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# EXPLORING REALLOCATION'S APPARENT WEAK CONTRIBUTION TO GROWTHˆ

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Exploring Reallocation’s Apparent Weak Contribution to Growthˆ
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## ABSTRACT

Two recent meta-analyses use variants of the Baily, Hulten, and Campbell (1992) (BHC) decompositions to ask whether recent robust growth in Aggregate Labor Productivity (ALP) across twenty-five countries is due to lower barriers to input reallocation. They find weak gains from measured reallocation and strong within-plant productivity gains. We show these findings may be because BHC indices decompose ALP growth using plant-level output-per-labor (OL) as a proxy for the marginal product of labor and changes in OL as a proxy for changes in plant-level productivity. We provide simple examples to show that 1) reallocation growth from labor should track marginal changes in labor weighted by the marginal product of labor, 2) BHC reallocation growth can be positively correlated, negatively correlated, or uncorrelated with actual growth arising from the reallocation of inputs, and that 3) BHC indices can mistake growth from reallocation as growth from productivity, principally because OL is neither a perfect index of marginal products nor plant-level productivity. We then turn to micro-level data from Chile, Colombia, and Slovenia, and we find for the first two that BHC indices report weak or negative growth from labor reallocation. Using the reallocation definition based on marginal products we find a positive and robust role for labor reallocation in all three countries and a reduced role of plant-level technical efficiency in growth. We close by exploring potential corrections to the BHC decompositions but here we have limited success.

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# 1 Introduction

Recent empirical work by Hsieh and Klenow (2009) and Petrin and Sivadasan (2013) finds that there are large differences between inputs' marginal products across plants in China, India, and Chile, suggesting the existence of barriers to the reallocation of inputs. Policy-makers have speculated that the elimination of these barriers should lead to economic growth from reallocation and in the last few decades this presumption has led to reforms in many countries targeted at reducing them.

Two recent meta-analyses - one by Bartelsman, Haltiwanger, and Scarpetta (2004) (BHS) and one by Pages, Pierre, and Scarpetta (2009) (PPS) - together examine twenty-five countries across Europe, the Americas, and East Asia, many of which have recently adopted reforms aimed at facilitating the freer movement of inputs across plants. They show that there has been strong growth in aggregate labor productivity (ALP) - defined as aggregate value-added divided by total labor - across most of these countries.[1] In order to examine the sources of this growth both studies decompose ALP into "real productivity" and "reallocation" components using the approaches from Baily, Hulten, and Campbell (1992) (BHC) and Foster, Haltiwanger, and Krizan (2001) (FHK). These decompositions include three terms, a "within" growth term which increases when establishment-level value-added-per-labor increases, a "between" growth term which increases when labor shares increase at establishments with higher value-added-per-labor, and a "cross" or "covariance" term that increases when there is a contemporaneous increase in labor shares and value-added-per-labor. The first term is regarded as the contribution of real productivity to growth, the second term is regarded as the contribution of the reallocation of inputs to growth, and the final term includes a mix of both sources of growth.

Contrary to the folk-wisdom of reallocation following deregulation, the main findings from both papers are that most of the growth has been driven by within-plant productivity growth.[2]

[1] The complete list from BHS is Argentina, Chile, Colombia, Estonia, Finland, France, Korea, Latvia, Netherlands, Portugal, Slovenia, Taiwan, UK, USA, and West Germany. The complete list from PPS is Venezuela, Nicaragua, Peru, Paraguay, Brazil, Mexico, El Salvador, Colombia, Panama, Costa Rica, Argentina, Dominican Republic, and Chile.

[2] See Figure 4.8 in PPS and Figure 9 in BHS.

Nine of the twenty-five countries have negative between-plant reallocation and four more have weak positive between-plant reallocation. Twenty-three of the twenty-five countries have a covariance term that is negative. The United States, for example, had both a negative between term and a negative covariance term over the years 1987-1997, suggesting inputs were moving from high-value to low-value activities during a period when GDP growth averaged a robust 3% per annum.

In this paper we explore possible reasons for this apparent weak or negative contribution of input reallocation to growth during prosperous times. We start by showing that both the within and the between components of ALP growth can lead to mistaken inferences in terms of characterizing the sources of growth. Consider a single-good economy with two plants that convert the single input labor into output via the production functions

$$Q_i = \omega_i \, l^{\beta_l}, \;\; i = 1, 2$$

with $\omega_i$ denoting plant-level technical efficiency and $\beta_l < 1$. At the output-maximizing allocation of labor $(l_1^*, l_2^*)$ marginal products are equated across plants

$$\frac{\partial Q_1(l_1^*)}{\partial l} = \frac{\partial Q_2(l_2^*)}{\partial l}$$

as are output-to-labor ratios,

$$\frac{Q_1(l_1^*)}{l_1^*} = \frac{Q_2(l_2^*)}{l_2^*}.$$

Now suppose $\Delta l$ of labor is reallocated from plant 2 to plant 1. The marginal products are such that

$$\frac{\partial Q_1(l_1^* + l)}{\partial l} < \frac{\partial Q_2(l_2^* - l)}{\partial l} \quad \forall l > 0,$$

so aggregate output falls by $\Delta Q$, the integral over the differences in these marginal products:

$$\Delta Q = \int_0^{\Delta l} (\frac{\partial Q_2(l_2^* - l)}{\partial l} - \frac{\partial Q_1(l_1^* + l)}{\partial l}) dl,$$

which is the difference between the lost output at plant 2 and the gained output at plant 1.

How do BHC and FHK behave? If we let $\Delta s_i$ denote the change in share then the BHC/FHK between terms are given as

$$\Delta s_1 \frac{Q_1(l_1^*)}{l_1^*} + \Delta s_2 \frac{Q_2(l_2^*)}{l_2^*},$$

so despite output falling due to labor reallocation both the BHC and FHK between terms are *zero* because the output-per-labor ratios are equal before labor is reallocated and $\Delta s_1 = -\Delta s_2$. On productivity growth the BHC/FHK within-terms sum the product of the base-period share times the change in output-per-labor across firms. It is straightforward to show that $\Delta \frac{Q_1}{l_1} < 0$ and $\Delta \frac{Q_2}{l_2} > 0$ so the within term is *non-zero* even though there is no change in the technical efficiency term $\omega_i$. The example illustrates that the use of the base period output-per-labor as an index for reallocation can be problematic because it is not equal to the marginal product of labor at either plant once labor starts reallocating. Similarly, on productivity growth the use of the change in output-per-labor as an index of the change in plant-level productivity is problematic because, except for the special case of constant returns to scale, output-per-labor changes in response to changes in input levels without any change in technical efficiency.

In Section 2 we generalize this example in two ways. We show that 1) BHC/FHK reallocation can be positively correlated, negatively correlated, or uncorrelated with actual growth arising from the reallocation of inputs, and that 2) consistent with the empirical findings of BHS/PPS, it is easy to construct examples where with strong ALP growth that is entirely due to reallocation BHC/FHK find that within growth is strong, between growth is weak, and the covariance term is strongly negative.

In Sections 3 and 4 we turn to micro-level data from Chile, Colombia, and Slovenia to try to understand whether the findings in BHS and PPS may be due to the use of output-per-labor as an index of both changes in technical efficiency and changes in marginal products. These three countries went through periods of deregulation prior to or during our sample periods and they all experienced strong ALP growth over the balance of these periods. In addition to calculating BHC/FHK on all three data sets, we use the framework from Petrin and Levinsohn (2012), where the aggregation of establishment-level changes of technical efficiency and input reallocations add up exactly to changes in aggregate value added, holding primary input use constant.[3] This definition leads to a decomposition that calculates labor reallocation by tracking marginal changes in labor weighted by the marginal product of labor instead of output-per-labor, just as in the calculation of $\Delta Q$ above.[4]

We show that the findings of BHS and PPS are qualitatively the same as what we find in our data. In Slovenia we find reasonably strong between reallocation using BHC/FHK, but in Chile and Colombia there is weak between growth. We also find that the covariance term is negative in all 40 country-year pairs in our data. In contrast, when we use the definition of labor reallocation based on marginal products we find labor's reallocation contributes positively and meaningfully to growth in 31 of the 40 country-year pairs in our data, More generally, aggregate input reallocation is positive in 36 of the 40 country-year pairs and it accounts for most of the economic growth that takes place relative to technical efficiency growth.[5]

There are other measurement issues that arise with the BHC/FHK definition of reallocation and we spend the final sections of the paper investigating whether correcting for these measurement issues changes the outcomes of the BHC/FHK decompositions. In Section 6 we show that the aggregate labor productivity between term can be decomposed into a term related to reallocation and a term related to the change in the total number of establishments, the latter of which often works to reduce the total between term in our data. In Chile and Colombia separating out the number of establishments term leads to a small but positive increase in between reallocation while in Slovenia it leads to a dramatic increase in between reallocation.

In Section 7 we then look to see whether the decompositions change when we control for capital and labor heterogeneity across establishments by using total factor productivity instead of ALP. We also try to control for unobserved prices and unobserved levels of capacity utilization, and we look at five year differences for all three countries instead of annual

[3] Applications include Petrin, White, and Reiter (2011), Cubas et al. (2011), and Kwon et al. (2009).

[4] It is straightforward to show that the reallocation gains calculated in Restuccia and Rogerson (2008), Hsieh and Klenow (2009), and Petrin and Sivadasan (2013) are special cases of the reallocation framework in Petrin and Levinsohn (2012), and that their setup nests measured growth and reallocation in any theory model that defines aggregate productivity growth as they do. For example, this includes the models of reallocation by Aghion and Howitt (1992), Aghion and Howitt (1994), Caballero and Hammour (1994), Ericson and Pakes (1995), Melitz (2003), or Lentz and Mortensen (2008).

[5] The numbers do not exactly match with BHS's or PPS's numbers for these three countries due to several differences, including sample years.

observations. None of these corrections changes the substance of the BHC/FHK findings. We now turn to the discussion of the ALP decompositions.

# 2 Decompositions of Aggregate Labor Productivity Growth

We review the most popular decompositions of ALP and then provide two examples that illustrate how the these decompositions can be misleading in their assessment of the sources of growth.

## 2.1 Continuous Time ALP and Discrete Time Approximations

We denote the amount of labor input and value added of plant $i$, at time $t$ by $L_{it}$ and $VA_{it}$ respectively. For a given plant, $VL_{it} = \frac{VA_{it}}{L_{it}}$ is value added per laborer, or plant-level labor productivity, $L_t = \sum_i L_{it}$ is aggregate labor input in the economy, and $s_{it} = \frac{Lit}{L_t}$ is the employment share of plant $i$ at time $t$. Aggregate labor productivity (ALP) at time $t$ - $VL_t$ - is then defined as

$$VL_t = \frac{\sum_i VA_{it}}{\sum_i L_{it}}.$$

We can then express $VL_t = \sum_i \frac{L_{it}}{L_t} * \frac{VA_{it}}{L_{it}} = \sum_i s_{it} * VL_{it}$, so the change in $VL_t$ in continuous time is the sum of the following two components: $d(VL_t) = \sum_i s_{it}\, dVL_{it} + \sum_i ds_{it}\, VL_{it}$.

Data are not reported in continuous time so practitioners use discrete time approximations to continuous time growth. We employ the two most popular approximations, one from Baily, Hulten, and Campbell (1992) and one from Foster, Haltiwanger, and Krizan (2001), each of which decomposes ALP into a real productivity growth and a reallocation component. Both of these decompositions add up to

$$\frac{VL_t - VL_{t-1}}{VL_{t-1}} \tag{1}$$

but differ in the ways they decompose the numerator $A \equiv VL_t - VL_{t-1}$. In what follows, we compare how each method decomposes the numerator of the growth rate in equation (1), $VL_t - VL_{t-1}$.

The most commonly used form of ALP decomposition, which is used in Pages, Pierre, and

Scarpetta (2009), is Baily, Hulten, and Campbell (1992) and given by

$$
\begin{aligned}
A_1 \quad \equiv \quad & \underbrace{\sum_{i \in \mathbf{C}} s_{it-1} * \Delta VL_{it}}_{\text{Within effect}} + \underbrace{\sum_{i \in \mathbf{C}} VL_{it-1} * \Delta s_{it}}_{\text{BHC between effect}} + \underbrace{\sum_{i \in \mathbf{C}} \Delta VL_{it} * \Delta s_{it}}_{\text{Cross term}} \\
& \underbrace{+\sum_{i \in \mathbf{E}} s_{it} * VL_{it} - \sum_{i \in \mathbf{X}} s_{it-1} * VL_{it-1}}_{\text{BHC Net Entry}}, \qquad (2)
\end{aligned}
$$

where $\Delta VL_{it} = VL_{it} - VL_{it-1}$, $\Delta s_{it} = s_{it} - s_{it-1}$, and $\mathbf{C}$, $\mathbf{E}$, and $\mathbf{X}$ denote the set of continuing, entering, and exiting establishments at time $t$.[6] The first term is the sum of establishment-level changes in value added-per-laborer and is referred to as the within-continuing-plant productivity growth term, or simply the "within effect." The second term is the sum of changes in employment share times the establishment-level value added-per-laborer at time $t-1$ and is referred to as the reallocation term for continuing establishments, or the "between effect." The between term contributes positively to ALP when the labor market share of higher value added-per-laborer plants at time $t-1$ increases from $t-1$ to $t$. The cross term or "covariance" contributes positively when plants with increasing labor shares are also plants that have increases in value added-per-worker. The between term is viewed as the "clean" reallocation term because it holds real productivity constant while the covariance term contains both growth from real productivity and reallocation. The last two terms reflect the impact of net entry on ALP.[7]

[6] We follow the convention in the literature by using time $t-1$ weights for the within and between terms in both BHC and FHK decomposition. Appendix D discusses alternative representations of the BHC decomposition using other weights.

[7] The only difference between Pages, Pierre, and Scarpetta (2009) our decomposition is that we include entrants and exiters and they focus only on continuing plants. This difference does not affect the substance of our findings.

The FHK decomposition is given by

$$A_2 \equiv \underbrace{\sum_{i\in\mathbf{C}} s_{it-1} * \Delta VL_{it}}_{\text{Within effect}} + \underbrace{\sum_{i\in\mathbf{C}} (VL_{it-1} - VL_{t-1}) * \Delta s_{it}}_{\text{FHK Between effect}} + \underbrace{\sum_{i\in\mathbf{C}} \Delta VL_{it} * \Delta s_{it}}_{\text{Cross term}}$$
$$\underbrace{+\sum_{i\in\mathbf{E}} s_{it} * (VL_{it} - VL_{t-1}) - \sum_{i\in\mathbf{X}} s_{it-1} * (VL_{it-1} - VL_{t-1})}_{\text{FHK Net Entry}}. \quad (3)$$

The FHK within term and the covariance term are identical to those of BHC decomposition in equation (2). The FHK between term differs from the BHC between term in that it is positive if establishments with above-average productivity increase their shares $s_{it}$. Because BHC and FHK sum to the same quantity by construction, the difference in the FHK between term and the BHC between term exactly equals the difference in the BHC net entry term and the FHK net entry term. We now explore the ALP decomposition in two simple examples.

## 2.2 Decomposing Growth: Example One

We consider a single-good economy with the single input labor in which there are $N$ producers that differ in their elasticities of output with respect to labor (or productivity in this setup):

$$Q_i = \omega\, l^{\beta_i},$$

with $\beta_i < 1$ $i = 1, \ldots, N$.[8] The consumption good price is normalized to 1 and labor is supplied at constant wage $w$. Plants solve

$$max_l\, Q_i(l) - wl$$

and in the competitive equilibrium, which is also the welfare maximizing equilibrium, plants will choose labor such that $\frac{\partial Q_i(l)}{\partial l} - w = 0$. Thus in equilibrium plants that have higher $\beta_i$'s

[8] For a setting with heterogeneous consumers, differentiated products, and imperfect competition see Petrin and Levinsohn (2012).

will use more labor and have *lower* output-to-labor ratios given by

$$\frac{Q_i}{l_i} = \frac{w}{\beta_i}.$$

As in Hsieh and Klenow (2009) we introduce taxes or subsidies $\tau_i$ $i = 1, \ldots, N$ on the output of each plant, which leads plants to solve the new problem:

$$max_l \left[\frac{1}{1+\tau_i}\right] Q_i(l) - wl$$

and thus choose labor such that

$$\frac{\partial Q_i(l)}{\partial l} - (1+\tau_i)w = 0.$$

Aggregate output falls because labor reallocates from the taxed to the subsidized plants. If $l_i(t_i)$ denotes the chosen labor level at plant $i$ for any given level of tax $t_i$ then the cost in terms of lost output of each tax $\tau_i$ can be expressed as the integral over the difference between the marginal product and the wage from $l_i^0 = l_i(0)$ to $l_i^1 = l_i(\tau_i)$:

$$\int_{l_i^0}^{l_i^1} \left(\frac{\partial Q_i(l)}{\partial l} - w\right) dl = -\frac{\tau_i^2}{2} w \tag{4}$$

for each $i$ so total welfare falls by $-\sum_{i=1}^{N} \frac{\tau_i^2}{2} w$.

Depending upon how the taxes/subsidies correlate with the $\beta_i$'s, the BHC and FHK between terms can be negative, zero, or positive. If taxes/subsidies are independent of the $\beta_i$'s then the plant-level changes in shares will be independent of the initial output-per-labor ratios. Since the sum of the changes in shares always equals zero, the expected value of BHC/FHK between terms equals zero.[9] If the taxes/subsidies are positively correlated with $\beta_i$ - so more productive plants are taxed and less productive plants are subsidized - labor will move in the direction of the low $\beta_i$ plants, labor shares will increase at the plants that initially have higher output-per-labor plants and decrease at plants that initially have lower output-

[9] As the number of plants increases the between term converges to zero.

per-labor plants, leading to positive measured reallocation. Similarly, if the taxes/subsidies are such that the more productive plants are subsidized and the less productive plants are taxed then labor shares will increase (decrease) at the lower (higher) output-per-labor plants, leading to negative measured reallocation. Thus the between term can be uncorrelated, negatively correlated, or positively correlated with the actual change in output because initial output-per-labor ratios do not reflect the changes in marginal products that occur as labor is reallocated.

On measured aggregate productivity growth the finding is similar, as changes in output-per-labor do not reflect changes in technical efficiency. While there has been no change in the $\beta_i$'s, one can show plants' output-per-labor ratios change by

$$\Delta \frac{Q_i}{l_i} = \tau_i \frac{w}{\beta_i},$$

so the BHC/FHK aggregate real productivity growth terms will generally be *non-zero*. For example, in general there will be positive aggregate real productivity growth if the high $\beta_i$ plants are taxed and the low $\beta_i$ plants are subsidized as the high labor-share plants have increasing output-per-labor ratios and the low labor-share plants have decreasing output-per-labor ratios.

## 2.3 Decomposing Growth: Example Two

Here we provide a simple numerical example that illustrates it is easy to mimic the general findings in the BHS/PPS studies of strong positive measured within growth, negative but small between growth, and strong negative covariance term when there is no change in technical efficiency but when barriers to the movements of inputs are eliminated. We use the production function from the previous section and set $N = 2$, $\beta_1 = 0.8$, $\beta_2 = 0.5$, $\omega = 2$, and let there be 2.515 units of labor. In the output maximizing setting marginal products are equated with 2 units of labor at plant 1 and 0.515 units of labor at plant 2. Now suppose the economy is in a state where there are 1.5 units at plant 1 and 1.015 units at plant 2 with barriers preventing reallocation. If these barriers are removed so the inputs are reallocated to the output maximizing setting then one can show that ALP increases by 0.054 (5.4%). Even though all growth is due to reallocation the ALP decomposition has a within component that is 0.262, a between component that is -0.028, and a covariance component that is -0.179.[10]

# 3 Aggregate Productivity Growth and Reallocation

We start by illustrating the Petrin and Levinsohn (2012) decomposition of aggregate productivity growth (APG) in a setting with no intermediate inputs or capital and in Section 3.2 we generalize the setup. In both cases APG is defined such that aggregation of plant-level changes in technical efficiency and input reallocations add up to changes in final demand, holding capital and labor use constant.

## 3.1 One-input Economy

There are $N$ plants in the economy each producing a single good with a single input labor $l$. Production technologies are given by

$$Q_i(l_i, \omega_i),$$

with $\omega_i$ denoting the level of plant $i$'s technical efficiency. With no intermediate inputs total output at plant $i$ that goes to final demand is just $Q_i$. Assuming a common wage $W$ and letting $P_i$ denote the price of plant i's output APG is then given as the difference between the change in aggregate final demand and the change in aggregate costs:

$$APG \equiv \sum_i P_i dQ_i - \sum_i W dl_i, \tag{5}$$

[10]Specifically, the production functions are given as $Q_1 = 2\,l^{0.8}$ and $Q_2 = 2\,l^{0.5}$ so at the distorted/non-distorted levels of labor allocation firm 1 produces 2.766/3.482 and firm 2 produces 2.014/1.435 units of output, so total output increase with the removal of the distortions from 4.781 to 4.917, or 0.136, giving an increase in ALP of 0.136/2.515 = 0.054. Output-per-labor for firm 1 decreases by -0.103 from 1.844 to 1.741 and for firm 2 increases by 0.801 from 1.985 to 2.786. The share of labor at firm 1 increases by 0.198 (from 0.596 to 0.795) and decreases at firm 2 by -0.198 (from 0.403 to 0.204). The within term is then given by -0.103*0.596+0.801*0.403 = 0.262, the between term is 1.844*0.198-1.985*0.198=-0.028, and the covariance term is -0.103*0.198-0.801*0.198=-0.179.

By totally differentiating $Q_i(l_i, \omega_i)$ one can see that (5) decomposes as:

$$\sum_i (P_i \frac{\partial Q_i}{\partial l} - W) dl_i + \sum_i P_i \frac{\partial Q_i}{\partial \omega_i} d\omega_i. \tag{6}$$

$\sum_i P_i \frac{\partial Q_i}{\partial \omega_i} d\omega_i$ are the total gains from technical efficiency changes and are equal to the sum over $i$ of the value of the extra output firm $i$ is able to produce given $d\omega_i$. Reallocation growth is given by

$$\sum_i (P_i \frac{\partial Q_i}{\partial l} - W) dl_i$$

so if $dl_i$ of labor that was previously unemployed is reallocated to plant $i$ then the value of aggregate output changes by $(P_i \frac{\partial Q_i}{\partial l} - W)$, the difference between the value of the marginal product and the input price. In the case where a small amount of labor reallocates from $j$ to $i$ so $dl_i = -dl_j$ aggregate output would change by difference in the value of marginal products between $i$ and $j$:

$$P_i \frac{\partial Q_i}{\partial l} - P_j \frac{\partial Q_j}{\partial l}.$$

In the case that labor reallocates across plants but total labor is held constant ($\sum_i dl_i = 0$), the change in aggregate output from reallocation is given by

$$\sum_i P_i \frac{\partial Q_i}{\partial l} dl_i.$$

We return to the theory examples where we have changes in labor that are not infinitesimal, so the value of the marginal products must be integrated over the changes in labor to calculate labor reallocation. In example one with a common output price $P_i = 1$ and common wage $W_i = w$ for all $i$, the aggregate change in output due to labor reallocation would be given as noted earlier:

$$\sum_{i=1}^{N} \int_{l_i^0}^{l_i^1} \left( \frac{\partial Q_i(l, \omega_i)}{\partial l} - w \right) dl = -\sum_{i=1}^{N} \frac{\tau_i^2}{2} w. \tag{7}$$

In example two it is straightforward to show integration over the changes in marginal products yields growth from labor reallocation (divided by total labor) exactly equal to 5.4%.[11] In both cases the changes in aggregate output due to reallocation equal what the Petrin and Levinsohn (2012) decomposition reports for labor reallocation because that is how they define reallocation.

### 3.2 General Setup

The production technology is now given by $Q_i(X_i, M_i, \omega_i)$, where $X_i = (X_{i1}, \ldots, X_{iK})$ is the vector of K primary input amounts (types of labor and capital) used at plant $i$ and $M_i = (M_{i1}, \ldots, M_{iJ})$ is the vector giving the amount of each plant $j$'s output used as an intermediate input at plant $i$.[12] The total amount of output from plant $i$ that goes to final demand $Y_i$ is then

$$Y_i = Q_i - \sum_j M_{ji},$$

where $\sum_j M_{ji}$ is the total amount of $i$'s output that serves as intermediate input within plant $i$ and across other plants $j \neq i$. The amount of $i$'s output that goes to final demand is then given as $dY_i = dQ_i - \sum_j dM_{ij}$. APG is again given as the difference between the change in aggregate final demand and the change in aggregate costs, and in this generalized setup is equal to:

$$APG \equiv \sum_i P_i dY_i - \sum_i \sum_k W_{ik} dX_{ik}, \tag{8}$$

where $W_{ik}$ equals the unit cost to $i$ of the $k^{th}$ primary input and $dX_{ik}$ is the change in the use of that primary input at plant $i$.[13]

[11] The difference in the integrals is given by

$$\frac{\Delta Q}{2.515} = \frac{1}{2.515}\left(\int_{1.5}^{2} 1.6\, l^{-0.2} dl - \int_{0.515.}^{1.015} l^{-0.5} dl\right) = 5.4\%.$$

[12] Here we suppress their fixed cost term for transparency.

[13] In the general setup from Petrin and Levinsohn (2012) the path of primary and intermediate inputs and productivity shocks for plant $i$ is given as $Z_{it} = (X_{it}, M_{it}, \omega_{it})$, $t \in [0,1]$. For the entire economy they write $Z_t = (Z_{1t}, Z_{2t}, \ldots, Z_{Nt})$. Given $Z_t$, output quantities are determined by the production technologies and $Q_t = (Q_{1t}(Z_{1t}), \ldots, Q_{Nt}(Z_{Nt}))$. Prices are assumed to be uniquely determined by $Q_t$, given as $P_t = (P_{1t}(Q_t), \ldots, P_{Nt}(Q_t))$, and similarly for primary input costs $W_t = (W_{1t}(Z_t), \ldots, W_{Kt}(Z_t)))$. $Y_{it}$ can then be directly calculated for all $i$ and $t \in [0,1]$.

(8) decomposes as:

$$\sum_i \sum_k (P_i \frac{\partial Q_i}{\partial X_k} - W_{ik}) dX_{ik} + \sum_i \sum_j (P_i \frac{\partial Q_i}{\partial M_j} - P_j) dM_{ij} + \sum_i P_i \frac{\partial Q_i}{\partial \omega_i} d\omega_i, \tag{9}$$

where $\frac{\partial Q_i}{\partial X_k}$ and $\frac{\partial Q_i}{\partial M_j}$ are the partial derivatives of the output production function with respect to the $kth$ primary input and the $jth$ intermediate input respectively, $dM_{ij}$ is the change in intermediate input $j$ at plant $i$. $\sum_i P_i \frac{\partial Q_i}{\partial \omega_i} d\omega_i$ is again the gains from technical efficiency changes and reallocation is now given as

$$\sum_i \sum_k (P_i \frac{\partial Q_i}{\partial X_k} - W_{ik}) dX_{ik} + \sum_i \sum_j (P_i \frac{\partial Q_i}{\partial M_j} - P_j) dM_{ij}.$$

where the reallocation terms include a value of marginal product term and an input cost term for each plant and every primary and intermediate input. We now turn to estimation.

### 3.3 Estimation

For estimation we work with the value-added production function. In growth rates APG by this definition can be expressed as the weighted sum of establishment-level growth rates in value added minus the establishment-level growth rates in primary inputs and is given as

$$APG = \sum_i D_i^v dlnVA_i - \sum_i \sum_k s_{ik} dlnX_{ik}, \tag{10}$$

with $D_i^v = \frac{VA_i}{\sum_i VA_i}$(the Domar weight) and the cost share for the $k$th primary input given as $s_{ik} = \frac{W_{ik} X_{ik}}{\sum_i VA_i}$. We write the value-added production function as

$$ln(VA_i) = \sum_k \varepsilon_{ik}^v lnX_{ik} + ln\omega_i^v, \tag{11}$$

with $\varepsilon_{ik}^v$ denoting the elasticity of (value-added) output with respect to the primary inputs, and the establishment-level value-added technical efficiency given as $ln\omega_i^v$. APG can then be decomposed as

$$\underbrace{\sum_i D_i^v \sum_k (\varepsilon_{ik}^v - s_{ik}) dlnX_{ik}}_{\text{Reallocation of Labor and Capital}} + \underbrace{\sum_i D_i^v \sum_j (\varepsilon_{ij}^v - s_{ij}) dlnM_{ij}}_{\text{Reallocation of Materials}} + \underbrace{\sum_i D_i^v dln\omega_i^v}_{\text{Technical Efficiency}} . \quad (12)$$

Aggregate growth arising from the reallocation of primary inputs is given by $\sum_i D_i^v \sum_k (\varepsilon_{ik}^v - s_{ik}) dlnX_{ik}$ and growth from aggregate technical efficiency - the analog to the within term from ALP - is given by $\sum_i D_i^v dln\omega_i^v$.

Equation (10) can be estimated directly from the discrete data using Tornquist-Divisia approximations.[14] We estimate production function parameters in equation (11) separately for each SIC 3-digit industry code for Chile and Colombia and NACE 2-digit industry code for Slovenia using the proxy method from Wooldridge (2009) that modifies Levinsohn and Petrin (2003) to address the simultaneous determination of inputs and productivity.[15] The estimate of establishment-level technical efficiency is then

$$\widehat{ln\omega^v}_{it} = ln(VA_{it}) - \left( \widehat{\epsilon^v}_{jP} \, lnL_{it}^P + \widehat{\epsilon^v}_{jNP} \, lnL_{it}^{NP} + \widehat{\epsilon^v}_{jK} \, lnK_{it} \right),$$

where $\widehat{\epsilon^v}_{j\cdot}$ denote the estimated elasticities of value added with respect to the inputs in industry $j$. We use Tornquist-Divisia approximations for each term in equation (12).[16] We use three primary inputs as regressors: production (blue-collar) workers $L_{it}^P$, non-production (white-collar) workers $L_{it}^{NP}$, and capital $K_{it}$ and aggregate the two labor inputs in our reallocation results.

[14]We chain-weight to update prices on an annual basis (they are included in the Domar weights). For example, $APG = \sum_i \overline{D}_{it}^v \Delta lnVA_{it} - \sum_i \overline{D^v}_{it} \sum_k \overline{s}_{ikt}^v \Delta lnX_{ikt}$ where $\overline{D}_{it}^v$ is the average of establishment $i$'s value-added share weights from period $t-1$ to period $t$, $\Delta$ is the first difference operator from period $t-1$ to period $t$, $\overline{s}_{ikt}$ is the average across the two periods of establishment $i$'s expenditures for the kth primary input as a share of establishment-level value-added.

[15]The approach is robust to the comment by Ackerberg, Caves, and Frazer (2008) and is one line of code in Stata.

[16]For the reallocation terms we use the approximations $\sum_i \overline{D}_{it}^v \sum_k (\varepsilon_{ik}^v - \overline{s}_{ikt}) \Delta lnX_{ikt}$ and $\sum_i \overline{D}_{it}^v \sum_j (\varepsilon_{ij}^v - \overline{s}_{ijt}) \Delta lnM_{ijt}$. For the within growth (technical efficiency) term we use $\sum_i \overline{D}_{it}^v \Delta ln\omega_{it}^v$.

## 4 Data and Results

This section describes our plant-level manufacturing data from Chile and Colombia, and firm-level data from Slovenia and our findings.

**Chilean and Colombian Manufacturing Data** The Chilean and Colombian data are annual and span the periods of 1979-95 and 1977-91, respectively. Here we provide a brief overview of these data. Numerous other productivity studies use them, and we refer interested readers to those papers for a more detailed data description.[17]

The Chilean data, provided by Chile's Instituto Nacional de Estadistica (INE), are unbalanced panels and cover all manufacturing plants with at least 10 employees. The Colombian data from the Annual Manufacturing Survey, provided by Colombia's Departamento Administrativo Nacional de Estadistica (DANE), are also unbalanced panels and cover all plants for the years 1977-82 and the plants with at least 10 employees for the years 1983-91. In both data sets, plants are observed annually and they include a measure of nominal gross output, two types of labor, capital, and intermediate inputs, including fuels and electricity. Labor is the number of man-years hired for production, and plants distinguish between their blue- and white-collar workers. Liu (1991) documents the method for constructing the real value of capital for the Chilean data, and we use the same method for the Colombian data.[18] We use double-deflated value added for Chilean results and single-deflated value added for Colombia because intermediate input deflators are not available there.[19]

**Slovenian Manufacturing Data** For Slovenian data, we use the annual accounting data provided by the Slovenian Statistical Office and other sources from 1994 through 2004.

[17] See Liu (1991), Liu (1993), Liu and Tybout (1996), and Levinsohn and Petrin (2003) for the Chilean data and Roberts (1996) for the Colombian data.

[18] For the Chilean data, the real value of capital is a weighted average of the peso value of depreciated buildings, machinery, and vehicles. We assume each has a depreciation rate of 5%, 10%, and 20%, respectively. Some plants don't report initial capital stock, although they record investment. When possible, we used a capital series that they report for a subsequent base year. For a small number of plants, they don't report capital stock in any year. We estimated a projected initial capital stock based on other reported plant observables for these plants. We then used the investment data to fill out the capital stock data.

[19] See Appendix C for the details of the construction of double-deflated value-added.

Our data are an unbalanced panel and covers all manufacturing firms.[20] We use single-deflated value added because no intermediate input deflator is available. The Slovenian data are distinct from Chilean and Colombian data in that it is firm-level data and not plant-level data and there exists both a firm-level deflator and a capacity utilization rate for a subset of firms.

As an ex-socialist country Slovenia went through extensive changes in its economic system starting in 1988. The deregulation of entry in 1988 allowed the setup of privately owned firms and resulted in expansion of private businesses. In addition, price and wage liberalization took place during the period of 1987-93. The process of privatization of state-owned firms started in 1994 and continued throughout the 1990s. For this reason, several empirical studies of productivity dynamics have used Slovenian data.[21]

### 4.1 ALP and APG Decompositions for Chile, Colombia, and Slovenia

We show the same weak patterns for ALP reallocation raised elsewhere exist for our manufacturing data from Chile and Colombia. We also show that when we decompose growth using APG we find a much smaller role for within-firm growth and a stronger role for reallocation relative to ALP.

Tables 1 and 2 document these facts for Chile. The second column in Table 1 is the annualized growth rate of aggregate value added and the third column is the growth rate of aggregate labor productivity. Most of the Pinochet market-based reforms were put into place by 1980 and aggregate value added increased on average by 4.16% over the sample period. While ALP increased by somewhat less over the entire sample period - 0.73% per year - if one focuses on the more recent history of 1988 to 1995 ALP is over 3% per year.

Columns 4 through 9 in Table 1 report the BHC and FHK decomposition of ALP into its real productivity growth, reallocation of employment for continuing establishments, and entry and exit components. For BHC columns 4 and 5 show that within plant growth of aggregate labor productivity clearly dominates the between reallocation term as it is over 10

[20] In Appendix A-1, we discuss how we construct the Slovenian data set from four distinct sources.

[21] See, for example, Konings and de Loecker (2006), Polanec (2006), and Bartelsman, Haltiwanger, and Scarpetta (2010).

times the magnitude on average (3.42% vs. 0.26%). Column 6 is the between term for the FHK decomposition and it is a third of within-firm growth averaging 1.04%. The contribution of the cross-term in column 7 to the aggregate labor productivity is negative in every year and the mean of the contribution over time is −3.86%.

Table 2 reports APG which averaged 3.40% over the sample period. The within-firm growth is less than a third of APG, averaging 0.95%, while labor reallocation's contribution over the same time period is almost equal to within-firm growth at 0.76%. Overall growth from the reallocation of inputs at continuing firms averages 1.60% and thus total reallocation in Chile plays a bigger role in growth than technical efficiency growth.

Tables 3 and 4 present the results from Colombia over a similar time period. They largely echo the findings from Chile although the results are even stronger. Between 1978 and 1991 ALP increases on average by 3.94% per year and APG averaged 3.22% per year. The BHC and FHK between term's average contribution to the aggregate labor productivity is 1.10% and 1.34% when the within term's average contribution is over five times larger at 6.04%. The covariance term is again negative in every year and the sample average is −3.44%. In contrast Table 4 shows that APG labor reallocation is twice the contribution of technical efficiency growth (0.52% versus 0.25%), and input reallocation is almost entirely responsible for growth over the period at 3.63%.

Tables 5 and 6 show that over the 1995 to 2004 period Slovenia records even stronger growth than both Chile and Colombia. ALP and APG increase on average by 6.53% and 5.17% respectively. The contribution of the between reallocation term is significantly stronger in Slovenia than in Chile and Colombia - 3.34% for BHC and 3.11% for FHK - but it still makes a smaller contribution to the ALP than the within term of 4.96%. The covariance term is again negative in every year and contributes on average −2.65% to growth. From Table 6 we see of the 5.17% growth in APG less than half comes from within-firm growth (2.17%). Labor reallocation contributes 1.15% to growth and total reallocation across all inputs averages 3.42% per year, again suggesting most growth over this period is due to the realignment of inputs.

We also explored the so-called FHK method 2 decomposition, which is closely related to

Griliches and Regev (1995) decomposition.[22] The story does not change on reallocation as we find the FHK method 2's between term for continuing plants are significantly smaller than the BHC between term for all three countries. In particular, in Chile and Colombia, the FHK method 2's between term is negative on average across sample years.

## 5 The ALP Between Term and the Number of Establishments

In this section we show that the ALP between term can be decomposed into a term related to reallocation and a term related to the change in the total number of establishments. The latter term can work to reduce the total between term when an economy is expanding.[23]

Letting $N_t$ denote the number of establishments in the economy, the average share of labor at an establishment at time $t$ is equal to $s_t = \frac{\sum s_{it}}{N_t} = \frac{1}{N_t}$, the individual establishment's relative share of labor is given as $\tilde{s}_{it} = s_{it} - s_t$, and the change in relative share from $t-1$ to $t$ is $\Delta\tilde{s}_{it} = \tilde{s}_{it} - \tilde{s}_{i,t-1}$. The between term then decomposes as follows:

$$\begin{aligned} (BHC\ Between) &= \sum_{i\in\mathbf{C}_t} VL_{i,t-1}\Delta s_{it} \\ &= \sum_{i\in\mathbf{C}_t} VL_{i,t-1}\{(s_{it}-s_t)-(s_{it-1}-s_{t-1})\} + (s_t - s_{t-1})\sum_{i\in\mathbf{C}_t} VL_{i,t-1} \\ &= \underbrace{\sum_{i\in\mathbf{C_t}} \Delta\tilde{s}_{it} VL_{i,t-1}}_{\text{First component}} + \underbrace{(\frac{1}{N_t}-\frac{1}{N_{t-1}})\sum_{i\in\mathbf{C}_t} VL_{i,t-1}}_{\text{Second component}}, \end{aligned} \tag{13}$$

where $\mathbf{C}_t$ is the set of continuing establishments at time $t$. The first component is positive when relative labor shares in the industry move in the direction of higher productivity establishments. The second component is equal to the sum of value-added per labor across establishments multiplied by $\frac{1}{N_t} - \frac{1}{N_{t-1}}$. It is unrelated to the reallocation of inputs. Because the sum of value-added per labor is always positive the second term confounds the first component in the negative direction when the number of establishments increases and the positive

[22] The decomposition method 2 in FHK (2001) is given by $A = \sum_{i\in\mathbf{C}} \overline{s_{it}}\Delta VL_{it} + \sum_{i\in\mathbf{C}}(\overline{VL_{it}} - \overline{VL_t})\Delta s_{it} + \sum_{i\in\mathbf{E}} s_{it}(VL_{it} - \overline{VL_t}) - \sum_{i\in\mathbf{X}} s_{it-1}(VL_{it-1} - \overline{VL_t})$, where a bar over a variable denotes the period average $t-1$ and $t$.

[23] Exactly the same argument can be made for the between term in a multi-factor productivity decomposition.

direction when the number of establishments decreases.

Table 7 presents the decomposition of the between term for Chile. Over the early period of the data when Chile is going through a recession there is a decrease in the number of plants and the second term confounds the first component in the positive direction. After the economy fully recovers and there is growth in the number of plants starting in 1987 as shown in Figure 1-a, the second component works to lower the overall between term. Comparing the first term to the overall BHC term we see that on average it is 0.44% higher over the sample period, that is, overall the second term has confounded between growth down. In Colombia the story is similar as the second term works to reduce the overall BHC term in eight of the fourteen years and the first component is on average 0.27% higher than the between term (see Table A1).

The Chilean and Colombian data only cover plants with at least 10 employees, so the fact that small plants are missing in the data may partly drive the results for Chile and Colombia. The Slovenian data allow us to examine this issue as they record all firms in the economy. Table 8 shows this confounding effect is most pronounced in Slovenia where the growth rate of number of firms is positive in every year, as shown in Figure 1-b. In every year the second component works to reduce measured reallocation, and over the entire sample period the average effect is $-5.80\%$. Overall, separating this component out changes the reallocation message substantially in one country and to a smaller degree in the other two countries.[24]

# 6 Other Measurement Corrections

In this section we explore whether controlling for unobserved prices, for heterogeneity in capital and labor levels, and for unobserved capacity utilization has an impact on the ALP between and covariance terms. We also explore the longer differences for the decompositions and contrast the results with the year-to-year results.

[24] The unit of observation is a firm for Slovenian data and the sample includes both single- and multi-product firms. To examine how the results in Table 8 are sensitive to how we measure the unit of observations, we restrict our sample to single-product firms. Table A6 shows that for this limited sample, the second component in BHC Between term is negatively correlated with the growth rate of the number of firms in every year. This pattern echoes with the finding from Table 8, suggesting that the results in Table 8 are robust to the definition of the unit of observations in the context of single- vs. multi-product firms.

### 6.1 Controlling for Unobserved Prices

The estimated productivity residual is affected by the fact that the typical measure of gross output used in establishment-level data is not $Q_{it}$ but instead is the nominal value of total shipments $P_{it}Q_{it}$ deflated by an industry price deflator $P_t$:

$$\ln \frac{P_{it}Q_{it}}{P_t} = \ln Q_{it} + \ln P_{it} - \ln P_t.$$

In terms of estimated growth rates, the size of the price measurement error added to $VL_{it}$ is $\ln P_{it} - \ln P_t - (\ln P_{it-1} - \ln P_{t-1}) = \Delta \ln P_{it} - \Delta \ln P_t$. A negative covariance between employment share and $VL_{it}$ could be caused by increasing quantities and decreasing prices, that is, a movement down the demand curve for the establishment's products as the establishment increases output and decreases prices to sell that extra output. If labor inputs increase to increase output, then labor share might increase when $VL_{it}$ falls.

We use the Slovenian firm-level data to explore this possibility. 24% of the observations in the Slovenian data are on establishments for which product-specific quantities and revenues are collected. We use these quantities to construct unit prices for each of the establishment's products and then use the quantity-weighted average of these prices as the firm-level price deflator. We then return to the original data and replace the industry-level output deflator with the firm-level output deflator for these 24% of observations. We then recalculate the BHC and FHK decompositions on the full sample which has been partially corrected for the price measurement error.[25][26]

Table 9 presents the results of aggregate labor productivity decomposition by the BHC and FHK using the new sample. If the measurement error in price is indeed a cause of the negative covariance/cross term, we should expect the level of covariance to be higher when we use the sample with the mix of a firm-level deflator and an industry-level deflator. Column 7 in Table 9 shows that the covariance is virtually unchanged from the uncorrected results

[25] We use the full sample so results are comparable to Table 5.

[26] Our attempt is related to Foster, Haltiwanger, and Syverson (2008) in that both employ a plant-level price information. We do not, however, take their route- i.e., deriving physical productivity and estimating the level of idiosyncratic demand at the plant level- due to the severe limitation in the number of observations in our sample.

in Table 5. While the information on prices is limited to only one-quarter of the sample, the results are suggestive that the price measurement error story is not the cause of the negative covariance term.[27]

### 6.2 Controlling for Capital and Labor Heterogeneity by Using Multi-Factor Productivity (TFP)

There are at least two possible factors why not controlling for capital and labor heterogeneity in levels can generate the puzzling pattern in ALP. First, if establishments are substituting capital for labor then establishments with increasing ALP - because they are increasing capital and reducing labor - are also establishments that are reducing their labor share. Second, as discussed in Foster, Haltiwanger, and Krizan (2001), measurement error in labor can generate the spuriously negative covariance between labor productivity growth and labor share growth. To see whether these stories hold in the data we return to the estimates of the value-added production functionand use the estimates $\widehat{\ln \omega}_{it}^{v}$ as the measure of establishment-level productivity. This measure controls for heterogeneity in both capital levels and for two types of labor. The multi-factor measure of aggregate productivity and its growth rate are given as

$$\begin{aligned} \ln \omega_t^v &= \sum_i s_{it} \widehat{\ln \omega}_{it}^{v} \\ \Delta \ln \omega_t^v &= \ln \omega_t^v - \ln \omega_{t-1}^v. \end{aligned}$$

Table 10 presents the results for Chile. Conditioning on different labor types and capital causes the average BHC between term to change from being slightly positive (in Table 1) to $-6.24\%$. The covariance terms remain negative in all years but two. Table A2 presents the results for Colombia and the findings are largely the same as the positive but weak between term becomes mostly negative and every covariance term remains negative. In contrast, the

[27] The results in Tables 5 and 9 may be driven by the presence of measurement error, which may not work in one direction when products are differentiated in vertical and horizontal dimensions. To address this point, we restrict our attention to Metal industry (NACE 2digit code 28), which we believe produces more homogeneous products on average than those in other industries. Tables A4 and A5, which corresponds to Tables 5 and 9, respectively, calculate the BHC/FHK decompositions using industry-level and establishment-level price deflator, respectively. Again we did not find any significant differences in the cross term across Tables A4 and A5, confirming that the price measurement error is not driving the significantly negative cross term in Slovenia.

results from Table 11 for Slovenia do change. The BHC between turn increases and the covariance terms become positive for every year except one. Distinguishing between value-added per laborer and multi-factor productivity growth can change the covariance term and increase the between term relative to ALP but apparently is not the general source of the problem.[28]

### 6.3 Controlling for Capacity Utilization

Let capacity utilization be denoted as $util_{it}$, so that the true capital input is $\ln(K_{it} * util_{it}) = \ln K_{it} + \ln util_{it}$,, where $K_{it}$ is the observed capital input. Increases in unobserved capacity utilization appear as an increase in technical efficiency in the value-added production function:

$$\Delta\widehat{\ln \omega}_{it}^{v} = \Delta \ln \omega_{it}^{v} + \varepsilon_{iK}^{v} \Delta util_{it}.$$

If unobserved capital utilization were negatively correlated with labor, it could generate the negative covariance. For example, within-establishment substitution between hiring new bodies and increasing utilization rates could lead to a negative covariance term.

A separate survey for the Slovenian data is collected and it asks about utilization. This allows us to correct 11% of the observations in the Slovenian data for unobserved utilization. Once the capital terms have been corrected for this subset, these observations are added back to the full Slovenian data set. We compare these results to the multi-factor productivity results from Table A3 and find that the results are virtually unchanged. While the sample of plants for which we can correct for utilization is a small fraction of the total firms, unobserved capacity appears to not affect either the between terms or the covariance terms.

### 6.4 Longer Differences for Decompositions

Our results so far are based on annual data, but the BHC/FHK decompositions can depend heavily on the time horizon of the calculations because year-to-year observations can be more

[28] Measurement error in output will not explain the negative covariance term for the multi-factor productivity measure, because the measurement error generates a positive covariance. See Foster, Haltiwanger, and Krizan (2001) for details.

volatile, especially in the entry and exit term. We explore this possibility by pretending that we only observe data at five-year or ten-year differences. For instance, for the five-year differences in the Chilean manufacturing data spanning from 1979 through 1995, we assume that we observe data from years 1979, 1984, 1989, and 1994, and we rerun the whole decomposition, including the production function estimation for the multifactor productivity.

Tables 12 and 13 present the decomposition results for ALP and multi-factor productivity, respectively, for Chilean Manufacturing data with five-year differences. Overall, these two tables confirm no clear improvement over the annual data in terms of explaining the weak reallocation and cross term for continuing establishments. Two tables show the negative between term and negative covariance still exist for the five year differences decomposition. The magnitudes of these terms do not seem much different either, from the ones we calculate by simply adding up the annual growth rates for five years. The results for ten-year differences for Chile and five-year and ten-year differences for Colombia and Slovenia exhibit a similar pattern.[29]

# 7 Conclusions

We have shown that the recent findings reported in Bartelsman, Haltiwanger, and Scarpetta (2004) and Pages, Pierre, and Scarpetta (2009) of a weak or negative contribution of input reallocation to growth coupled with strong within-plant productivity gains may in part be an artifact of the way the BHC and FHK decompositions define these terms. These decompositions use plant-level output-per-labor as a proxy for the marginal product of labor and changes in output-per-labor as a proxy for changes in plant-level productivity. Our examples illustrate that BHC indices can mistake growth from reallocation as growth from productivity because output-per-labor is neither a perfect index of marginal products nor plant-level productivity. They also illustrate that reallocation growth from labor should track marginal changes in labor weighted by the marginal product of labor.

Our empirical work looks at Chile, Colombia, and Slovenia, and a comparison of reallo-

[29] Due to space limitations, we do not show those tables, which are available upon request.

cation and real productivity growth across methodologies suggests there may be merit to the points raised in our theoretical examples. We find for Chile and Colombia BHC indices report weak or negative growth from labor reallocation during periods of overall economic growth, whereas using the reallocation definition based on marginal products we find a positive and robust role for labor reallocation in all three countries and a significantly reduced role of plant-level technical efficiency in growth.

We close with a note of caution on the generality of our empirical findings. While we do find an increased role for reallocation and a reduced role for technical efficiency in all three countries, we have only looked at those countries and their manufacturing sectors.[30] Further work needs to be done on other micro-level data to see if the patterns we find are prevalent in most micro-level data sets.

[30] Recent studies have begun to examine the relationship between productivity growth and resource reallocation across all sectors (see, e.g., Menezes-Filho and Muendler 2011; IADB 2010; McMillan and Rodrik 2011; de Vries et al. 2012).

# Appendix

## A-1 Construction of Slovenian dataset

To construct the data set, we merge annual data sets from four distinct sources. The first source is the Agency of the Republic of Slovenia for Public Legal Records and Related Services (AJPES), which compiles the annual accounting data for all firms and for sole proprietors in manufacturing with at least 30 workers. The data set is comprised of firm-level data, although the accounting data are not consolidated. It is an unbalanced panel that includes a measure of nominal output, capital, and intermediate inputs. The second source is the Slovenian Statistical Office (SORS) that maintains the Slovenian Employment Registry (SER), which records employment durations of all workers in the economy and contains information on the employer's identity and employees' educational attainment, all of which are then used to determine the numbers of skilled and unskilled workers. The third source is the Slovenian Tax Office (TORS). The data contain information on annual labor income for each employee, which is used to calculate the annual cost of skilled and unskilled labor. The fourth data set is the industrial production (IP) survey of firms with at least 10 employees, performed annually by the SORS. It contains information on nominal output and physical quantities, disaggregated by products that are defined according to the 8-digit combined nomenclature (CN) product classification. From these, the prices of products are calculated and the price indices at the firm-level are constructed.

## A-2 Construction of Firm-level Price Deflator

The firm-level price index is calculated using the annual industrial production (manufacturing and mining) survey for a set of Slovenian firms. The survey contains information on quantities and values sold by product, defined according to PRODCOM 8-digit code. The 2002-2009 provides information on non-response, which ranges between 9% and 15%. For example, in 2002, the number of surveyed establishments is 2, 366, out of which 12% (285) did not respond. Additional surveyed units are mis-classified; for example, a unit is classified as manufacturing or mining but performs other activities. We eliminated these units. For example, the address book contained 2,484 cases, of which 118 were mis-classified.

The data set is not a survey but should contain all establishments. The source of information is: http://www.stat.si/doc/metod_porocila/21_LPK_IND_L_2009.pdf

The product classifications used have changed over time. The SORS used a 9-digit national variety of NACE during 1989-1993, which distinguishes between 3,469 products. During 1994-2008, SORS used an 8-digit NACE, which distinguishes 5,666 product codes in 1994 and 1995; 5,622 product codes during 1996-2001; 5,153 during 2002-2003; 5,142 in 2004; etc. In 2004, a subset of 4,600 products were in manufacturing industries.

We use concordance files between different product classifications to create a time invariant product classification.

To calculate the firm-level price index, we have to deal with several issues. The ideal Fischer price index formula for firm $i$ between periods $t-1$ and $t$ is:

$$FPI_{it,t-1} = \sum_{j \in J_i} \overline{w}_{jit} \frac{p_{jit}}{p_{jit-1}},$$

where $J_i$ is the set of output goods, $\overline{w}_{jit} = \frac{w_{jit}+w_{jit-1}}{2}$ and $w_{jit} = p_{jit}q_{jit}/\sum_{j \in J_i} p_{jit}q_{jit}$. Alternatively, one may use lagged or current weights. The Statistical Office uses lagged weights, as it does not possess the information on the revenue shares:

$$FPI_{it}^{lag} = \sum_{j \in J_i} w_{jit-1} \frac{p_{jit}}{p_{jit-1}}.$$

## C Construction of Double-Deflated Value Added

Establishment $i$'s price and quantity at time $t$ are given by $P_{it}$ and $Q_{it}$. As with most establishment-level data, we do not observe establishment-level prices, so we deflate establishment-level revenues $P_{it}Q_{it}$ with 3-digit industry gross output deflators, with $P_{st}$ denoting the price index for industry $s$ at time $t$. We define double-deflated value added as

$$VA_{it} = \frac{P_{it}Q_{it}}{P_t} - \frac{\sum_j P_{jt}M_{ijt}}{P_t^M},$$

where $P_{jt}$ is the price of input $j$ at time $t$ and $M_{ijt}$ is the amount of $j$ used as an intermediate input in $i$'s production, and we deflate expenditures on intermediate inputs using a 3-digit industry price index for materials, which we denote $P_t^M$. We use double-deflated value added for Chilean results. For Colombian and Slovenian results, since intermediate input deflators are not available, we use single-deflated value added using only the industry gross output price deflators $P_{st}$:

$$VA_{it} = \frac{P_{it}Q_{it} - \sum_j P_{jt}M_{ijt}}{P_{st}}.$$

Finally, we use the consumer price index as a common deflator across all establishments in any year to calculate an alternative measure of single-deflated value added. Qualitatively, the results across these different value-added specifications are similar, so we primarily discuss the double-deflated value-added results.

### D Alternative Representation of Labor Productivity Growth Decomposition

Using the different periods of weights, we can construct the sum of the within and between terms in several ways. For instance, we can decompose the sum into $\sum_i \frac{s_{it}+s_{it-1}}{2}\Delta VL_{it} + \sum_i \frac{VL_{it}+VL_{it-1}}{2}\Delta s_{it}$ (Tornquist approximation) or $\sum_i s_{it}\Delta VL_{it} + \sum_i VL_{it-1}\Delta s_{it}$.

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Figure 1-a Number of Plants, Chile

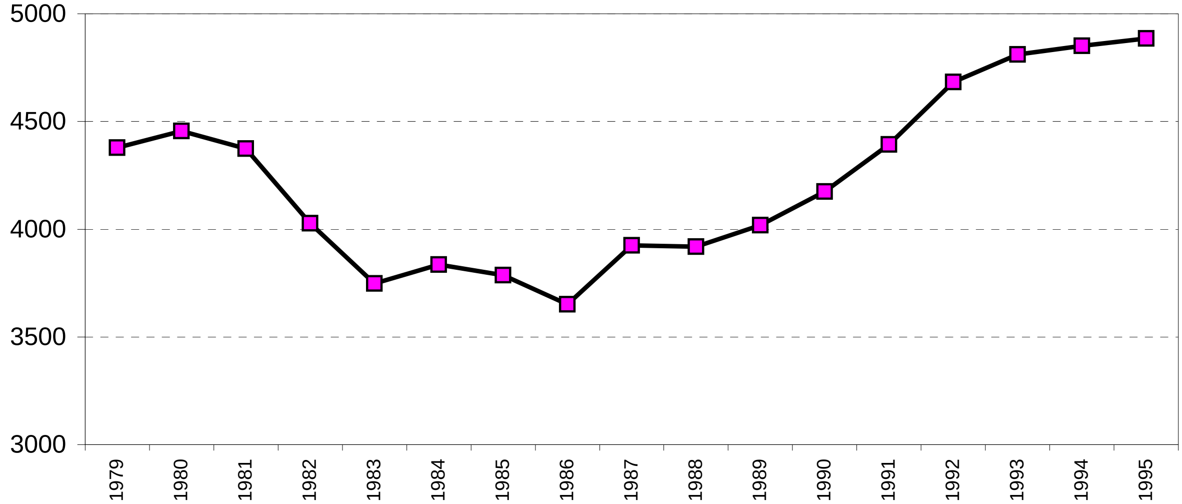


Figure 1-b Number of Firms, Slovenia

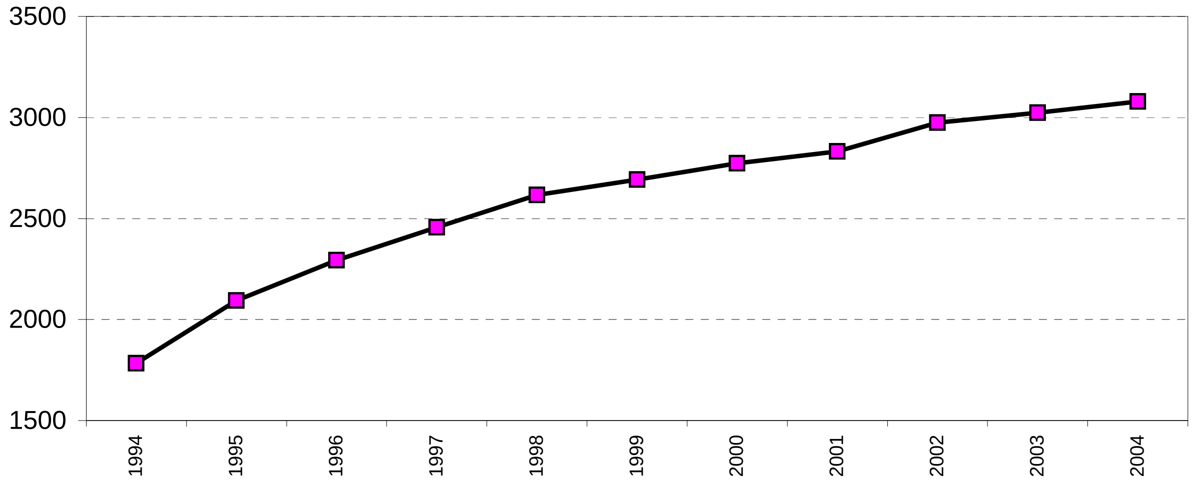


Figure 1-c Number of Plants, Colombia

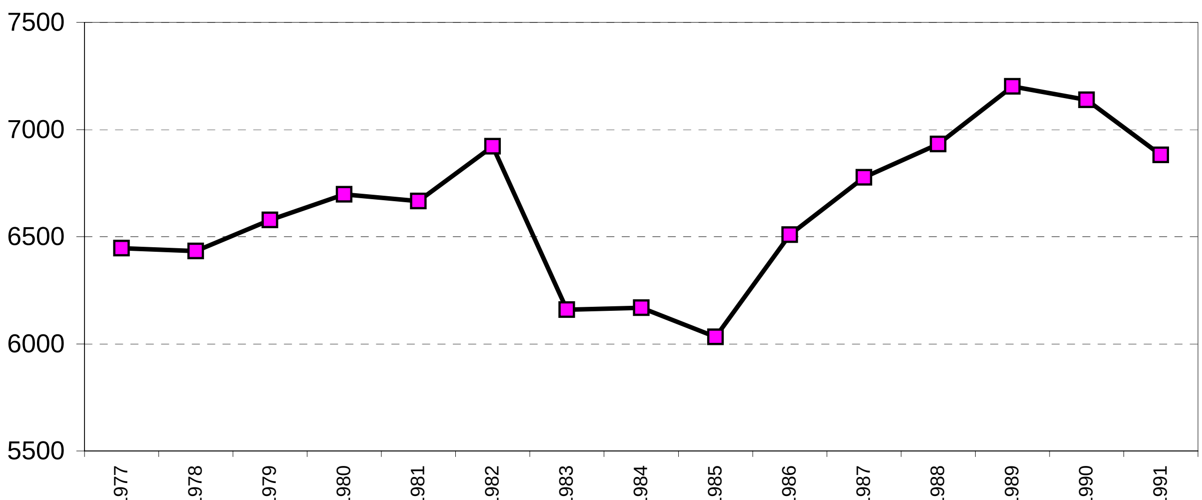

Table 1
Aggregate Labor Productivity (ALP) Growth Rate, Chilean Manufacturing 1980-95
BHC (1992) and FHK (2001) ALP Decomposition

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1980 | -3.28 | -7.15 | -5.18 | 2.57 | 2.26 | -4.22 | -0.31 | 0.00 |
| 1981 | 1.37 | 5.63 | 8.14 | -0.55 | 0.06 | -2.11 | 0.15 | -0.46 |
| 1982 | -21.76 | -4.81 | -9.44 | 8.04 | 3.76 | -2.15 | -1.27 | 3.01 |
| 1983 | -0.27 | -1.80 | -0.12 | 1.11 | -0.18 | -2.13 | -0.66 | 0.64 |
| 1984 | 9.94 | 2.90 | 10.02 | -3.75 | -2.07 | -4.63 | 1.26 | -0.42 |
| 1985 | 3.72 | -4.01 | -0.73 | 0.76 | -0.05 | -3.22 | -0.82 | -0.01 |
| 1986 | 8.43 | 1.19 | 6.61 | -0.31 | -2.03 | -3.88 | -1.23 | 0.49 |
| 1987 | 7.34 | -5.54 | -1.72 | -4.31 | -0.80 | -3.22 | 3.70 | 0.20 |
| 1988 | 6.55 | -1.81 | 0.61 | -1.30 | -0.85 | -2.55 | 1.43 | 0.98 |
| 1989 | 11.02 | 0.64 | 4.40 | -1.47 | 1.00 | -4.35 | 2.07 | -0.40 |
| 1990 | 3.74 | 2.57 | 7.01 | 0.14 | 1.25 | -5.73 | 1.15 | 0.04 |
| 1991 | 7.03 | 3.28 | 6.50 | 1.20 | 4.79 | -6.86 | 2.44 | -1.14 |
| 1992 | 14.55 | 5.07 | 7.98 | -3.22 | 0.86 | -3.78 | 4.08 | 0.00 |
| 1993 | 5.58 | 4.21 | 7.41 | 1.39 | 3.06 | -5.71 | 1.12 | -0.55 |
| 1994 | 2.39 | 1.69 | 2.51 | 2.81 | 3.30 | -3.64 | 0.01 | -0.48 |
| 1995 | 10.19 | 9.61 | 10.79 | 0.97 | 2.30 | -3.50 | 1.34 | 0.02 |
| Average | 4.16 | 0.73 | 3.42 | 0.26 | 1.04 | -3.86 | 0.90 | 0.12 |
| St. Dev. | 8.28 | 4.60 | 5.74 | 2.96 | 2.06 | 1.38 | 1.63 | 0.93 |

Notes: Percentage growth rates. Labor productivity is defined as the ratio of value added over employment. "Value Added" is the growth rate of aggregate value added, which is constructed by summing the establishment-level double-deflated value added across establishments and then taking the annual growth rate. "Labor Productivity Growth" represents the aggregate labor productivity growth with entry and exit. Labor Productivity Growth is decomposed into four components: (1) within, (2) between, (3) cross, and (4) net entry term, using equation 2 in text for BHC (1992) and equation 3 in text for FHK (2001). We use employment share for the share weights. Both (1) within and (2) between terms use base-period share for the weights.

Table 2
Aggregate Multifactor Productivity Growth Rate, Chilean Manufacturing 1980-95
Petrin and Levinsohn (2012) Aggregate Productivity Growth (APG) Decomposition

| Year | Value Added | (0) APG | APG Decomposition: (0) = (1) + (2) + (3) | | | |
|---|---|---|---|---|---|---|
| | | | | Reallocation | | |
| | | | (1) Technical Efficiency | (2) Total Reallocation | Labor Reallocation | (3) Net Entry |
| 1980 | -3.28 | -5.18 | -3.50 | -0.31 | -0.10 | -1.37 |
| 1981 | 1.37 | -3.61 | 1.43 | 0.65 | -0.78 | -5.70 |
| 1982 | -21.76 | -11.68 | -16.47 | -2.82 | -2.20 | 7.62 |
| 1983 | -0.27 | 3.81 | -0.39 | 1.59 | -0.59 | 2.60 |
| 1984 | 9.94 | 10.19 | 7.94 | 1.56 | 1.46 | 0.69 |
| 1985 | 3.72 | 5.65 | 3.29 | 0.64 | 1.57 | 1.71 |
| 1986 | 8.43 | 5.14 | 6.75 | 0.86 | 1.15 | -2.47 |
| 1987 | 7.34 | 7.24 | -3.88 | 3.22 | 1.53 | 7.90 |
| 1988 | 6.55 | 5.59 | 3.31 | 0.51 | 1.49 | 1.78 |
| 1989 | 11.02 | 8.53 | 0.96 | 6.22 | 2.41 | 1.35 |
| 1990 | 3.74 | 1.03 | -0.56 | 2.42 | 1.26 | -0.82 |
| 1991 | 7.03 | 3.76 | 1.68 | 2.19 | 1.60 | -0.11 |
| 1992 | 14.55 | 10.61 | 6.66 | 2.28 | 1.79 | 1.67 |
| 1993 | 5.58 | 3.56 | -0.75 | 4.34 | 1.52 | -0.03 |
| 1994 | 2.39 | 0.06 | -0.08 | 2.32 | 0.63 | -2.18 |
| 1995 | 10.19 | 9.70 | 8.74 | -0.01 | -0.50 | 0.97 |
| Average | 4.16 | 3.40 | 0.95 | 1.60 | 0.76 | 0.85 |
| St. Dev. | 8.28 | 6.10 | 6.01 | 2.05 | 1.24 | 3.40 |

Notes: Percentage growth rates. The plant-level multifactor productivity is calculated by using production function parameters that vary across 3-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, holding input constant. We use value-added share for weights. APG is decomposed into four components: (1) technical efficiency, (2) reallocation, and (3) net entry term, using equation 12 in text.

Table 3
Aggregate Labor Productivity (ALP) Growth Rate, Colombian Manufacturing 1978-91
BHC (1992) and FHK (2001) ALP Decomposition

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1978 | 11.93 | 8.56 | 9.84 | 1.77 | 2.36 | -4.17 | 1.13 | 0.54 |
| 1979 | 9.89 | 6.78 | 6.72 | 2.50 | 2.94 | -2.84 | 0.41 | -0.03 |
| 1980 | 6.92 | 6.55 | 7.14 | 0.94 | 1.75 | -1.94 | 0.42 | -0.40 |
| 1981 | -10.11 | -8.68 | -6.56 | 1.49 | 2.26 | -2.62 | -1.00 | -1.77 |
| 1982 | 0.30 | 2.47 | 3.95 | 1.99 | 3.11 | -3.77 | 0.30 | -0.82 |
| 1983 | 0.05 | 3.75 | 4.44 | 2.32 | 1.46 | -2.78 | -0.24 | 0.62 |
| 1984 | 6.69 | 8.58 | 8.32 | 1.95 | 1.26 | -2.17 | 0.48 | 1.17 |
| 1985 | 7.35 | 10.85 | 17.18 | 1.12 | -0.05 | -7.17 | -0.28 | 0.89 |
| 1986 | 10.76 | 0.91 | 5.83 | -1.96 | 0.15 | -3.74 | 0.77 | -1.33 |
| 1987 | -1.55 | -1.80 | 2.63 | -3.77 | -1.45 | -2.11 | 1.45 | -0.87 |
| 1988 | 9.48 | 10.51 | 14.79 | 3.20 | 2.10 | -7.88 | 0.40 | 1.50 |
| 1989 | 3.39 | 1.99 | 4.43 | 0.00 | 0.65 | -2.67 | 0.23 | -0.43 |
| 1990 | 4.55 | 3.95 | 4.08 | 1.93 | 1.62 | -2.21 | 0.14 | 0.45 |
| 1991 | 0.26 | 0.78 | 1.75 | 1.95 | 0.61 | -2.14 | -0.78 | 0.57 |
| Average | 4.28 | 3.94 | 6.04 | 1.10 | 1.34 | -3.44 | 0.24 | 0.01 |
| St. Dev. | 6.03 | 5.31 | 5.71 | 1.87 | 1.26 | 1.87 | 0.67 | 0.97 |

Notes: "Value Added" is the growth rate of aggregate value added, which is constructed by summing the establishment-level single-deflated value added across establishments and then taking the annual growth rate. For other technical details, see notes to Table 1.

Table 4
Aggregate Multifactor Productivity Growth Rate, Colombian Manufacturing 1978-91
Petrin and Levinsohn (2012) Aggregate Productivity Growth (APG) Decomposition

| Year | Value Added | (0) APG | APG Decomposition: (0) = (1) + (2) + (3) | | | |
|---|---|---|---|---|---|---|
| | | | | Reallocation | | |
| | | | (1) Technical Efficiency | (2) Total Reallocation | Labor Reallocation | (3) Net Entry |
| 1978 | 11.93 | 5.59 | -1.11 | 9.79 | 2.76 | -3.09 |
| 1979 | 9.89 | 9.03 | -0.48 | 8.84 | 1.91 | 0.67 |
| 1980 | 6.92 | 5.85 | 2.87 | 3.25 | 1.14 | -0.27 |
| 1981 | -10.11 | -11.19 | -14.13 | 4.76 | 0.15 | -1.83 |
| 1982 | 0.30 | -2.44 | -2.86 | 3.94 | 0.02 | -3.53 |
| 1983 | 0.05 | -0.98 | -0.20 | 1.71 | -1.05 | -2.49 |
| 1984 | 6.69 | 6.45 | 4.76 | 2.10 | -0.08 | -0.42 |
| 1985 | 7.35 | 9.24 | 11.30 | -2.05 | -2.89 | -0.01 |
| 1986 | 10.76 | 10.37 | 12.83 | 1.02 | -0.34 | -3.48 |
| 1987 | -1.55 | -1.83 | -13.15 | 4.37 | 1.18 | 6.95 |
| 1988 | 9.48 | 9.56 | 5.58 | 3.56 | 1.44 | 0.41 |
| 1989 | 3.39 | 2.40 | 0.22 | 2.48 | 0.18 | -0.30 |
| 1990 | 4.55 | 3.53 | 0.03 | 4.07 | 2.02 | -0.57 |
| 1991 | 0.26 | -0.50 | -2.19 | 2.98 | 0.84 | -1.29 |
| Average | 4.28 | 3.22 | 0.25 | 3.63 | 0.52 | -0.66 |
| St. Dev. | 6.03 | 6.09 | 7.55 | 2.96 | 1.43 | 2.61 |

Notes: The production function parameters that vary across 3-digit ISIC are estimated using Wooldridge (2009). For other technical details, see notes to Table 2.

Table 5
Aggregate Labor Productivity (ALP) Growth Rate, Slovenian Manufacturing 1995-2004
BHC (1992) and FHK (2001) ALP Decomposition
Industry-level Price Deflator

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1995 | 4.01 | 5.51 | -0.82 | 7.68 | 5.79 | -4.92 | 3.58 | 5.47 |
| 1996 | 7.39 | 8.40 | 5.47 | 5.65 | 5.25 | -3.61 | 0.89 | 1.29 |
| 1997 | 14.60 | 15.05 | 12.72 | 5.69 | 6.30 | -5.74 | 2.37 | 1.76 |
| 1998 | 2.90 | 0.07 | -1.98 | 4.53 | 4.90 | -3.94 | 1.46 | 1.08 |
| 1999 | 8.35 | 6.56 | 7.21 | -0.82 | 0.55 | -0.84 | 1.00 | -0.37 |
| 2000 | 8.27 | 6.42 | 6.00 | 1.78 | 1.23 | -1.75 | 0.39 | 0.94 |
| 2001 | 4.28 | 4.25 | 3.98 | 2.38 | 1.57 | -1.34 | -0.77 | 0.05 |
| 2002 | 9.04 | 6.44 | 6.42 | -0.75 | 1.32 | -1.31 | 2.08 | 0.01 |
| 2003 | 6.54 | 8.09 | 6.80 | 4.54 | 2.57 | -1.92 | -1.34 | 0.64 |
| 2004 | 4.62 | 4.54 | 3.84 | 2.69 | 1.63 | -1.13 | -0.85 | 0.21 |
| Average | 7.00 | 6.53 | 4.96 | 3.34 | 3.11 | -2.65 | 0.88 | 1.11 |
| St. Dev. | 3.41 | 3.81 | 4.16 | 2.80 | 2.19 | 1.75 | 1.57 | 1.67 |

Notes: "Value Added" is the growth rate of aggregate value added, which is constructed by summing the establishment-level single-deflated value added across establishments and then taking the annual growth rate.We use a 2-digit industry-level price deflator to obtain deflated value added. We use employment share for the share weights. Both (1) within and (2) between terms use base-period share for the weights. For other technical details, see notes to Table 1.

Table 6

Aggregate Multifactor Productivity Growth Rate, Slovenian Manufacturing 1995-2004

Petrin and Levinsohn (2012) Aggregate Productivity Growth (APG) Decomposition

Industry-level Price Deflator

| Year | Value Added | (0) APG | APG Decomposition: (0) = (1) + (2) + (3) | | | |
|---|---|---|---|---|---|---|
| | | | | Reallocation | | |
| | | | (1) Technical Efficiency | (2) Total Reallocation | Labor Reallocation | (3) Net Entry |
| 1995 | 4.01 | 2.68 | -3.01 | 3.21 | 2.07 | 2.48 |
| 1996 | 7.39 | 5.95 | 3.70 | 2.41 | 1.72 | -0.16 |
| 1997 | 14.60 | 12.60 | 5.00 | 6.83 | 1.32 | 0.77 |
| 1998 | 2.90 | 0.63 | -3.95 | 4.47 | 1.91 | 0.11 |
| 1999 | 8.35 | 6.05 | 3.96 | 2.75 | 0.61 | -0.66 |
| 2000 | 8.27 | 6.10 | 3.42 | 3.57 | 0.96 | -0.90 |
| 2001 | 4.28 | 3.14 | 2.02 | 2.71 | 0.74 | -1.58 |
| 2002 | 9.04 | 6.51 | 3.92 | 2.42 | 0.66 | 0.17 |
| 2003 | 6.54 | 4.81 | 4.24 | 3.19 | 0.61 | -2.62 |
| 2004 | 4.62 | 3.22 | 2.35 | 2.67 | 0.86 | -1.81 |
| Average | 7.00 | 5.17 | 2.17 | 3.42 | 1.15 | -0.42 |
| St. Dev. | 3.41 | 3.23 | 3.11 | 1.35 | 0.57 | 1.45 |

Notes: The plant-level multifactor productivity is calculated by using production function parameters that vary across 2-digit NACE. We use a 2-digit industry-level price deflator to obtain deflated value added. For other technical details, see notes to Table 2.

Table 7

Aggregate Labor Productivity (ALP) Growth Rate, Chilean Manufacturing 1980-95

BHC (1992) Between Term Decomposition

| Year | BHC | BHC (1992) Between Term Decomposition: (0) = (1) + (2) | | Number of Plants |
|---|---|---|---|---|
| | (0): Between Term | (1) First component | (2) Second component | |
| 1980 | 2.57 | 3.51 | -0.95 | 1.76 |
| 1981 | -0.55 | -1.48 | 0.93 | -1.84 |
| 1982 | 8.04 | 3.56 | 4.49 | -7.96 |
| 1983 | 1.11 | -2.23 | 3.34 | -6.91 |
| 1984 | -3.75 | -2.70 | -1.04 | 2.35 |
| 1985 | 0.76 | 0.11 | 0.64 | -1.33 |
| 1986 | -0.31 | -1.99 | 1.68 | -3.54 |
| 1987 | -4.31 | -0.83 | -3.48 | 7.50 |
| 1988 | -1.30 | -1.38 | 0.08 | -0.15 |
| 1989 | -1.47 | -0.12 | -1.34 | 2.50 |
| 1990 | 0.14 | 2.32 | -2.17 | 3.91 |
| 1991 | 1.20 | 4.18 | -2.98 | 5.27 |
| 1992 | -3.22 | 0.50 | -3.72 | 6.60 |
| 1993 | 1.39 | 2.98 | -1.60 | 2.69 |
| 1994 | 2.81 | 3.32 | -0.51 | 0.85 |
| 1995 | 0.97 | 1.39 | -0.42 | 0.70 |
| Average | 0.26 | 0.70 | -0.44 | 0.78 |
| St. Dev. | 2.96 | 2.36 | 2.29 | 4.36 |

Notes: Percentage growth rates. BHC Between Term is decomposed into two terms using equation 13 in the text.

Table 8
Aggregate Labor Productivity (ALP) Growth Rate, Slovenian Manufacturing 1995-2004
BHC (1992) Between Term Decomposition

| Year | BHC (0): Between Term | BHC (1992) Between Term Decomposition: (0) = (1) + (2) (1) First component | (2) Second component | Number of Firms |
|---|---|---|---|---|
| 1995 | 7.68 | 27.33 | -19.65 | 17.44 |
| 1996 | 5.65 | 15.61 | -9.96 | 9.55 |
| 1997 | 5.69 | 12.73 | -7.04 | 7.06 |
| 1998 | 4.53 | 10.80 | -6.27 | 6.56 |
| 1999 | -0.82 | 1.97 | -2.79 | 2.90 |
| 2000 | 1.78 | 4.63 | -2.85 | 2.97 |
| 2001 | 2.38 | 4.40 | -2.02 | 2.13 |
| 2002 | -0.75 | 3.67 | -4.42 | 5.05 |
| 2003 | 4.54 | 6.01 | -1.47 | 1.65 |
| 2004 | 2.69 | 4.26 | -1.57 | 1.82 |
| Average | 3.34 | 9.14 | -5.80 | 5.71 |
| St. Dev. | 2.80 | 7.79 | 5.59 | 4.89 |

Notes: Percentage growth rates. BHC Between Term is decomposed into two terms using equation 13 in the text.

Table 9
Aggregate Labor Productivity (ALP) Growth Rate, Slovenian Manufacturing 1995-2004
BHC (1992) and FHK (2001) ALP Decomposition
Firm-level and Industry-level Price Deflator

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1995 | 7.20 | 9.96 | 3.19 | 8.78 | 5.89 | -4.35 | 2.35 | 5.24 |
| 1996 | 4.32 | 7.59 | 2.83 | 7.35 | 4.93 | -2.42 | -0.18 | 2.24 |
| 1997 | 12.94 | 12.64 | 11.26 | 5.06 | 6.10 | -5.86 | 2.18 | 1.14 |
| 1998 | 8.23 | 5.99 | 6.60 | 3.53 | 3.70 | -4.25 | 0.11 | -0.06 |
| 1999 | 10.27 | 7.36 | 7.22 | -1.55 | 0.48 | -1.03 | 2.72 | 0.69 |
| 2000 | 9.13 | 8.50 | 7.66 | 3.11 | 1.51 | -1.63 | -0.64 | 0.96 |
| 2001 | 4.77 | 4.57 | 7.39 | 1.84 | 1.45 | -1.25 | -3.40 | -3.02 |
| 2002 | 9.78 | 8.32 | 8.01 | -0.06 | 1.24 | -1.40 | 1.78 | 0.48 |
| 2003 | 2.94 | 4.75 | 3.84 | 4.18 | 2.33 | -1.85 | -1.43 | 0.43 |
| 2004 | 7.63 | 9.87 | 5.13 | 3.94 | 1.13 | -0.93 | 1.74 | 4.54 |
| Average | 7.72 | 7.96 | 6.31 | 3.62 | 2.88 | -2.50 | 0.52 | 1.27 |
| St. Dev. | 3.05 | 2.50 | 2.60 | 3.10 | 2.11 | 1.71 | 1.98 | 2.34 |

Notes: The number of observations with an establishment-level price deflator accounts for 24% of the total number of observations. For these observations, we use an establishment-level price deflator to obtain deflated value added. Otherwise, we use a 2-digit industry-level price deflator to obtain deflated value added. For other technical details, see notes to Table 5.

Table 10
Aggregate Multifactor Productivity Growth Rate, Chilean Manufacturing 1980-95
BHC (1992) and FHK (2001) Decomposition

| Year | Value Added | (0) Multifactor Prod. Growth | BHC (1992) / FHK (2001) Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1980 | -3.28 | -19.86 | -13.72 | 1.07 | -1.45 | 0.04 | -7.25 | -4.73 |
| 1981 | 1.37 | 4.02 | 3.47 | -9.38 | -4.55 | 1.00 | 8.94 | 4.11 |
| 1982 | -21.76 | -11.33 | -21.87 | 38.17 | 4.24 | -1.17 | -26.46 | 7.47 |
| 1983 | -0.27 | -3.46 | -6.08 | 10.05 | -0.06 | -0.08 | -7.36 | 2.75 |
| 1984 | 9.94 | 4.27 | 11.69 | -19.51 | -6.46 | -0.41 | 12.49 | -0.56 |
| 1985 | 3.72 | -5.38 | 1.03 | 5.81 | -0.50 | -0.80 | -11.43 | -5.12 |
| 1986 | 8.43 | 8.12 | 9.54 | 12.06 | -1.30 | -3.01 | -10.47 | 2.88 |
| 1987 | 7.34 | -7.10 | -3.87 | -29.29 | -1.78 | -1.36 | 27.43 | -0.09 |
| 1988 | 6.55 | 4.26 | 4.07 | -3.71 | -0.19 | -0.13 | 4.03 | 0.51 |
| 1989 | 11.02 | 0.05 | -0.50 | -18.34 | 0.97 | -2.22 | 21.11 | 1.80 |
| 1990 | 3.74 | 4.21 | 6.89 | -7.78 | 0.90 | -2.18 | 7.27 | -1.41 |
| 1991 | 7.03 | 7.46 | 7.52 | -24.90 | 3.32 | -2.64 | 27.49 | -0.73 |
| 1992 | 14.55 | 7.98 | 10.12 | -33.14 | -0.77 | -1.41 | 32.41 | 0.04 |
| 1993 | 5.58 | 0.42 | 2.77 | -11.30 | 2.06 | -2.68 | 11.64 | -1.73 |
| 1994 | 2.39 | 0.28 | -1.08 | -1.20 | 2.71 | -0.89 | 3.45 | -0.45 |
| 1995 | 10.19 | 5.54 | 4.07 | -8.42 | 2.18 | -1.73 | 11.61 | 1.01 |
| Average | 4.16 | -0.03 | 0.88 | -6.24 | -0.04 | -1.23 | 6.56 | 0.36 |
| St. Dev. | 8.28 | 7.75 | 8.93 | 17.84 | 2.80 | 1.14 | 16.23 | 3.12 |

Notes: Percentage growth rates. The plant-level multifactor productivity is calculated using production function parameters that vary across 3-digit ISIC estimates using Wooldridge (2009). "Value Added" is the growth rate of aggregate value added, which is constructed by summing the establishment-level double-deflated value added across establishments and then taking the annual growth rate. "Multifactor Prod. Growth" represents the aggregate multifactor productivity growth with entry and exit, which is the weighted sum of plant-level multifactor productivity across establishments. We use employment share for the share weights. Multifactor Prod. Growth is decomposed into four components: (1) within, (2) between, (3) cross, and (4) net entry term, using equation 2 in text for BHC (1992) and equation 3 in text for FHK (2001). Both (1) within and (2) between terms use base-period share for the weights.

Table 11
Aggregate Multifactor Productivity Growth Rate, Slovenian Manufacturing 1995-2004
BHC (1992) and FHK (2001) Decomposition
Industry-level Price Deflator

| Year | Value Added | (0) Multifactor Prod. Growth | BHC (1992) / FHK (2001) Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1995 | 4.01 | 2.22 | -1.85 | 33.57 | 1.94 | -0.35 | -29.15 | 2.48 |
| 1996 | 7.39 | 6.25 | 3.00 | 8.42 | 1.67 | 0.35 | -5.52 | 1.23 |
| 1997 | 14.60 | 13.37 | 6.63 | -8.80 | 1.46 | 0.31 | 15.23 | 4.97 |
| 1998 | 2.90 | 1.41 | -2.09 | -4.01 | 2.32 | 0.22 | 7.28 | 0.96 |
| 1999 | 8.35 | 2.10 | 2.96 | -24.84 | -1.59 | 1.34 | 22.64 | -0.61 |
| 2000 | 8.27 | 4.70 | 3.13 | 9.76 | 0.44 | 0.69 | -8.87 | 0.44 |
| 2001 | 4.28 | 4.10 | 2.46 | 14.95 | 1.10 | 0.27 | -13.58 | 0.27 |
| 2002 | 9.04 | 5.30 | 3.40 | -34.14 | 1.24 | 0.31 | 35.73 | 0.35 |
| 2003 | 6.54 | 3.76 | 1.79 | 34.40 | 0.55 | 1.08 | -33.51 | 0.34 |
| 2004 | 4.62 | 3.12 | 1.76 | 19.85 | 1.55 | 0.16 | -18.65 | -0.35 |
| Average | 7.00 | 4.63 | 2.12 | 4.92 | 1.07 | 0.44 | -2.84 | 1.01 |
| St. Dev. | 3.41 | 3.42 | 2.55 | 22.92 | 1.10 | 0.48 | 22.63 | 1.64 |

Notes: The plant-level multifactor productivity is calculated using production function parameters that vary across 2-digit NACE estimates using Wooldridge (2009). "Value Added" is the growth rate of aggregate value added, which is constructed by summing the establishment-level single-deflated value added across establishments and then taking the annual growth rate. We use a 2-digit industry-level price deflator to obtain deflated value added. For other technical details, see notes to Table 10.

Table 12
Aggregate Labor Productivity (ALP) Growth Rate, Chilean Manufacturing, Five-Year Differences in 1984-94
BHC (1992) and FHK (2001) ALP Decomposition

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1984 | -15.89 | -5.67 | 2.27 | 8.52 | 4.05 | -14.66 | -1.80 | 2.67 |
| 1989 | 42.79 | -9.45 | 2.98 | -10.23 | -5.94 | -7.77 | 5.57 | 1.28 |
| 1994 | 37.49 | 18.24 | 23.92 | -7.57 | 2.43 | -7.50 | 9.38 | -0.61 |
| Average | 21.46 | 1.04 | 9.72 | -3.09 | 0.18 | -9.98 | 4.38 | 1.11 |
| St. Dev. | 32.46 | 15.02 | 12.30 | 10.15 | 5.36 | 4.06 | 5.68 | 1.65 |

Notes: Percentage growth rates. We use Chilean data from years 1979, 1984, 1989, and 1994.

Table 13
Aggregate Multifactor Productivity Growth Rate, Chilean Manufacturing, Five-Year Differences in 1984-94
BHC (1992) and FHK (2001) Decomposition

| Year | Value Added | (0) Multifactor Prod. Growth | BHC (1992) / FHK (2001) Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1984 | -15.89 | -22.51 | -19.84 | 30.13 | -2.55 | -3.39 | -29.40 | 3.27 |
| 1989 | 42.79 | -2.65 | 3.07 | -41.74 | -11.38 | 2.15 | 33.87 | 3.51 |
| 1994 | 37.49 | 20.64 | 23.01 | -68.21 | 2.26 | -3.58 | 69.42 | -1.05 |
| Average | 21.46 | -1.51 | 2.08 | -26.61 | -3.89 | -1.61 | 24.63 | 1.91 |
| St. Dev. | 32.46 | 21.60 | 21.44 | 50.89 | 6.92 | 3.25 | 50.05 | 2.57 |

Notes: Percentage growth rates. We use Chilean data from years 1979, 1984, 1989, and 1994.

Table A1
Aggregate Labor Productivity (ALP) Growth Rate, Colombian Manufacturing 1978-91
BHC (1992) Between Term Decomposition

| Year | BHC (0): Between Term | BHC (1992) Between Term Decomposition: (0) = (1) + (2)<br>(1) First component | <br>(2) Second component | Number of Plants |
|---|---|---|---|---|
| 1978 | 1.77 | 1.66 | 0.11 | -0.22 |
| 1979 | 2.50 | 3.70 | -1.20 | 2.25 |
| 1980 | 0.94 | 1.86 | -0.93 | 1.84 |
| 1981 | 1.49 | 1.23 | 0.26 | -0.48 |
| 1982 | 1.99 | 3.91 | -1.91 | 3.84 |
| 1983 | 2.32 | -3.39 | 5.71 | -11.02 |
| 1984 | 1.95 | 2.03 | -0.08 | 0.15 |
| 1985 | 1.12 | -0.02 | 1.14 | -2.20 |
| 1986 | -1.96 | 1.94 | -3.89 | 7.91 |
| 1987 | -3.77 | -1.54 | -2.22 | 4.12 |
| 1988 | 3.20 | 4.43 | -1.23 | 2.29 |
| 1989 | 0.00 | 2.04 | -2.05 | 3.88 |
| 1990 | 1.93 | 1.46 | 0.47 | -0.86 |
| 1991 | 1.95 | -0.02 | 1.98 | -3.61 |
| Average | 1.10 | 1.38 | -0.27 | 0.56 |
| St. Dev. | 1.87 | 2.11 | 2.30 | 4.46 |

Notes: Percentage growth rates. BHC Between Term is decomposed into two terms using equation 13 in the text.

Table A2
Aggregate Multifactor Productivity Growth Rate, Colombian Manufacturing 1978-91
BHC (1992) and FHK (2001) Decomposition

| Year | Value Added | (0) Multifactor Prod. Growth | BHC (1992) / FHK (2001) Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1978 | 11.93 | 0.69 | 2.83 | -2.66 | 1.92 | -3.12 | 3.64 | -0.94 |
| 1979 | 9.89 | 0.93 | 0.96 | -1.90 | 1.51 | -2.06 | 3.94 | 0.52 |
| 1980 | 6.92 | 3.76 | 4.60 | -6.00 | 0.33 | -1.70 | 6.87 | 0.53 |
| 1981 | -10.11 | -13.53 | -12.90 | -4.68 | 1.33 | -1.45 | 5.50 | -0.51 |
| 1982 | 0.30 | -2.92 | -1.96 | -7.83 | 0.72 | -1.30 | 8.18 | -0.38 |
| 1983 | 0.05 | 0.05 | -0.79 | 7.18 | 0.55 | -1.35 | -4.99 | 1.64 |
| 1984 | 6.69 | 5.07 | 4.35 | 6.17 | 0.89 | -1.44 | -4.01 | 1.27 |
| 1985 | 7.35 | 2.74 | 3.80 | 9.10 | 0.09 | -2.85 | -7.32 | 1.69 |
| 1986 | 10.76 | 1.94 | 1.77 | -16.11 | 0.14 | -1.97 | 18.25 | 2.00 |
| 1987 | -1.55 | -10.26 | 1.22 | -18.39 | -0.47 | -7.04 | 13.95 | -3.97 |
| 1988 | 9.48 | 11.94 | 6.64 | 15.78 | 7.42 | -8.63 | -1.86 | 6.50 |
| 1989 | 3.39 | 2.11 | 1.91 | -3.37 | 1.72 | -1.93 | 5.49 | 0.40 |
| 1990 | 4.55 | 3.88 | 3.32 | 4.26 | 1.88 | -1.59 | -2.11 | 0.27 |
| 1991 | 0.26 | 2.09 | 0.28 | 12.13 | 1.61 | -1.77 | -8.55 | 1.97 |
| Average | 4.28 | 0.61 | 1.14 | -0.45 | 1.40 | -2.73 | 2.64 | 0.79 |
| St. Dev. | 6.03 | 6.27 | 4.64 | 10.09 | 1.89 | 2.25 | 7.89 | 2.26 |

Notes: Percentage growth rates. The plant-level multifactor productivity is calculated using production function parameters that vary across 3-digit ISIC estimates using Wooldridge (2009). "Value Added" is the growth rate of aggregate value added, which is constructed by summing the establishment-level single-deflated value added across establishments and then taking the annual growth rate. For other details, see notes to Table 10.

Table A3
Aggregate Multifactor Productivity Growth Rate, Slovenian Manufacturing 1995-2004
BHC (1992) and FHK (2001) Decomposition
Industry-level Deflator, Capital Input Adjusted by Capacity Utilization Rate

| Year | Value Added | (0) Multifactor Prod. Growth | BHC (1992) / FHK (2001) Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1995 | 4.01 | 9.74 | 4.45 | 34.05 | 2.20 | -0.39 | -28.37 | 3.49 |
| 1996 | 7.39 | 7.48 | 4.22 | 8.06 | 1.23 | 0.38 | -5.17 | 1.65 |
| 1997 | 14.60 | 11.84 | 6.36 | -9.53 | 0.86 | 0.30 | 14.70 | 4.32 |
| 1998 | 2.90 | 1.09 | -1.49 | -4.86 | 1.54 | 0.16 | 7.28 | 0.88 |
| 1999 | 8.35 | 2.87 | 3.24 | -25.34 | -1.84 | 1.26 | 23.71 | 0.21 |
| 2000 | 8.27 | 4.42 | 2.80 | 9.75 | 0.33 | 0.72 | -8.85 | 0.57 |
| 2001 | 4.28 | 4.44 | 3.39 | 15.24 | 1.22 | 0.28 | -14.47 | -0.45 |
| 2002 | 9.04 | 5.11 | 3.66 | -35.12 | 0.66 | 0.25 | 36.32 | 0.55 |
| 2003 | 6.54 | 3.42 | 2.33 | 34.83 | 0.61 | 1.10 | -34.84 | -0.61 |
| 2004 | 4.62 | 3.85 | 1.93 | 20.07 | 1.58 | 0.15 | -18.30 | 0.20 |
| Average | 7.00 | 5.43 | 3.09 | 4.72 | 0.84 | 0.42 | -2.80 | 1.08 |
| St. Dev. | 3.41 | 3.30 | 2.03 | 23.42 | 1.09 | 0.48 | 22.95 | 1.63 |

Notes: We replace the capital input with the capital input multiplied by the capacity utilization rate whenever possible, and end up replacing 11% of the total number of observations.

Table A4

Aggregate Labor Productivity (ALP) Growth Rate, Slovenian Manufacturing 1995-2004

BHC (1992) and FHK (2001) ALP Decomposition

Metal Industry (NACE 28), Industry-level Price Deflator

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1995 | 12.80 | 12.49 | 16.07 | 3.14 | 3.24 | -17.46 | 10.74 | 10.64 |
| 1996 | 5.89 | 8.24 | 2.06 | 11.86 | 7.72 | -4.30 | -1.38 | 2.75 |
| 1997 | 21.53 | 19.01 | 14.75 | -2.38 | 3.08 | -2.68 | 9.32 | 3.86 |
| 1998 | 7.05 | 3.47 | -0.22 | 4.11 | 3.88 | -2.70 | 2.28 | 2.51 |
| 1999 | 18.37 | 5.54 | 9.30 | -5.33 | 0.91 | -1.45 | 3.03 | -3.22 |
| 2000 | 15.99 | 9.42 | 6.31 | 1.63 | 2.45 | -1.71 | 3.18 | 2.36 |
| 2001 | 14.06 | 9.46 | 8.47 | 0.41 | 1.92 | -1.48 | 2.06 | 0.55 |
| 2002 | 9.70 | 5.68 | 4.70 | -2.34 | 0.90 | -1.04 | 4.36 | 1.12 |
| 2003 | 14.45 | 12.03 | 10.50 | 0.05 | 1.24 | -1.45 | 2.94 | 1.75 |
| 2004 | -0.93 | -0.73 | -1.94 | 4.87 | 1.47 | -0.92 | -2.74 | 0.66 |
| Average | 11.89 | 8.46 | 7.00 | 1.60 | 2.68 | -3.52 | 3.38 | 2.30 |
| St. Dev. | 6.60 | 5.46 | 6.00 | 4.81 | 2.05 | 5.00 | 4.13 | 3.50 |

Notes: We use a 2-digit industry-level price deflator to obtain deflated value added. We use employment share for the share weights. Both (1) within and (2) between terms use base-period share for the weights. For other technical details, see notes to Table 1.

Table A5

Aggregate Labor Productivity (ALP) Growth Rate, Slovenian Manufacturing 1995-2004

BHC (1992) and FHK (2001) ALP Decomposition

Metal Industry (NACE 28), Industry-level and Firm-level Price Deflator

| Year | Value Added | (0) Labor Prod. Growth | BHC (1992) / FHK (2001) ALP Decomposition: (0) = (1) + (2) + (3) + (4) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | (1) Within | (2) Between | | (3) Cross | (4) Net Entry | |
| | | | | BHC | FHK | | BHC | FHK |
| 1995 | 18.85 | 18.72 | 21.96 | 3.26 | 3.25 | -17.42 | 10.92 | 10.92 |
| 1996 | 9.51 | 11.93 | 5.66 | 11.49 | 7.38 | -4.00 | -1.23 | 2.89 |
| 1997 | 17.39 | 15.18 | 15.36 | -3.19 | 2.11 | -1.86 | 4.88 | -0.43 |
| 1998 | 13.51 | 10.92 | 7.48 | 4.12 | 3.18 | -2.09 | 1.40 | 2.34 |
| 1999 | 20.69 | 6.08 | 10.71 | -7.23 | 0.32 | -1.78 | 4.37 | -3.18 |
| 2000 | 6.88 | 6.25 | 3.15 | 5.91 | 1.81 | -1.33 | -1.49 | 2.61 |
| 2001 | 11.29 | 6.82 | 7.02 | -0.65 | 0.95 | -1.39 | 1.85 | 0.25 |
| 2002 | 10.67 | 1.83 | 3.18 | -6.93 | 0.41 | -0.81 | 6.39 | -0.95 |
| 2003 | 14.73 | 12.12 | 10.29 | -0.21 | 1.16 | -1.00 | 3.04 | 1.67 |
| 2004 | 1.99 | 2.85 | 1.93 | 4.99 | 1.02 | -0.66 | -3.42 | 0.55 |
| Average | 12.55 | 9.27 | 8.67 | 1.16 | 2.16 | -3.23 | 2.67 | 1.67 |
| St. Dev. | 5.71 | 5.41 | 6.21 | 5.94 | 2.10 | 5.07 | 4.24 | 3.75 |

Notes: The number of observations with an establishment-level price deflator accounts for 23% of the total number of observations in metal industry. For these observations, we use an establishment-level price deflator to obtain deflated value added. Otherwise, we use a 2-digit industry-level price deflator to obtain deflated value added. For other technical details, see notes to Table 5.

Table A6
Aggregate Labor Productivity (ALP) Growth Rate, Slovenian Manufacturing 1995-2004
BHC (1992) Between Term Decomposition
Single-Product Firms

| Year | BHC (0): Between Term | BHC (1992) Between Term Decomposition: (0) = (1) + (2) | | Number of Firms |
|---|---|---|---|---|
| | | (1): First component | (2) Second component | |
| 1995 | -13.46 | 0.38 | -13.84 | 15.00 |
| 1996 | 5.54 | 7.74 | -2.19 | 2.48 |
| 1997 | 2.90 | 12.65 | -9.75 | 11.52 |
| 1998 | -9.14 | -1.36 | -7.78 | 8.70 |
| 1999 | -1.60 | 3.40 | -5.01 | 5.00 |
| 2000 | 4.88 | 10.95 | -6.08 | 7.62 |
| 2001 | 2.03 | 0.50 | 1.53 | -1.77 |
| 2002 | 1.50 | 5.08 | -3.58 | 4.50 |
| 2003 | 10.80 | 4.52 | 6.29 | -7.33 |
| 2004 | 1.16 | 0.14 | 1.02 | -1.40 |
| Average | 0.46 | 4.40 | -3.94 | 4.43 |
| St. Dev. | 7.09 | 4.79 | 5.91 | 6.71 |

Notes: Percentage growth rates. BHC Between Term is decomposed into two terms using equation 13 in the text. The sample is single-product firms.