100.00	97.98
Average	34.06	100.00	95.53

Source: Author's calculations from Data Compiled by the CSO

Appendix A.7: Aggregate multifactor productivity growth rate, Swaziland manufacturing 1994–2003: LP APG decomposition, manufacturing value-added index Single-deflator.

Year	Value-Added Growth	APG (0)	APG Decomposition: (0)= (1) + (2) + (3)					
				Reallocation				
			Technical Efficiency (1)	Total Reallocation (2)	Labour Reallocation	Working Proprietors Reallocation	Paid Employees Reallocation	Net Entry (3)
1995	7.76	2.51	0.91	-9.65	1.39	-1.48	2.87	11.25
1996	23.10	16.03	3.17	-7.89	0.92	-0.16	1.08	20.74
1997	-44.35	-34.12	-3.08	18.52	9.31	-0.06	9.37	-49.56
1998	265.55	240.84	1.67	-1.74	0.69	0.02	0.67	240.91
1999	275.57	261.04	1.23	9.22	2.94	-0.02	2.95	250.59
2000	-16.28	-16.07	-14.97	-5.48	0.42	-0.14	0.56	4.38
2001	37.42	34.85	8.71	20.43	0.42	0.43	-0.01	5.72
2002	-20.74	-21.81	-3.04	-29.53	-1.15	-1.21	0.06	10.76
2003	-36.71	-33.05	-22.31	2.69	8.35	-1.62	9.97	-13.43
Mean	**54.59**	**50.02**	**-2.77**	**-0.38**	**2.33**	**-0.42**	**2.75**	**53.48**
Median	**7.76**	**2.51**	**0.91**	**-1.74**	**0.92**	**-0.14**	**1.08**	**10.76**
Std Dev	**125.32**	**116.24**	**9.66**	**15.46**	**3.70**	**0.75**	**3.90**	**110.93**

Notes: As in Nishida *et al.* (2014), numbers are percentage growth rates. The plant-level multifactor productivity is calculated by using production function parameters that vary across 2-digit ISIC. We obtain the estimates by using Wooldridge (2009). APG represents the aggregate productivity growth with entry and exit, which is defined as aggregate change in final demand *minus* aggregate expenditure in inputs, holding input constant. We use value-added share (Domar) for weights. APG is decomposed into four components: (1) technical efficiency, (2) reallocation, and (3) net entry term, using Eq. 17 in text.

Appendix A.8: Aggregate multifactor productivity growth rate, Swaziland manufacturing 1994–2003: LP APG decomposition, consumer price index double-deflator.

Year	Value-Added Growth	APG (0)	APG Decomposition: (0)= (1) + (2) + (3)						
			Technical Efficiency (1)	Reallocation					Net Entry (3)
				Total Reallocation (2)	Labour Reallocation	Working Proprietors Reallocation	Paid Employees Reallocation		
1995	27.96	19.22	7.23	-0.95	2.53	-0.89	3.41		12.94
1996	21.85	11.94	1.63	-7.17	1.40	-0.30	1.71		17.48
1997	-41.95	-27.47	-1.81	20.30	10.07	-0.05	10.11		-45.96
1998	268.72	235.19	1.93	-1.48	-0.04	0.01	-0.05		234.74
1999	270.96	251.41	0.97	8.69	3.01	-0.01	3.01		241.75
2000	-17.72	-17.44	-16.14	-6.01	0.61	-0.18	0.79		4.72
2001	42.77	39.22	9.56	23.23	0.53	0.44	0.09		6.44
2002	-23.53	-24.96	-4.76	-31.25	-1.23	-1.28	0.05		11.06
2003	-36.51	-31.45	-22.93	3.59	9.67	-0.43	10.10		-12.10
Mean	**56.95**	**50.63**	**-2.43**	**0.99**	**2.65**	**-0.27**	**2.92**		**52.34**
Median	**21.85**	**11.94**	**0.97**	**-0.95**	**1.40**	**-0.18**	**1.71**		**11.06**
Std Dev	**124.24**	**111.90**	**10.59**	**16.20**	**4.12**	**0.52**	**4.09**		**107.13**

Notes: As in Nishida *et al.* (2014), numbers are percentage growth rates. The plant-level multifactor productivity is calculated by using production function parameters that vary across 2-digit ISIC. We obtain the estimates by using Wooldridge (2009). APG represents the aggregate productivity growth with entry and exit, which is defined as aggregate change in final demand *minus* aggregate expenditure in inputs, holding input constant. We use value-added share (Domar) for weights. APG is decomposed into four components: (1) technical efficiency, (2) reallocation, and (3) net entry term, using Eq. 17 in text.

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