Productivity and Reallocation: Evidence from Ecuadorian Firm-Level Data*

Anson T. Y. Ho† Kim P. Huynh‡ David T. Jacho-Chávez§

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Abstract

Ecuador, a developing small open economy, serves as an important case study for aggregate productivity growth and inputs reallocation. Since little is known about the economic performance of Ecuador with its crisis and reforms between 1998 and 2007, this paper utilizes a comprehensive micro data set from Ecuador's National Institute of Statistics and Censuses (Instituto Nacional de Estadística y Censos) to study Ecuadorian firm dynamics in that period. It is found that reallocation of factor inputs (2.6 percent) and technical efficiency growth (3.2 percent) on the intensive margin are the dominant sources of aggregate productivity growth. Net entry, as a channel of reallocation on the extensive margin, generally has minor effects (-0.1 percent) and only contributes to productivity growth in later recovery period (2002-2004).

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†Bank of Canada, 234 Wellington St., Ottawa ON, K1A 0G9, Canada. E-mail: contact@atyho.info.

‡Bank of Canada, 234 Wellington St., Ottawa ON, K1A 0G9, Canada. E-mail: kim@huynh.tv.

§Department of Economics, Emory University, Rich Building 306, 1602 Fishburne Dr., Atlanta, GA 30322-2240, USA. E-mail: djachocha@emory.edu.

1. Introduction

Understanding firm productivity and the efficient reallocation of resources is a central question in industrial economics. It is well understood that reallocation of resources from low productivity to high productivity firms will increase aggregate productivity. However, there may be frictions that prevent this reallocation from occurring. Most acutely, these frictions are common in developing countries and their study is therefore of interest.

Our study adds to this literature by focusing on the case of Ecuador, a developing small-open economy (SOE), that faced a crisis and undertook deep structural reforms for which little is known. In this paper, we study the determinants of aggregate productivity growth in Ecuador during the period 1998-2007. During this period, the Ecuadorian government implemented various policies addressing the shortcomings of economic growth. These reforms entailed economic policies that reduced market distortion and facilitated resource reallocation. Some of them were targeted to improving the allocative efficiency of resources among incumbent plants, while others were launched to encourage entry of efficient plants and the exit of inefficient ones.

Using Ecuadorian plant level data and the methodology proposed by Petrin and Levinsohn (2012), we estimate and decompose Aggregate Productivity Growth (APG) into: (1) technical efficiency improvement, (2) inputs reallocation of incumbent plants (intensive margin) based on labour and capital, and (3) input reallocation due to plants entry and exit (extensive margin). Quantifying and understanding the magnitudes of these different margins can inform researchers and policymakers regarding the functioning of the real economy. We conduct the decomposition over four time periods: 1998-2000, 2000-2002, 2002-2004, 2004-2006, and we show that the source of variation in APG differs across the time periods considered. During the crisis in 1998-2000, technical efficiency and input reallocation on both margins play a role in the APG decrease. However, in later periods the source of APG growth was mostly due to technical efficiency and input reallocation on the intensive margin.

Our results show the importance of distinguishing the effects of capital and labour reallocation on productivity growth. This case study also suggests that understanding the underlying mechanism of APG, input distortions, and its reallocation is important for policy makers as it quantifies on what margin (if any) policies should be directed towards. It sheds light on the causes of slow productivity growth in Latin America emphasized in Inter-American Development Bank (2010). Findings in this paper also suggest the need to remove factor market distortions via labour and/or capital market reforms, whereas policies to encourage entry and minimise exit may not have a strong positive effect on APG.

Understanding the source of APG in Ecuador is a useful case study for firm dynamics in a developing SOE. We compare and contrasts our findings to the existing literature which provides mixed empirical evidence. Our study finds evidence that supports the important role of input reallocation on productivity growth, in line with a strand of literature showing that reallocation improves productivity. On the intensive margin, reallocation may enhance the flow of resource from less productive firms to more productive ones. For example, Petrin, Reiter, and White (2011) highlight the positive role of reallocation in the United States. Eslava, Haltiwanger, Kugler, and Kugler (2004, 2010) find that deregulation in Colombia created a positive impact on productivity. On the extensive margin, Davis and Haltiwanger (1990) and Caballero and Hammour (1994) point out that recessions, although painful, serve as the cleansing effect – inefficient firms are culled while the efficient ones thrive – resulting in an increase in overall productivity.

Our results also highlight that the reallocation effect is not definitive, and it may decrease productivity in an economic crisis. These findings reconcile with the strand of literature arguing that reallocation may intensify market frictions and reduce productivity. On the intensive margin, Barlevy (2002) shows that low quality matches of firms and workers during recession creates inefficient reallocation of labour, known as the sullying effect. Oberfield (2013) and Chen and Irarrazabal (2015) find that misallocation has strong negative effects on productivity in the Chilean manufacturing sector. Petrin and Sivadasan (2013) find that labour market immobility can be a reason for the large gaps between marginal product and marginal cost in Chilean plant level data. Asker, Collard-Wexler, and De Loecker (2014) find that much of the dispersion in productivity is due to capital misallocation caused by the dynamic adjustment costs. On the extensive margin, Nishimura, Nakajima, and Kiyota (2005) point out that the entry and exit mechanism may not lead to efficient reallocation in Japan. Ouyang (2009) shows that recessions may destroy potentially superior firms during their infancy. Hallward-Driemeier and Rijkers (2013) document that financial market imperfections in Indonesia attenuates the relationship between productivity and firm survival.

This paper is organised in the following fashion: Section 2 describes the data used, offers some descriptive statistics, and investigates the reallocation and productivity patterns; Section 3 discusses the APG decompositions; Section 4 analyzes the input distortions, while Section 5 concludes.

2. Stylised Facts

The Ecuadorian economic crisis spans from 1998 to 2000, with the real exchange rate of Sucre (Ecuador's former domestic currency) depreciated 62.3 percent against the US dollar and 16 out of the 40 banks failed. Figure 1 illustrates the difficult macroeconomic conditions faced by Ecuador over the sample period. A detailed description of the crisis and subsequent labour and capital market reforms is provided in Online Appendix A.1.

The impacts of an economic crisis are highlighted by the volatile patterns of plants turnover and inputs reallocation over the sample period. Plants turnover, i.e. entry and exit, are indicative of an plant's extensive margin of production decisions. On the other hand, patterns of input reallocation are useful for understanding the extent to which resources are being transferred between plants.

2.1. Ecuadorian Annual Survey of Manufacturing & Mining

Our analyses are based on the Encuesta Anual de Manufactura y Minería prepared by the Ecuadorian National Institute of Statistics and Censuses (Instituto Nacional de Estadística y Censos, hereafter INEC). Construction of data set is based on the list of *plants* identified in the 1984 Economic Census. The survey initially started in 1998 aiming to capture all of the manufacturing plants based on reported addresses as well as their economic relevance. It covers plants with at least 10 employees for the period of 1998–2007.[1] Each plant is assigned with a unique taxpayer registration number (Registro Único de Contribuyentes, RUC).[2] New entrants are identified through tax records and added to the survey every year.[3] Plants are tracked over time and compelled by law to respond to the survey every year. Survey responses are required to follow official accounting standard and are cross-validated with the Ecuadorian Internal Revenue Service.[4]

We focus on plants' value-added, which is the total value of sales and changes in inventory, minus the total value of intermediate inputs (i.e. raw materials, parts and accessories, and packing). Capital is defined as the annual average net capital measured at replacement value, which takes into account the significant market revaluation of capital due to the depreciation of Sucre in 1999-2000.[5] Plants' value-added and other monetary variables are deflated to 2000-US dollars using the sector-specific producer price index (PPI) and the general PPI, respectively.[6] Monetary values reported in domestic currency (Ecuadorian Sucres) before official dollarisation are first adjusted to values in 2000 using the PPI, and then they are converted into US dollars by the official exchange rate at the time of dollarisation (25,000 Sucres per US dollar).[7]

[1] While it would be beneficial to include observations before 1998, unfortunately compatible data is unavailable.

[2] The survey potentially included informal plants that existed in 1984. However, these plants were unlikely to remain informal at the beginning of the survey in 1998.

[3] Entry (and exit) of informal plants may potentially affect the measurement of entry and exit rates in Table 2. However, the existence of informal plants should have insignificant influence on our analysis for resources reallocation and Aggregate Productivity Growth (Section 3) because these plants are restricted in size and only account for a small fraction of the market share.

[4] We thank Diego Rojas from INEC for clarifying the technical details of the annual survey.

[5] This is a conservative measurement of plant level capital, because it has a even more severely decrease during the crisis if revaluation is not considered. A detailed explanation for the definition of capital and its measurement is provided in Online Appendix A.2.

[6] Índices de Precios al Productor, Total (Nacional-Exportación), subclase de la nomenclatura CIIU-3.

[7] The general PPI increased about 4 times from 1998 to 2000, which is roughly consistent with the depreciation of Sucre against the US dollar in the same period of time.

Plants are classified into sectors by their two-digit International Standard Industrial Classification (ISIC Rev.3.1) code. Sectors with less than 0.5 percent of total observations are dropped. Plants with negative value-added or negative capital in one or more years are dropped. We also excluded plants with top and bottom 1 percent value-added-labour ratio and/or capital-labour ratio to eliminate outliers. As a result, we have a sample of 1,992 plants with a total of 11,713 observations. Data composition is reported in Table 1. We also ensure the longitudinal consistency of the data by checking for multiple entries/exits.[8] Missing plant-year specific observations due to temporarily exits are linearly interpolated following Petrin and Levinsohn (2012).

For analysing plants turnover, inputs reallocation, and the aggregate productivity growth, we construct changes in four biennial windows.[9] It allows us to provide an understanding of which time period contributed to most of the variation. Results are converted to *annual* values, by dividing the biennial values by two.

2.2. Turnover & Reallocation Patterns

Plants' entry and exit patterns are reported in the top panel of Table 2. Entry is defined as the number of new plants in period t that do not exist in period $t-1$, where t is a two-year window. Similarly, exit is the number of plants that exist in period $t-1$ but not in period t. Both are expressed as fractions of the average number of plants in period t and $t-1$. The net entry rate was volatile over the sample period due to the economic crisis and the aftermath recovery. As expected from an economy under crisis, the net entry rate was the lowest (-4.3 percent) in 1998-2000, when the exit rate was the highest and more than double of the entry rate. The net entry rate reached the highest (3.1 percent) in 2002-2004, as the entry rate increased steadily and peaked at 10 percent while the exit rate remained at lower levels after the crisis.

Patterns of labour and capital reallocation are reported in the middle and the bottom panel of Table 2. We focus on the creation, destruction, and reallocation rates. Job (capital) creation is the sum of new jobs (capital) at new entrants and incumbent plants; destruction is the sum of lost jobs (capital) at exitors and incumbent plants; reallocation is the sum of jobs (capital) created and jobs (capital) destructed. All job (capital) creation, destruction, and reallocation rates are expressed as fractions of the average employment (capital) in period t and $t-1$.

For labour reallocation, the reallocation rate was highest (20.6 percent) in 1998-2002 and gradually decreased to 15.7 percent in 2004-2006. During the crisis, both the job creation and destruction rates were about 10 percent. Reallocation remained high in 2000-2002 as job creation increased to 14.1 percent while job destruction decreased to 6.2 percent. Expanding incumbents

[8] There is a small fraction of plants (about 1%) that temporarily exits and later re-enters the sample. For the effects on entry and exit, we ignored temporary exits and re-entries by treating plants' first entry and last exit as the only valid ones.

[9] Results at annual intervals are available in Online Appendix C.

contributed most of the job creation, except in 2002-2004 when plant entry was the highest. In contrast, exitors and incumbents had similar job destruction rates. Entrants were bigger than exitors in terms of employment, but both were below the median level.[10]

For capital reallocation, the crisis period had the highest reallocation rate (31 percent) when capital destruction (21.6 percent) was more than twice of its creation (9.4 percent). The trend immediately reversed in 2000-2002 as capital creation increased to 16.7 percent while its destruction reduced to 7 percent. Net capital creation shows more variation, with massive net capital destruction in 1998-2000 and strong net capital creation in 2000-2002. The incumbents generally account for the major share of capital creation and destruction. In terms of median capital-labour ratio, entrants were bigger than exitors except in the crisis years.

3. Aggregate Productivity Growth Decomposition

The role of resource reallocation in productivity growth is unclear for an economy under transition. Resources misallocation may increase during a crisis, as inputs may not be flowing to productive plants due to heightened market frictions. Market reforms as a response, on the other hand, may improve the allocative efficiency. On the extensive margin, productivity may gain from a cleansing effect as unproductive plants exit, but in a crisis situation productive plants may also exit due to a drastic increase in market frictions. Thus, it is important to study how input reallocation and technological progress are converted into an aggregate productivity adjustment process.

Existing macroeconomic literature largely focuses on measuring the effect of reallocation on total factor productivity (TFP). The conventional OP-BHC-FHK decomposition method in Olley and Pakes (1996), Baily, Hulten, and Campbell (1992), and Foster, Haltiwanger, and Krizan (2001) is based on output-weighted aggregates of plant level TFP. The reallocation effect is measured by changes in plants' TFP-weighted *output share*, and it improves productivity when high TFP plants have bigger market shares. For instance, Eslava, Haltiwanger, Kugler, and Kugler (2004, 2010) estimate TFP growth in Colombia due to market reforms and quantify the role of adjustment costs on resources reallocation.

For an economy in crisis and its allocative efficiency in question, we adopted an alternative method in Petrin and Levinsohn (2012) to measure and decompose the *Aggregate Productivity Growth* (APG). It explicitly measures productivity growth due to TFP improvements and resources reallocation, taking into account plant level heterogeneity and returns to scale.[11] The

[10] The median size of employment increased from 32 in 1998 to 35 in 2006. See Online Appendix A.3 for details.

[11] Interested readers are referred to Petrin and Levinsohn (2012) and Kwon, Narita, and Narita (2015) for details. As with other decomposition methods, a potential caveat is that concurrent policy reforms make it hard to identify the direct effects of a specific policy.

reallocation effect is based on plants' *wedges* between the marginal product and marginal cost of input, typically used as a measure of misallocation in the theoretical literature (see Restuccia and Rogerson, 2008; Guner, Ventura, and Xu, 2008; Hsieh and Klenow, 2009, among others). APG improves when input is reallocated from a plant with smaller marginal product-marginal cost gap to a plant with a bigger gap. Technical details of the decomposition method is included in Appendix A.

Accounting for the extent of misallocation is important in measuring the reallocation effect on productivity growth. Under the APG decomposition, inputs flowing from a higher TFP plant with a lower TFP plant may still improve productivity, provided that input reallocation sufficiently reduces misallocation. On the contrary, such reallocation will show up as productivity loss in the OP-BHC-FHK decomposition, as the higher TFP plant loses market share to the lower TFP plant. For example, Cubas, Ho, Huynh, and Jacho-Chávez (2016) use the FHK decomposition method to analyse labour productivity in Ecuador, and they find that reallocation improves productivity while productive plants are losing market shares. Important differences between APG and BHC-FHK decompositions is further discussed in Petrin and Levinsohn (2012).

3.1. Methodology

We assume value-added (Y) is produced via a Cobb-Douglas production function using capital (K) and labour (L). For plants i in period t, the production of Y_{it} is specified as

$$Y_{it} = z_{it} K_{it}^{\alpha_j} L_{it}^{\gamma_j}, \tag{3.1}$$

where z_{it} is the TFP of plant i in period t, α_j and γ_j are the elasticity of output for capital and labour in sector j, respectively.

Aggregate Productivity Growth (APG) is defined as the change in aggregate value-added residual, which is equal to the change in aggregate value-added minus the change in aggregate expenditure, expressed as a percentage of the aggregate value-added. In continuous time setting, APG at time t is

$$\text{APG}(t) = \left(\sum_i dY_{it} - \sum_i r_{it} dK_{it} - \sum_i w_{it} dL_{it} \right) \Big/ \sum_i Y_{it}. \tag{3.2}$$

By substituting production function (3.1) and $d\ell = \ell d \ln \ell$ for $\ell \in \{K, L\}$ into (3.2),

$$\text{APG}(t) = \sum_i D_{it} d \ln z_{it} + \sum_i D_{it} \left(\alpha_j - s_{it}^K \right) d \ln K_{it} + \sum_i D_{it} \left(\gamma_j - s_{it}^L \right) d \ln L_{it} \tag{3.3}$$

with

$$D_{it} = \frac{Y_{it}}{\sum_i Y_{it}}, \; s_{it}^K = \frac{r_{it} K_{it}}{Y_{it}}, \text{ and } s_{it}^L = \frac{w_{it} L_{it}}{Y_{it}}, \tag{3.4}$$

where D_{it} is the Domar weight, s_{it}^K and s_{it}^L are the capital and labour shares of value-added, respectively.

The total APG from period $t-1$ to t is measured by taking the time integral of (3.2) as

$$\text{APG}_{t-1,t} = \int_{t-1}^{t} \text{APG}(\tau) d\tau, \tag{3.5}$$

which can be empirically approximated in discrete time intervals. It can be decomposed by substituting (3.3) into (3.5) and further categorising plants by their entry/exit status. The discrete time approximation is written as

$$\begin{aligned} \text{APG}_{t-1,t} \simeq & \underbrace{\sum_{i\in I_t} \bar{D}_{it} \Delta \ln z_{it}}_{\text{TE}} + \underbrace{\sum_{i\in I_t} \bar{D}_{it} \left(\gamma_j - \bar{s}_{it}^L\right) \Delta \ln L_{it}}_{\text{APG}_{RE}^L} + \underbrace{\sum_{i\in I_t} \bar{D}_{it} \left(\alpha_j - \bar{s}_{it}^K\right) \Delta \ln K_{it}}_{\text{APG}_{RE}^K} \\ & + \underbrace{\sum_{i\in E_t} D_{it} \left(1 - s_{it}^K - s_{it}^L\right)}_{\text{Entry}} - \underbrace{\sum_{i\in X_{t-1}} D_{it-1} \left(1 - s_{it-1}^K - s_{it-1}^L\right)}_{\text{Exit}}, \end{aligned} \tag{3.6}$$

with

$$\bar{D}_{it} = \frac{D_{it} + D_{it-1}}{2}, \ \bar{s}_{it}^L = \frac{s_{it}^L + s_{it-1}^L}{2}, \text{ and } \bar{s}_{it}^K = \frac{s_{it}^K + s_{it-1}^K}{2}, \tag{3.7}$$

where I_t, E_t, X_{t-1} denote the set of plants at period t that are incumbents, new entrants, and exitors respectively; Δ is the first difference operator for continuous time approximation; $\bar{D}_{it}$ is incumbent i's average Domar weight between $t-1$ and t; $\bar{s}_{it}^L$ and $\bar{s}_{it}^K$ are incumbent i's average value-added shares for labour and capital between $t-1$ and t, respectively.

The first three terms measure APG from the incumbent plants. Technical Efficiency (TE) is the weighted sum of changes in plant level TFP. It entails how within-plant productivity changes affect the overall APG. Reallocation terms measure productivity changes coming from the reallocation of labour (APG_{RE}^L) and capital (APG_{RE}^K).

Productivity gain from reallocation depends on the allocative efficiency and the flow of inputs. Typical factors affecting allocative efficiency include taxes, market frictions, and adjustment costs. The amount of input misallocation, i.e. *distortion*, is measured by the difference between the value-added elasticity and the factor share. In Online Appendix E, we show that input wedges as percentage of factor shares are equivalent to the notion of *distortion taxes* in the theoretical literature.[12] Reallocation improves productivity when factor inputs are directed to

[12] The effect of input misallocation on TFP is measured by Restuccia and Rogerson (2008) and Guner, Ventura, and Xu (2008) in a perfect competition setting, and by Hsieh and Klenow (2009) in a monopolistic competition setting. Online Appendix E contains a formal tests whether the distributions of distortion has changed over time based on the methodology described in Huynh and Jacho-Chávez (2010), Huynh, Jacho-Chávez, Petrunia, and Voia (2011),Huynh, Jacho-Chávez, Kryvtsov, Shepotylo, and Vakhitov (2016), and Chu, Huynh, Jacho-Chávez, and Kryvtsov (2018).

plants with positive distortions or away from those with negative distortions. When frictions are severe enough to prevent any input flow ($\Delta \ell_{it} = 0$ for $\ell = L, K$), the reallocation effect will not exist even if misallocations indicate large potential gains. Conversely, in a typical neoclassical setting that resources are efficiently allocated, plants' marginal product of inputs equal to their marginal cost and further reallocation will not improve productivity.[13]

The last two terms measure the entry and exit effects on APG, and the net entry effect is the difference between them. The entry effect in period t is equal to the aggregate value-added residual of all entrants operated in period t but not in period $t-1$, since they contribute to APG by creating new value-added residuals. Similarly, the exit effect is the aggregate value-added residual of all exitors operated in period $t-1$ and not in period t, as their disappearances represent a loss in the existing value-added residuals. Net entry effect is positive when high TFP entrants replace low TFP exitors or entrants with lighter distortions replace exitors with heavier distortions.

For our APG estimation, factor shares for each sector are estimated following Wooldridge (2009) and results are reported in Table 3.[14] Labour expenditure ($w_{it}L_{it}$) is taken from the data, which allow wages to vary across plants to reflect differences in labour quality. Since there is no reported data on the returns on capital, we calculated plants' capital expenditures by using plant level capital and the market interest rate in the corresponding year. The market interest rate is defined as the weighted average lending rate charged by private banks on 84- to 91-days US dollar loans, reported by the Central Bank of Ecuador. This simplifying assumption ($r_{it} = r_t$, $\forall i$) is also used in Gopinath, Kalemli-Ozcan, Karabarbounis, and Villegas-Sánchez (2017).

3.2. APG Results

Estimates from the APG decomposition are reported in Table 4.[15] Results are expressed in *annual* values. Our results show that APG is the predominant contributor to value-added growth. From 1998 to 2006, value-added on average grows by 6.2 percent per year, of which 5.8 percent is due to APG. Changes in the aggregate labour and capital expenditures only contribute 0.6 percent and -0.2 percent value-added growth, respectively.

Improvements in technical efficiency (TE) and inputs reallocation (APG_{RE}) are the main drivers for APG. From 1998-2006, technical efficiency and input reallocation on average contribute 3.2 and 2.6 percent APG, respectively. Capital and labour reallocation have similar

[13] First order conditions imply that $\partial Y_{it}/\partial L_{it} - w_{it} = 0 = \gamma_j - s^L_{it}$ and $\partial Y_{it}/\partial K_{it} - r_{it} = 0 = \alpha_j - s^K_{it}$.

[14] Ackerberg, Caves, and Frazer (2015) provide a critique of production function estimators based on inversion such as Levinsohn and Petrin (2003). Wooldridge (2009) addresses this critique by adding extra moment conditions. Further, Ackerberg, Caves, and Frazer (2015) find that fixed effects estimates will be the lower bound while OLS is the upper bound; while Levinsohn and Petrin (2003) and Wooldridge (2009) lie somewhere in between. Online Appendix B provides estimates of these alternative methods.

[15] Results for the APG decomposition in annual-intervals are reported in Online Appendix C.

overall importance, they respectively promote APG by 1.3 percent and 1.2 percent. On the extensive margin, net entry only has minor effect with an average -0.1 percent APG.

In biennial intervals, APG is more volatile and the relative importance of the decomposition terms varies. Productivity declines by 5.2 percent during the crisis. The drop in APG is equally important on the intensive margins with technical efficiency (-1.5 percent) and reallocation (-1.4 percent), as well as the net entry effect (-2.2 percent) on the extensive margin. APG strongly rebounds to 13.4 percent as the economy recovers in 2000-2002. In contrast, it is mainly driven by the intensive margins with technical efficiency (6.1 percent) and reallocation (7.2 percent). From 2002 onwards, technical efficiency continue to be an important source for APG while the reallocation effect varies significantly.

Volatility in the reallocation effect is mainly due to capital reallocation. It reduces APG by 2.8 percent when there is substantial capital destruction during the crisis. The trend is reversed in 2000-2002 when capital reallocation contributes 5.6 percent APG, which marks the strongest effect of input reallocation in all periods. APG from capital reallocation is close to zero in 2002-2004 and resume with 2.3 percent in 2004-2006. On the contrary, labour reallocation makes positive and stable contributions to APG, even during the crisis in 1998-2000 (1.3 percent), suggesting that labour market reforms during the crisis may have improved the allocative efficiency. Productivity growth from labour reallocation in post-crisis periods remains above 1.0 percent, except a notable drop in 2002-2004 possibly because the labour market reforms was partially reversed in 2003.[16]

Overall, the net entry effect is limited because the entry and exit effects roughly cancel out each other. Entrants and exitors are also smaller in size and account for less weight on the APG.[17] Nonetheless, net entry still has economically sizable effects on APG during the crisis, when the net entry rate is negative and bigger plants exit the market. It also make a notable contribution of 1.4 percent APG in 2002-2004, when net entry rate is the highest and entrants are substantially bigger than the exitors.

Our findings provide an interesting comparison to existing studies on emerging economies. Compared to the 1982 Chilean crisis studied in Nishida, Petrin, and Polanec (2014), the Ecuadorian crisis has a more moderate impact on APG. The decline in technical efficiency is substantially smaller, and capital reallocation plays a more important role in the post-crisis APG. Midrigan and Xu (2014) argue that firms' self-financing reduces capital misallocation, so that it only generates small productivity losses even in less financially developed countries such as Colombia. On the other hand, our estimated productivity loss due to capital misallocation suggests that the self-financing mechanism may not function during a crisis, and capital reallocation is an important source of productivity growth in the post-crisis period. This finding

[16]See Table A.1 in Online Appendix A for details.

[17]See Section 2 for entrants' and exitors' characteristics.

also makes an interesting contrast with Gopinath, Kalemli-Ozcan, Karabarbounis, and Villegas-Sánchez (2017) showing that capital inflows are increasingly misallocated in southern Europe from 1999-2012. On the extensive margin, productivity loss from net exit during the Ecuadorian crisis is consistent with the exit of productive plants in the 1997-1998 Indonesian crisis (Hallward-Driemeier and Rijkers, 2013). Our findings also suggest that net entry only contribute to productivity growth in later periods of recovery. In a broader sense, the decrease in technical efficiency during the Ecuadorian crisis is consistent with Gopinath and Neiman (2014) findings on the 2001-2002 Argentine crisis, that productivity decreases due to within-firm substitution of inputs.

3.3. Source of APG from Reallocation

Since inputs reallocation of incumbent plants plays a significant role in APG, we conducted further investigation on the source of inputs being reallocated. APG decomposition reflects two potential channels for input reallocation to increase APG: (1) more inputs are used in the aggregate economy that reduces the average misallocation, and (2) inputs are reallocated across plants for which inputs are disproportionally misallocated. Distinguishing the effects of these channel is important, because an economic crisis is commonly associated with substantial changes in the level of aggregate inputs (Calvo, Izquierdo, and Talvi, 2006). To separate these effects, APG^L_{RE} and APG^K_{RE} in equation (3.6) are rewritten as

$$
\begin{aligned}
\text{APG}^L_{RE} &= \sum_{i \in I_t} \bar{D}_{it} \left(\gamma^j - \bar{s}^L_{it}\right) \Delta \ln L_{it} \\
&= \underbrace{\bar{\mu}^L_t \sum_{i \in I_t} \bar{D}_{it} \Delta \ln L_{it}}_{\text{AVG}_L} + \underbrace{\sum_{i \in I_t} \bar{D}_{it} \left[\left(\gamma^j - \bar{s}^L_{it}\right) - \bar{\mu}^L_t\right] \Delta \ln L_{it}}_{\text{DAVG}_L}, \qquad (3.8)
\end{aligned}
$$

$$
\begin{aligned}
\text{APG}^K_{RE} &= \sum_{i \in I_t} \bar{D}_{it} \left(\alpha^j - \bar{s}^K_{it}\right) \Delta \ln K_{it} \\
&= \underbrace{\bar{\mu}^K_t \sum_{i \in I_t} \bar{D}_{it} \Delta \ln K_{it}}_{\text{AVG}_K} + \underbrace{\sum_{i \in I_t} \bar{D}_{it} \left[\left(\alpha^j - \bar{s}^K_{it}\right) - \bar{\mu}^K_t\right] \Delta \ln K_{it}}_{\text{DAVG}_K}, \qquad (3.9)
\end{aligned}
$$

where $\bar{\mu}^\ell_t$ for $\ell = L, K$ is the average distortion among N_{It} incumbents, such that

$$
\bar{\mu}^L_t = \sum_{i \in I_t} \left(\alpha^j - \bar{s}^L_{it}\right) \Big/ N_{It}, \qquad (3.10)
$$

$$
\bar{\mu}^K_t = \sum_{i \in I_t} \left(\gamma^j - \bar{s}^K_{it}\right) \Big/ N_{It}. \qquad (3.11)
$$

The first term, AVG_ℓ for $\ell = L, K$, measures APG from changes in the Domar-weighted aggregate inputs conditional on the average misallocation. When plants on average are input constrained, i.e. $\bar{\mu}_t^\ell > 0$ for $\ell = L, K$, additional aggregate inputs will relax their input constraints and improve their productivity. The second term, DAVG_ℓ for $\ell = L, K$, measures APG from input flows for plants with disproportional levels of misallocation. It indicates the allocative efficiency across plants. APG increases when more inputs are allocated to plants with above-average misallocations. Estimates are reported in Table 5.

APG from labour reallocation (APG_{RE}^L) predominantly come from increases in the aggregate use of labour (AVG_L). From 1998–2006, it contributes an average of 2.1 percent APG per year. Productivity gain from the aggregate change in labour resembles the net job creation pattern in Table 2. While the economy-wide net job creation is negative during the crisis, incumbents absorb the labour inputs released by exitors to ease their constraints, leading to a positive AVG_L (2.4 percent). For most years AVG_L is over 2 percent with the increase in aggregate labour input reflected in the net job creation. The negative DAVG_L shows that labour input flow is concentrated on incumbents with below-average misallocation, instead of moving towards more labour-constrained plants. A plausible reason is that plants with below-average labour misallocation is more able to attract workers, which explains why they have less misallocation to begin with. Overall, a strong positive AVG_L and a moderately negative DAVG_L suggest that while labour market reforms may have promoted employment through a more flexible labour market, there may also be other factors restricting labour inputs to move towards more constrained plants.

Capital reallocation (APG_{RE}^K) shows a contrasting pattern to labour reallocation. The aggregate change in capital (AVG_K) has minimal influences on APG, with an average of -0.1 percent from 1998–2006. The main source of growth comes from efficient reallocation of capital (DAVG_K), contributing 1.4 percent APG per year. The pattern of capital creation/destruction, AVG_K, and DAVG_K jointly shed light on the effects of capital allocation. During the crisis, the negative APG_{RE}^K is mainly driven by lower allocative efficiency (DAVG_K), while the substantial capital destruction only moderately affects AVG_K. This observation implies that capital destruction was concentrated in more capital-constrained plants with smaller market shares. The strong APG_{RE}^K (5.6 percent) in 2000–2002 is a reverse of the process. Substantial net capital creation, large DAVG_K (5.4 percent), and minor AVG_K (0.2 percent) indicates that capital mainly moved to plants that were small and disproportionally capital-constrained.

4. Plant-Level Distortions and Productivity Growth

The findings on Aggregate Productivity Growth suggest that inputs reallocation among incumbent plants is an important channel. Thus, we conduct further analyses on the incumbents to understand the relationship of plants' input misallocation with their characteristics. The measures of input misallocation are taken from the reallocation terms in equation (3.6) and are normalized to express as percentages of value-added share for factor input.[18] Specifically, denote the normalized labour (L) and capital (K) distortions for plant i in period t as τ_{it}^{ℓ} for $\ell \in \{L, K\}$,

$$\tau_{it}^{L} = \left(\gamma_j - \bar{s}_{it}^{L}\right) / \bar{s}_{it}^{L}, \tag{4.1}$$

$$\tau_{it}^{K} = \left(\alpha_j - \bar{s}_{it}^{K}\right) / \bar{s}_{it}^{K}. \tag{4.2}$$

Misallocation occurs when the distortion measure is *not* zero. The sign of distortion carries different economic meanings: $\tau_{it}^{\ell} > 0$ indicates that plant i's use of input $\ell = L, K$ is restricted and reallocating more units of ℓ to plant i will improve APG, and vice versa.

The fixed-effect regression models on input distortion are specified as

$$\begin{aligned} \tau_{it}^{\ell} = \; & \beta_i + \beta_j + \beta_t \\ & + I\{\tau_{it}^{\ell} \geq 0\} \times \{\beta_z^{+} \log z_{it-1} + \beta_k^{+} \log k_{it-1}\} \\ & + I\{\tau_{it}^{\ell} < 0\} \times \{\beta_z^{-} \log z_{it-1} + \beta_k^{-} \log k_{it-1}\} + u_{it}^{\ell}, \end{aligned} \tag{4.3}$$

where β_i, β_j, and β_t denote plant, sector, and time fixed-effects, respectively, z_{it-1} is plant TFP, and k_{it-1} is plant specific capital-labour ratio. $I\{\cdot\}$ represents the indicator function that is equal to one if its argument is true and zero otherwise. Interaction terms for positive and negative distortions are included to capture the different relationship between the direction of input distortions and plant characteristics. Plant level capital-labour ratio also reflects the extend of misallocation in a specific input and explains the extent to which APG is coming from a specific factor reallocation. The rationale of including capital-labour ratio is that input adjustments are interdependent. As illustrated in Eslava, Haltiwanger, Kugler, and Kugler (2010), plants' labour adjustments are conditional on their capital constraints, and vice versa. Thus, we use plants' capital-labour ratios to reflect the relative tightness of their capital and labour constraints. Results are reported in Table 6.

For input-constrained plants, i.e. $\tau_{it}^{\ell} \geq 0$, productive plants are subject to more input distortions, and capital distortions are more sensitive to plant level productivity. The positive β_z^{+} imply there exists a barrier for the growth of most productive plants as they are constrained by resources allocation.[19] We estimated that a one percent increase in TFP is associated with 0.51% and 3.80% more labour and capital distortions, respectively. There are various factors contributing to the higher sensitivity of capital distortion. The aggregate capital supply is more limited than the labor supply in Ecuador, so that plants are more restricted in capital use in general. Labour regulation reforms in response to the crisis may also provide greater flexibility in the labour market, which reduces the amount of labour distortions on productive plants.

[18] As noted in Section 3, this measure is equivalent to the notion of input distortion tax in the macroeconomic literature.

[19] We thank Marcela Eslava for this comment.

The distortion estimates on capital-labour ratio, i.e. β_k^+, provide further evidence on the relatively flexible labour market. A one percent increase in capital-labour ratio only raises labour distortion by 0.13% but reduces the capital distortion by 4.27%. These results suggest that plants with higher capital-labour ratio, thus higher marginal product of labour, are able to make labour adjustments and they are only associated with a sightly higher level of labour distortion. These plants, albeit still undersized, face much less capital distorion indicating plant level capital is more difficult to adjust.

For plants with surplus inputs, i.e. $\tau_{it}^\ell < 0$, productive ones are associated with less input misallocation. The positive β_z^+ indicate that plants with higher TFP are less oversized. Plants with higher capital-labour ratios are less oversized in labour but more excessive in capital use. It follows the economic intuition that high-TFP plants have higher marginal products of input, therefore they should use more inputs and become larger in scale. Thus, conditional on being undersized, the extent of misallocation become larger with higher TFP while oversized plants misallocation becomes smaller with higher TFP. The coefficient on capital distortion is substantially higher than its labour counterpart, which implies that capital misallocation was more severe in the Ecuadorian economy.

The analysis also shows that capital distortion was more severe for undersized plants with low capital-labour ratios. Oversized plants with higher capital-labour ratios are also associated with more misallocation, but the sensitivity is notably less than that for undersized plants. On the other hand, plants with higher capital-labour ratio have higher marginal product of labour and are associated with more labour misallocation, conditional on them being undersized.

5. Conclusions

Ecuador's economic performance in 1998-2007 serves as an interesting case study to understand aggregate productivity growth and inputs reallocation in a developing SOE. Using Ecuadorian plant level data, we documented stylised facts about plants turnover and inputs reallocation to illustrate the amount of frictions in this economy. The effects of input misallocation on aggregate productivity growth is estimated using the decomposition method by Petrin and Levinsohn (2012). Our results showed that technical efficiency growth and input reallocation (intensive margin) are more important than net entry of plants (extensive margin) for productivity growth. From 1998 to 2006, improvements in technical efficiency and inputs reallocation of incumbents contributed 3.2 and 2.6 percent to average annual productivity growth, while net entry just accounted for -0.1 percent. During the crisis, technical efficiency, reallocation of incumbent plants, and net entry of plants played equally important roles in the plummeting APG. Reallocation of incumbent plants was particularly important during the immediate recovery period in 2000-2002, while net entry only contributed moderate APG in 2002-2004. We also find that distortions are statistically significantly correlated with plant level TFP and their capital-labour ratios.

Our findings have important policy implications, as they highlight the need for distortions to be removed in factor markets via labour and/or capital market reforms. Policies to encourage entry and minimize exit may have limited and lagged effect on aggregate productivity growth. Overall, our results point to technical efficiency growth and input reallocation as important margins for re-adjustment. Nonetheless, the concurrent policy reforms undertaken in the sample period makes it hard to link specific policies to APG from reallocation. Thus, the efficacy of a specific policy is still an open question.

An interesting extension to be considered is the role of financial frictions on capital adjustment process. For instance, Buera, Kaboski, and Shin (2011) show that financial frictions distort capital allocation and negatively affect productivity. On the other hand, Midrigan and Xu (2014) suggest that efficient establishments can quickly accumulate internal funds and financial frictions only produce modest TFP losses. Gopinath, Kalemli-Ozcan, Karabarbounis, and Villegas-Sánchez (2017) use the introduction of the Euro and the decline in real interest rate to understand how capital inflow to Spain resulted in lower productivity. Similarly, dollarisation may have a similar impact on plants' input reallocation via removing the balance sheet effect. Research by Quispe-Agnoli and Whisler (2006) find that dollarisation improved the Ecuadorian banking sector. Unfortunately, at the present time there is no detailed financial balance sheet data for Ecuador that can be used to study this phenomena.

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Table 1: Classification of Industries Based on Two-Digit International SIC

ISIC	Industries	Proportion of Observations	Plants	Output
15	Food products and beverages	0.27	0.28	0.39
17	Textiles	0.07	0.07	0.07
18	Wearing apparel; dressing and dyeing of fur	0.08	0.07	0.01
19	Tanning and dressing of leather; leather products	0.03	0.03	0.02
20	Wood and of products of wood and cork	0.04	0.04	0.02
21	Paper and paper products	0.03	0.03	0.05
22	Publishing, printing and reprod. of recorded media	0.05	0.05	0.05
24	Chemicals and chemical products	0.08	0.08	0.10
25	Rubber and plastics products	0.08	0.08	0.08
26	Other non-metallic mineral products	0.06	0.06	0.03
27	Manufacture of basic metals	0.01	0.01	0.04
28	Fabricated metal products	0.05	0.06	0.04
29	Machinery and equipment n.e.c.	0.03	0.03	0.04
31	Electrical machinery and apparatus n.e.c.	0.01	0.02	0.02
34	Motor vehicles, trailers and semi-trailers	0.03	0.02	0.03
36	Furniture; manufacturing n.e.c.	0.07	0.07	0.02

Note: Plants are classified into sectors using their 2-digit ISIC Rev.3.1 code. An observation refers to values reported by a unique establishment in a specific year. Since our study period is from 1998 to 2007, there can be at most nine observations associated with a particular establishment. Sectors with less than 0.5% of total observations are dropped from the sample.

Table 2: Patterns for Resource Reallocation

	1998-2000	2000-2002	2002-2004	2004-2006
Entry and Exit Rates				
E Rate	0.040	0.072	0.101	0.053
X Rate	0.082	0.060	0.071	0.056
NE Rate	-0.043	0.012	0.031	-0.003
Labour Reallocation Pattern				
JC	0.102	0.141	0.101	0.111
by E	0.030	0.045	0.050	0.033
by I	0.072	0.096	0.050	0.079
JD	0.104	0.062	0.089	0.046
by X	0.058	0.033	0.040	0.018
by I	0.046	0.028	0.049	0.028
JR	0.206	0.203	0.190	0.157
l of E	29.5	23	25	22
l of X	21	20	18	16
Capital Reallocation Patterns				
KC	0.094	0.167	0.096	0.106
by E	0.033	0.055	0.045	0.029
by I	0.061	0.113	0.051	0.077
KD	0.216	0.070	0.108	0.058
by X	0.073	0.036	0.036	0.018
by I	0.142	0.034	0.071	0.040
KR	0.310	0.237	0.204	0.164
k/l of E	2.412	3.228	4.180	4.249
k/l of X	3.893	2.110	2.666	3.461

Note: Entry (E) and exit (X) rates are expressed as fractions of the average number of plants in period t and $t-1$, with t as a two-year period. Net entry (NE) rate is the difference between entry and exit rates. Job creation JC (capital creation KC) is defined as the sum of new jobs (capital) used by new entrants (E) and incumbent plants (I). Job destruction JD (capital destruction KD) is defined as the sum of all lost jobs (capital) at exitors (X) and incumbent plants (I). Job reallocation JR (capital reallocation KR) refers to the sum of job (capital) created and destructed. JC, JD, and JR (KC, KD, and KR) are expressed as fractions of the average employment (capital) in period t and $t-1$. The median number of workers employed and the median capital-labour ratio are denoted by l and k/l, respectively. All results are in *annual* values.

Table 3: Production Function Estimates

Sector	$\hat{\alpha}_j$	s.e.	$\hat{\gamma}_j$	s.e.
15	0.221	0.033	0.657	0.039
17	0.055	0.053	0.543	0.053
18 & 19	0.090	0.047	0.910	0.071
20	0.075	0.047	0.915	0.076
21 & 22	0.289	0.045	0.667	0.090
24	0.290	0.059	0.653	0.071
25	0.126	0.058	0.578	0.068
26	0.120	0.051	0.705	0.070
27 & 28	0.162	0.054	0.768	0.120
29 & 31	0.165	0.058	0.682	0.090
34	0.172	0.112	0.759	0.206
36	0.146	0.042	0.584	0.088

Note: Sectoral production functions were estimated following Wooldridge (2009). Due to relatively small number of observations in sector 19, 21, 27, and 31, these sectors are combined with sector 18, 22, 28, and 29, respectively, in our production function estimations.

Table 4: Aggregate Productivity Growth (APG) Decomposition

						APG_{RE}			APG_{NE}		
Year	ΔY	ΔL	ΔK	APG	TE	Labour	Capital	Total	Entry	Exit	Net
1998-2000	-0.064	-0.006	-0.006	-0.052	-0.015	0.013	-0.028	-0.014	0.016	0.038	-0.022
2000-2002	0.147	0.013	0.000	0.134	0.061	0.016	0.056	0.072	0.019	0.019	0.000
2002-2004	0.058	0.006	-0.002	0.053	0.032	0.006	0.001	0.008	0.028	0.014	0.014
2004-2006	0.107	0.010	0.002	0.095	0.052	0.014	0.023	0.038	0.013	0.008	0.006
Average	0.062	0.006	-0.002	0.058	0.032	0.012	0.013	0.026	0.019	0.020	-0.001
Std. Dev.	0.091	0.008	0.003	0.080	0.034	0.004	0.035	0.038	0.007	0.013	0.016

Note: ΔY is value-added growth. ΔL and ΔK refer to changes in the aggregate expenditure on labour and capital respectively. TE refers to technical efficiency, APG_{RE} is the Reallocation term, and APG_{NE} is the effect of Net Entry, which is Entry minus Exit. The TE and APG_{RE} terms are estimated from the production function following Wooldridge (2009). Results are in *annual* values.

Table 5: Aggregate Productivity Growth (APG) from APG_{RE}

	APG^{L}_{RE}			APG^{K}_{RE}		
Year	AVG_L	$DAVG_L$	Total	AVG_K	$DAVG_K$	Total
1998-2000	0.024	-0.010	0.013	-0.008	-0.020	-0.028
2000-2002	0.028	-0.012	0.016	0.002	0.054	0.056
2002-2004	0.009	-0.003	0.006	-0.002	0.003	0.001
2004-2006	0.022	-0.008	0.014	0.004	0.019	0.023
Average	0.021	-0.008	0.012	-0.001	0.014	0.013
Std. Dev.	0.008	0.004	0.004	0.005	0.031	0.035
1998-2006	0.005	-0.002	0.003	0.001	0.035	0.036

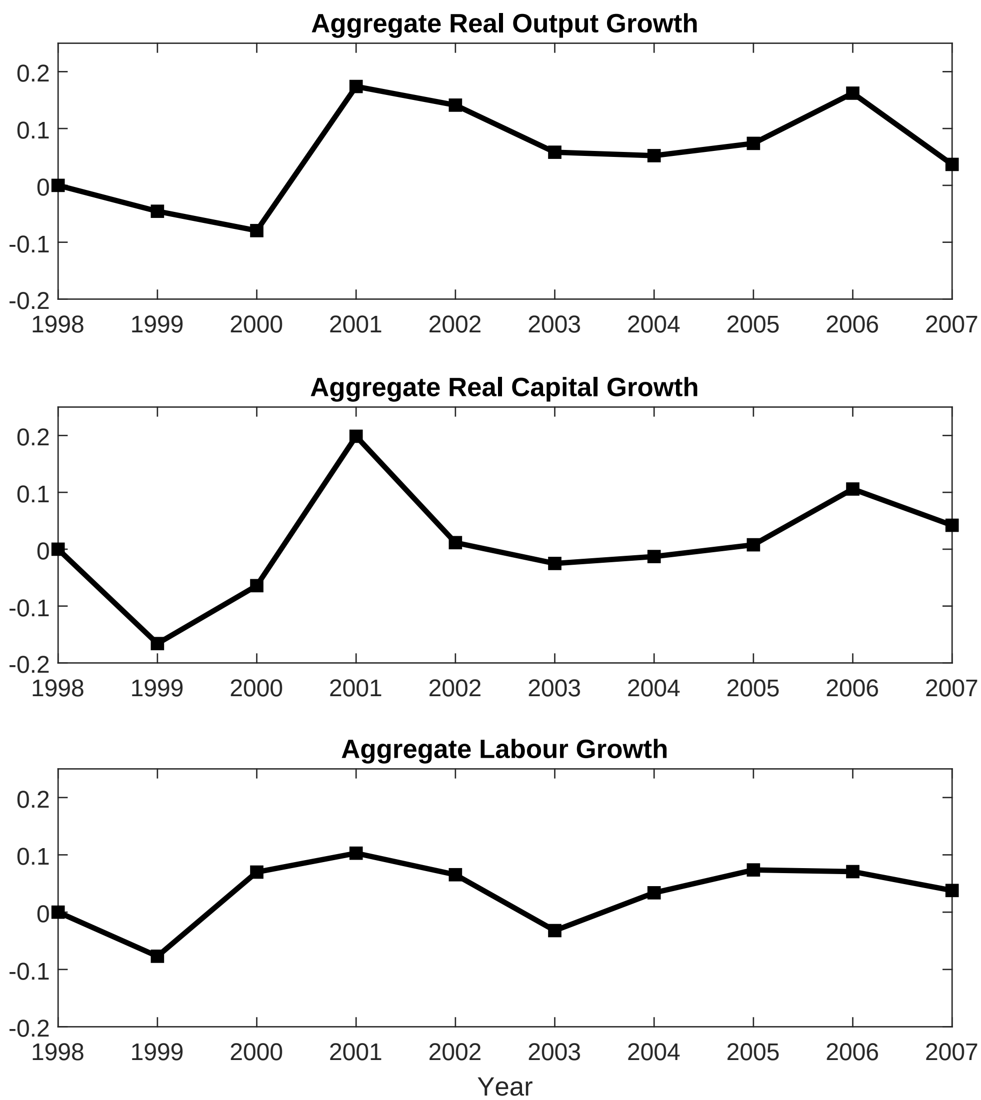
Note: APG^{L}_{RE} and APG^{K}_{RE} refer to APG from labour and capital reallocation, respectively. Total effects of reallocation is $AVG_\ell + DAVG_\ell$ for $\ell = L, K$.

Table 6: Regression Analysis on Input Misallocation and APG Reallocation

	Misallocation (τ_{it}^{ℓ})	
	$\ell = L$	$\ell = K$
$\ln z_{it} \vert \tau_{it} \geq 0$	0.507***	3.802***
	(0.03)	(0.40)
$\ln k_{it} \vert \tau_{it} \geq 0$	0.132***	-4.266***
	(0.02)	(0.26)
$\ln z_{it} \vert \tau_{it} < 0$	0.388***	2.156***
	(0.04)	(0.56)
$\ln k_{it} \vert \tau_{it} < 0$	0.087*	-1.124*
	(0.03)	(0.45)
Sector FE	YES	YES
Time Effect	YES	YES
Plant FE	YES	YES
R^2	0.211	0.158
N	4063	4063

Note: For statistical significance, * for $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$. Interaction terms for positive and negative misallocation are included because the interpretation of the coefficients goes in opposite directions. For plants with $\tau_{it}^{\ell} > 0$, $\beta_k^+ < 0$ suggests that *less* misallocation was associated with those who had higher capital-labour ratio; for plants with $\tau_{it}^{\ell} < 0$, $\beta_k^- < 0$ indicates that *more* misallocation occurs with those who had higher capital-labour ratio.

Figure 1: Aggregate Output, Capital, and Labour Growth in Ecuadorian Manufacturing Sector



Note: All monetary variables are based on US dollars in year 2000 value.

Appendix

A. Aggregate Productivity Growth Decomposition Method

This appendix contains technical details of the decomposition method in Section 3. To decompose the effects of entry and exits on *Aggregate Productivity Growth* (APG) from period $t-1$ to t, plants are categorised into the set of incumbents (I_t), entrants (E_t), and exitors (X_{t-1}), such that equation (3.5) can be reformulated as

$$\text{APG}_{t-1,t} = \sum_{i\in I_t}\int_{t-1}^{t}\text{APG}_i(\tau)d\tau + \sum_{i\in E_t}\int_{t-1}^{t}\text{APG}_i(\tau)d\tau + \sum_{i\in X_{t-1}}\int_{t-1}^{t}\text{APG}_i(\tau)d\tau, \tag{A.1}$$

where

$$\text{APG}_i(t) = \left(dY_{it} - r_{it}dK_{it} - w_{it}dL_{it}\right)\Big/\sum_i Y_{it} \tag{A.2}$$

is plant i's contribution to APG at time t. For the incumbents, equation (3.3) implies that

$$\begin{aligned}\sum_{i\in I_t}\int_{t-1}^{t}\text{APG}_i(\tau)d\tau \;=\;& \underbrace{\sum_{i\in I_t}\int_{t-1}^{t}D_{it}d\ln z_{it}}_{\text{TE}} + \underbrace{\sum_{i\in I_t}\int_{t-1}^{t}D_{it}\left(\alpha_j - s_{it}^{K}\right)d\ln K_{it}}_{\text{APG}_{RE}^{K}}\\ &+\underbrace{\sum_{i\in I_t}\int_{t-1}^{t}D_{it}\left(\gamma_j - s_{it}^{L}\right)d\ln L_{it}}_{\text{APG}_{RE}^{L}}.\end{aligned} \tag{A.3}$$

On the extensive margin, we follow the approach in Kwon, Narita, and Narita (2015) Online Appendix B to approximate the effects of entry and exit. For entrants, denote $\tau_i^E \in (t-1,t)$ as the time when plant i enters the sample,

$$\sum_{i\in E_t}\int_{t-1}^{t}\text{APG}_i(\tau)d\tau = \sum_{i\in E_t}\left[\int_{t-1}^{\tau_i^E}\text{APG}_i(\tau)d\tau + \int_{\tau_i^E}^{\tau_i^E}\text{APG}_i(\tau)d\tau + \int_{\tau_i^E}^{t}\text{APG}_i(\tau)d\tau\right], \tag{A.4}$$

where

$$Y_{it}^{R} \;=\; Y_{it} - r_{it}K_{it} - w_{it}L_{it} \tag{A.5}$$

$$\sum_{i\in E_t}\int_{t-1}^{\tau_i^E}\text{APG}_i(\tau)d\tau \;=\; 0 \tag{A.6}$$

$$\sum_{i\in E_t}\int_{\tau_i^E}^{\tau_i^E}\text{APG}_i(\tau)d\tau \;=\; \frac{Y_{i\tau_i^E}^{R}}{\sum_i Y_{i\tau_i^E}} \tag{A.7}$$

$$\sum_{i\in E_t}\int_{\tau_i^E}^{t}\text{APG}_i(\tau)d\tau \;=\; \frac{Y_{i\tau}^{R}}{\sum_i Y_{i\tau}}\bigg|_{\tau_i^E}^{t} - \int_{\tau_i^E}^{t}\frac{Y_{i\tau}^{R}}{\left(\sum_i Y_{i\tau}\right)^2}d\left(\sum_i Y_{i\tau}\right). \tag{A.8}$$

The residual value-added by plant i is defined in (A.5). The effect of entry on APG is the sum of (A.6), (A.7), and (A.8); (A.6) is equal to zero prior to plant i's entry; (A.7) is the difference between the left and right limits due to the jump in value-added residual; (A.8) is the post-entry APG from entrants derived using integration by parts. Assuming $Y_{it}^R \ll (\sum_i Y_{it})^2$, the entry effect on APG is approximated as

$$\begin{aligned}
\sum_{i \in E_t} \int_{t-1}^{t} \text{APG}_i(\tau) d\tau &\simeq \sum_{i \in E_t} \frac{Y_{it} - r_{it}K_{it} - w_{it}L_{it}}{\sum_i Y_{it}} \\
&= \sum_{i \in E_t} \frac{Y_{it}}{\sum_i Y_{it}} \left(1 - \frac{r_{it}K_{it}}{Y_{it}} - \frac{w_{it}L_{it}}{Y_{it}}\right) \\
&= \sum_{i \in E_t} D_{it} \left(1 - s_{it}^K - s_{it}^L\right). \qquad \text{(A.9)}
\end{aligned}$$

Similarly, denote τ_i^X as the time when plant i exits the sample, the effect of exits on APG can be written as

$$\begin{aligned}
\sum_{i \in X_{t-1}} \int_{t-1}^{t} \text{APG}_i(\tau) d\tau &= \sum_{i \in X_{t-1}} \left[\int_{t-1}^{\tau_i^X} \text{APG}_i(\tau) d\tau + \int_{\tau_i^X}^{\tau_i^X} \text{APG}_i(\tau) d\tau + \int_{\tau_i^X}^{t} \text{APG}_i(\tau) d\tau\right] \\
&\simeq \sum_{i \in X_{t-1}} -\left(\frac{Y_{it-1} - r_{it-1}K_{it-1} - w_{it-1}L_{it-1}}{\sum_i Y_{it-1}}\right) \\
&= -\sum_{i \in X_{t-1}} D_{it-1} \left(1 - s_{it-1}^K - s_{it-1}^L\right). \qquad \text{(A.10)}
\end{aligned}$$

The APG is the sum of (A.3), (A.9), and (A.10). The continuous-time APG for incumbents in (A.3) is converted to discrete-time using the Tornquist-Divisia approximation, in order to derive the APG decomposition in equation (3.6).

Productivity and Reallocation: Evidence from Ecuadorian Firm-Level Data
– Online Supplemental Materials –

Anson T. Y. Ho* Kim P. Huynh† David T. Jacho-Chávez‡

This appendix contains supplementary materials about the data set and the analyses reported in the paper. Section A provides supplementary information on the background of the Ecuadorian economic crisis, reforms on labour and capital regulations, definition of variables in the data set, and additional stylised facts. Section B reports estimation results with respect to alternative estimation methods. Section C includes results of our analyses at annual time intervals. Section D presents an alternative model specification under monopolistic competition. Section E provides a theoretical framework for understanding the reallocation terms in the Aggregate Productivity Growth (APG) decomposition and presents supplementary analyses on inputs misallocation.

In summary, the estimates presented in the main text lie in the middle of those from various estimation methods. Estimates using annual time intervals show more input reallocation but less aggregate productivity growth from reallocation. The pattern of distortions and aggregate productivity growth remain similar across different estimation methods and definition of time intervals.

*Bank of Canada, 234 Wellington St., Ottawa ON, K1A 0G9, Canada. E-mail: contact@atyho.info.

†Bank of Canada, 234 Wellington St., Ottawa ON, K1A 0G9, Canada. E-mail: kim@huynh.tv.

‡Department of Economics, Emory University, Rich Building 306, 1602 Fishburne Dr., Atlanta, GA 30322-2240, USA. E-mail: djachocha@emory.edu.

A. Supplementary Information

A.1. Background on the Ecuadorian Economic Crisis

This section provides a brief summary of the Ecuadorian economic crisis leading to the subsequent official dollarisation.[1] The crisis spans from 1998 to 2000, with the real exchange rate of Sucre (Ecuador's former domestic currency) depreciated 62.3 percent against the US dollar and 16 out of the 40 banks failed. In response, labour and capital market reforms were carried out to strengthen the economy. A summary of these reforms is provided in Table A.1 and A.2.

The economic crisis was originated from a series of external shocks that affected the Ecuadorian government's finance. El Niño floods in late 1997 and 1998 destroyed vast agricultural areas. Oil prices in the world market also sank to a historical low – less than 10 USD per barrel. Both factors reduced the government's tax revenue, which mainly came from agricultural products and crude oil. The spill-over effect of the Asian financial crisis also limited the foreign loanable funds for the debt-ridden government that had a 6.2 percent fiscal deficit and 66.3 percent total debt/GDP ratio.

The closure of a small bank in April 1998 triggered the crisis and evolved into widespread bank runs. The Central Bank of Ecuador (CBE, hereafter) provided emergency loans to illiquid banks and resulted in a 30 percent increase in the monetary base by the end of September 1998. Banks insolvency intensified in December 1998, as the public withdrew deposits to avoid a one percent financial transaction tax newly introduced to support the government's weak public finance. More banks failed. With the new deposit guarantee from the Agencia de Garantía de Depósitos (AGD), the banking crisis was further monetised. In the last quarter of 1998, the year-to-year inflation reached 15 percent and real GDP only grew by 0.1 percent. Bank deposits fled from Sucre to the US dollar. It shrank the CBE's net international reserves by 7.6 percent as they defended the crawling band exchange rate for Sucre.

The crisis was in its full scale in 1999. The CBE could no longer defend Sucre from depreciation and switched to free floating exchange rate regime. Sucre further depreciated and damaged the solvency of banks with adverse balance sheet effects. The banking system took another blow when the government defaulted its debts, making domestic banks holding government securities more vulnerable. Two more large banks failed and the deposit guarantee had brought the real growth rate of base money to above 50 percent. Real GDP fell by 7 percent that year.

With increasing dollarisation of bank liabilities and a plummeting demand of Sucres, the government officially dollarised the economy on January 11, 2000 at a fixed rate of 25,000 Sucres per US dollar.

[1] A detailed analysis is available in Beckerman (2002) and Jácome (2004).

Table A.1: Reforms on Labour Regulations in Ecuador 1998-2006

- **1998: Labour Outsourcing.**
  Allows firms to employ labour services from third party intermediary firms. It applies to activities of any nature, complementary, seasonal and part-time.

- **2000: Economic Transformation of Ecuador (Transformación económica del Ecuador).**
  Introduces hourly labour contracts, fixing the minimum hourly rate in $0.50 US dollar. Forbids the indexation of wages to a referential sectoral wage rate. Unifies the salaries, eliminating the mandatory payment an annual bonus salary (the 15th and 16th salary). Allows to hire temporary and seasonal workers up to 40% of the workforce in a firm. For temporary workers, it allows to exceed the maximum of 8 hours of the workday and constrains the amount of hourly workers.

- **2000: Promotion of Investment and Citizen Participation (Promoción De La Inversión Y Participación Ciudadana).**
  Repeals section of the Labour Code which permitted the holding of Collective Bargaining Agreement when there is an association of more than 30 workers. Regulates strikes, and facilitates layoffs. Workers who provide services for contractors or intermediaries, are entitled to share in the profits (art. 174).

- **2003: Reform of Art. 113 of the Labour Law (Reforma del artículo 113 del Código de Trabajo).**
  Establishes the mandatory payment of a 14th salary to workers (a bonus salary).

- **2004: Labour Disputes (Ley núm. 2004-29 reformatoria de la Ley núm. 2003-13).**
  Establishes oral trials for resolution of individual labour disputes, effective July 1, 2004.

Sources: Aguiar (2007); NATLEX Database, International Labor Organization.

Table A.2: Reforms on Capital Regulations in Ecuador 1998-2006

- **2000: Law for the Economic Transformation of Ecuador (TROLE I)**
  Reforms the monetary regime and the State Bank law to establish the conversion of the Sucres in circulation for US dollars at 25,000 sucres per US dollar.

- **2000: General Law of Institutions of the Financial System**
  Give solvency safeguards of financial institutions through greater control by the governmental oversight institution *Superintendencia de Bancos y Seguros* (SBS).

- **2000: Law of Rearrangement in Economic Matters in the Financial-Taxation Area**
  Deposits by firms and natural persons were guaranteed by the newly created *Agencia de Garantía de Depósitos* (AGD).

- **2001: The General Law of Financial Institutions (Codificación a las Instituciones del Sistema Financiero).**
  Reforms the standard that regulates the operation and closure of the financial institutions, as well as the monitoring and control of the SBS. Insurance companies and reinsurance are included with other financial institutions through the Social Security Act.

- **2002: Further reforms to existing laws.**
  Insure the balance of deposits with interest up to four times of the GDP per capita. Give the SBS greater power to set specific standards of solvency and financial prudence.

- **2003: Resolution of the Board Bank no. 601, 602-303.**
  Strengthen the prevention and the management of financial risks, expand the concepts of liquidity, market and credit risks. Expand the scope of credit information bureaus for supplying information.

- **2004: Resolution of the Bank Board no. 692-2004.**
  Mandatory calculation of risks on profitability ratios, solvency, non-performing loans and management at each financial institution.

- **2005: Credit Information Bureaus Act.**
  Provide financial institutions with complete information that will help them in making decisions regarding issues with credit risks.

Sources: Naranjo (2005); Yanchapaxi-León (2015).

A.2. Description of Variables

For output, we focus on plants' value-added, which is calculated as total value of sales plus addition to inventory, minus the total value of intermediate inputs. Sales include output produced by plants and secondary products purchased from other plants. Inventory is the sum of final goods and goods in production. Intermediate inputs include all inputs used in production and the cost of secondary products.

Net capital used in our analysis is the average of beginning and end-of-year net capital levels. INEC reports plants' gross capital at book value and its accumulated depreciation at the beginning and end of each year. The data set also includes information about market revaluation, which is used adjusts plants' capital from book value to replacement value. This is an important consideration, as our case study is about an economy going through an economic crisis. Changes in capital within a year includes plant's investments, market revaluation, as well as capital sold and its relevant write-off in the accumulated depreciation. End-of-year net capital is calculated as

$$\begin{aligned}
& \text{End-of-year net capital} \\
= \ & \text{End-of-year gross capital} - \text{End-of-year accumulated depreciation} \\
= \ & \text{Beginning-of-year gross capital} - \text{Beginning-of-year accumulated depreciation} \\
& + \text{investment} + \text{market revaluation} \\
& - (\text{gross capital sold} - \text{accumulated depreciation of capital sold}) \\
& - \text{End-of-year accumulated depreciation.}
\end{aligned}$$

Variables reported in the main text are plant level total capital (k) and capital per worker (k/l) with revaluation taken into account. Average net capital with and without market revaluation are reported in Table A.3. Market revaluation was positive and significant in 1998-2000 and was negligible after 2000. If market revaluation is not taken into consideration, the decrease in capital and capital per worker during the crisis is even *bigger* than the one used in our study, as shown in k_{noreval} and k_{noreval}/l in Table A.3, respectively.

Total number of workers is defined as the number of paid employees. Labour expenditure is calculated as the sum of employee compensation including wages and salaries, benefits, pension, profits sharing, and plant payments to Ecuadorian Social Security System (Instituto Ecuatoriano de Seguridad Social, IESS), Ecuadorian Institute for Educational Credit and Loans (Instituto Ecuatoriano de Credito Educativo y Becas, IECE), and Ecuadorian Professional Training Service (Servicio Ecuatoriano de Capacitación Profesional, SECAP).

A.3. Plant Size and Productivity

Additional descriptive statistics about plants' inputs, value-added, and their productivity are presented in Table A.4. The median plant employment steadily increases from 32 to 36 workers from 1998 to 2007, with a slight decrease in 2004-2005 due to the imposition of a bonus salary in 2003 (Table A.1). The median plant level capital drops more than 20 percent during the crisis. Since 2001, it increases steadily and surpasses the pre-crisis level since 2002. The median capital-labour ratio also reflects the same trend of changes as capital until 2003, since then it remains stable at levels similar to the pre-crisis one. For labour productivity (measured by value-added per worker), there is a continuous growth since 2000. By 2007, the labour productivity over 50 percent higher than that in 1998. As an overall trend, plants not only employ more inputs but are also more productive. The results regarding productivity are similar to Wong's (2009) study of trade liberalization and Ecuadorian productivity in 1997-2003.

The distribution of employment, capital, and capital-labour ratio are also visualised by high density region plots following (Huynh and Jacho-Chávez, 2007). The first column of Figure E.1 shows that the plant size distribution has become more positively skewed but the mode stays about the same. For capital distribution, it becomes more negatively skewed from 1998-2000 due to the crisis, and the changes are partially reversed in 2001-2003. The overall distribution becomes more compact in the post-crisis periods. As for the capital-labour ratio, the distribution becomes more negatively skewed, with a notable drop in the mode in 2000. The overall distribution becomes more compact after 2003 with the modes similar to the 1998 level.

Table A.3: Descriptive Statistics for Capital

Year	k	$k_{noreval}$	Reval.	k/l	$k_{noreval}/l$
1998	128.483	91.824	30.023	3.970	2.731
1999	115.685	73.924	33.436	3.388	2.139
2000	101.088	26.233	30.350	2.597	0.932
2001	118.724	111.807	0.000	3.205	2.873
2002	135.476	131.694	0.000	3.632	3.327
2003	148.058	145.319	0.000	3.946	3.533
2004	147.092	144.784	0.000	4.017	3.803
2005	147.204	146.023	0.000	4.049	3.846
2006	161.860	159.985	0.000	4.083	3.914
2007	166.381	166.381	0.000	4.088	3.821

Note: k is median capital level, k/l is median capital per worker for capital including revaluation (as used in the main text). k_{noreval} is median capital *without* revaluation, Reval. is the median capital revaluation level, and k_{noreval}/l is median capital per worker *without* revaluation. All monetary values are expressed in thousands of US dollars in year 2000 value.

Table A.4: Descriptive Statistics

Year	N	l	k	k/l	y/l
1998	1238	32	128.483	3.970	7.022
1999	1134	32	115.685	3.388	6.641
2000	1123	34	101.088	2.597	6.654
2001	1140	34	118.724	3.205	7.764
2002	1136	35	135.476	3.632	8.722
2003	1149	35	148.058	3.946	9.508
2004	1191	33	147.092	4.017	10.012
2005	1177	34	147.204	4.049	10.276
2006	1184	35	161.860	4.083	10.592
2007	1241	36	166.381	4.088	10.668

Note: N is the number of observations, y is median value-added, l is median number of workers, k is median capital level, y/l is median labour productivity, k/l is median capital per worker. All monetary values are expressed in thousands of US dollars in year 2000 value.

B. Sensitivity Analysis for Aggregate productivity Growth Decomposition

In this section, we conduct sensitivity analysis for the Aggregate Productivity Growth (APG) decomposition. The production function in (3.1) is estimated using ordinary least square (OLS), fixed-effects panel data method (FE), and the method in Levinsohn and Petrin (2003) (hereafter LP). For OLS, the production function for sector j is estimated by

$$\log Y_{it} = c_j + \alpha_j \log K_{it} + \gamma_j \log L_{it} + \{b_l \mathrm{YEAR}_l\}_{l=1999}^{2007} + \epsilon_{it}, \tag{B.1}$$

where c_j is the constant term, YEAR_l for $l = 1999, \ldots, 2007$ are dummy variables such that $\mathrm{YEAR}_l = 1$ if $l = t$ and 0 otherwise, and ϵ_{it} is the random component for plant i at time t.

For the fixed-effects panel data method, we estimate the factor shares as in Pavcnik (2002) with time dummy variables included in the equation. Specifically, the production function for sector j is estimated by

$$\log Y_{it} = c_i + \alpha_j \log K_{it} + \gamma_j \log L_{it} + \{b_l \mathrm{YEAR}_l\}_{l=1999}^{2007} + u_{it}, \tag{B.2}$$

where c_i is the fixed-effect for plant i, YEAR_l for $l = 1999, \ldots, 2007$ are dummy variables such that $\mathrm{YEAR}_l = 1$ if $l = t$ and 0 otherwise, and u_{it} is the random component for plant i at time t.

Estimation results are reported in Table B.1. For the OLS estimates, factor shares are mostly greater than the LP estimates. For some sectors, the estimated production function also exhibits increasing return to scale. For the FE estimates, capital share of value-added shows more variation across sectors. There is no systematic differences between the FE and LP estimates. In general, the FE estimates also show smaller estimated labour shares of value-added ($\hat{\gamma}_j$) than the LP estimates, especially for those in more labour intensive sectors according to ISIC codes.

Aggregate Productivity Growth decomposition (APG) with different production function estimates are reported in Table B.2. Note that only technical efficiency (TE) and reallocation terms (APG_{RE}) in APG are affected by different the production function estimates. Overall, the time pattern of TE and APG_{RE} are consistent across all OLS, FE and LP estimations. LP estimates for TE and APG_{RE} are in between those from OLS and FE, and they are considerably closer to the FE estimates. Comparing the results between OLS and FE, OLS attributes more APG to reallocation and less to technical efficiency.

Table B.1: Production Function Estimates

	OLS				FE				LP			
Sector	$\hat{\alpha}_j$	s.e.	$\hat{\gamma}_j$	s.e.	$\hat{\alpha}_j$	s.e.	$\hat{\gamma}_j$	s.e.	$\hat{\alpha}_j$	s.e.	$\hat{\gamma}_j$	s.e.
15	0.326	0.019	0.783	0.031	0.179	0.013	0.517	0.025	0.225	0.039	0.580	0.033
17	0.265	0.032	0.850	0.049	0.132	0.019	0.550	0.040	0.049	0.056	0.563	0.048
18 & 19	0.135	0.029	1.115	0.044	0.137	0.020	0.713	0.040	0.111	0.048	0.777	0.056
20	0.213	0.037	1.040	0.069	0.115	0.030	0.629	0.071	0.073	0.055	0.816	0.062
21 & 22	0.343	0.035	0.893	0.056	0.224	0.019	0.496	0.047	0.300	0.046	0.644	0.077
24	0.275	0.045	0.869	0.073	0.155	0.023	0.456	0.042	0.293	0.060	0.646	0.065
25	0.268	0.030	0.881	0.065	0.185	0.021	0.501	0.041	0.137	0.059	0.509	0.056
26	0.261	0.037	1.054	0.084	0.075	0.025	0.536	0.059	0.095	0.065	0.662	0.059
27 & 28	0.256	0.039	1.007	0.087	0.108	0.032	0.413	0.055	0.096	0.065	0.713	0.167
29 & 31	0.265	0.034	0.908	0.068	0.183	0.027	0.680	0.067	0.181	0.069	0.641	0.081
34	0.210	0.065	1.111	0.101	0.064	0.038	0.771	0.066	0.172	0.129	0.735	0.155
36	0.224	0.040	1.052	0.073	0.114	0.019	0.613	0.046	0.145	0.041	0.549	0.072

Note: OLS refers to ordinary least square estimation, FE refers to the fixed-effects estimation, and LP refers to Levinsohn and Petrin (2003). Coefficient estimates for year dummy variables are available upon request.

Table B.2: Aggregate Productivity Growth (APG) Decomposition

					APG_{RE}												
		TE			Labour			Capital			Total			APG_{NE}			
Year	APG	OLS	FE	LP	OLS	FE	LP	OLS	FE	LP	OLS	FE	LP	Entry	Exit	Net	
1998-2000	-0.052	-0.009	-0.012	-0.014	0.020	0.009	0.012	-0.041	-0.027	-0.027	-0.021	-0.018	-0.016	0.016	0.038	-0.022	
2000-2002	0.134	0.038	0.076	0.066	0.024	0.010	0.014	0.072	0.048	0.054	0.096	0.058	0.068	0.019	0.019	0.000	
2002-2004	0.053	0.036	0.036	0.033	0.009	0.004	0.006	-0.006	-0.001	0.001	0.003	0.004	0.007	0.028	0.014	0.014	
2004-2006	0.095	0.036	0.061	0.055	0.021	0.009	0.013	0.032	0.020	0.022	0.053	0.029	0.034	0.013	0.008	0.006	
Average	0.058	0.025	0.040	0.035	0.019	0.008	0.011	0.014	0.010	0.012	0.033	0.018	0.023	0.019	0.020	-0.001	
Std. Dev.	0.080	0.023	0.038	0.035	0.006	0.003	0.004	0.049	0.032	0.034	0.052	0.033	0.036	0.007	0.013	0.016	

Note: TE refers to technical efficiency, APG_{RE} is the Reallocation term, and APG_{NE} is the effect of Net Entry, which is Entry minus Exit. The TE and APG_{RE} terms are estimated from the production function using ordinary least square (OLS) and fixed-effects panel data method (FE).

C. Analyses at Annual Time Interval

In this section, we report our analyses at annual time interval. Entry and exit rates are shown in Table C.1. Generally the results show the same patterns as those at biennial intervals, with high entry rates in 2002-2004 and high exit rates in 1999. Entry rates are higher than the exit rates, except the crisis year 1999 and 2000. Both entry and exit rates at annual intervals are higher than those from biennial intervals, which indicates that a considerable number of plants only survives for one year.

Labour reallocation patterns are shown in Table C.2. The results at annual intervals exhibit similar patterns of job creation and job destruction as those at biennial intervals. In terms of levels, both job creation and job destruction are higher at annual intervals because it includes plants that operated one year only (entry and exit contemporaneously). Incumbent plants are still the bigger contributors to job creation. On the contrary, the importance of incumbent plants in job destruction at annual intervals significantly increases in 1998-2002. The size of entrants and exitors showed more variation at annual intervals, but entrants are still significantly bigger than exitors.

Capital reallocation patterns are reported in Table C.3. At annual intervals, capital creation and destruction are the highest in 2000-2001 and 1999-2000, respectively. This pattern is consistent with that at biennial intervals. As in the case of labour reallocation, capital creation and destruction are higher at annual intervals. Incumbent plants are the bigger contributors to capital reallocation; only during the crisis the exitors are bigger than the entrants in terms of capital per worker. The exitors in 1999 are also substantially bigger than those in the later years.

The productivity decomposition at annual intervals is reported in Table C.4. On average, value-added growth and changes in the aggregate expenditure on inputs are almost identical between the sample data with annual and biennial intervals. The average aggregate productivity growth (APG) is slightly lower at annual intervals because productivity gain from reallocation of incumbents and that from net entry are both smaller. These results imply that short-lived (with 1 or 2 year life) plants are more distorted in the use of inputs.

Table C.1: Entry and Exit Rates

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
E Rate	0.050	0.063	0.088	0.087	0.108	0.141	0.087	0.091	0.125
X Rate	0.107	0.074	0.069	0.064	0.086	0.075	0.077	0.073	0.093
NE Rate	-0.057	-0.011	0.019	0.024	0.023	0.066	0.010	0.018	0.032

Note: Entry (E) rate and exit (X) rate are expressed as fractions of the average number of plants at time t and $t-1$. Net Entry (NE) rate is the difference between entry and exit rates. There is a small fraction of plants that temporarily exits and later re-enters the sample. For these plants, only the first entry and final exit are included in the calculation of entry and exit rates, respectively.

Table C.2: Labour Reallocation Patterns

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
JC	0.106	0.173	0.195	0.171	0.136	0.146	0.153	0.148	0.142
by E	0.027	0.045	0.055	0.041	0.063	0.073	0.057	0.052	0.055
by I	0.078	0.127	0.140	0.130	0.073	0.073	0.096	0.096	0.087
JD	0.176	0.104	0.094	0.093	0.148	0.088	0.069	0.084	0.109
by X	0.075	0.052	0.040	0.028	0.051	0.036	0.032	0.030	0.057
by I	0.101	0.052	0.054	0.066	0.096	0.053	0.037	0.054	0.052
JR	0.282	0.276	0.289	0.264	0.284	0.234	0.222	0.232	0.251
l of E	25	28	21.5	24.5	28	23	21	25	23
l of X	17	20	18.5	20	14	22	16	19	18

Note: Job creation (JC) is defined as the sum of new jobs at new entrants (E) and incumbent plants (I). Job destruction (JD) is defined as the sum of all lost jobs at exitors (X) and incumbent plants (I). Job reallocation (JR) refers to the sum of job created and job destructed. JC, JD, and JR are expressed as fractions of the average employment at time t and $t-1$. Size of l is the median employment (in number of workers).

Table C.3: Capital Reallocation Patterns

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
KC	0.103	0.169	0.263	0.118	0.107	0.124	0.122	0.161	0.155
by E	0.013	0.065	0.078	0.035	0.046	0.064	0.052	0.053	0.051
by I	0.090	0.103	0.185	0.083	0.061	0.060	0.070	0.107	0.103
KD	0.279	0.234	0.079	0.102	0.125	0.109	0.095	0.073	0.115
by X	0.077	0.041	0.044	0.031	0.037	0.037	0.033	0.032	0.072
by I	0.202	0.193	0.036	0.071	0.088	0.073	0.062	0.040	0.043
KR	0.382	0.403	0.342	0.220	0.232	0.233	0.217	0.233	0.269
k/l of E	2.003	2.684	2.570	3.795	3.940	4.305	5.124	4.102	4.754
k/l of X	4.633	1.526	2.337	2.561	2.209	3.533	3.900	3.577	3.843

Note: Capital creation (KC) is defined as the sum of additional capital used by new entrants (E) and incumbent plants (I). Capital destruction (KD) is defined as the sum of all decreases in capital at exitors (X) and incumbent plants (I). Capital reallocation (KR) refers to the sum of job created and job destructed. KC, KD, and KR are expressed as fractions of the average capital level at time t and $t-1$. Size of k is median plant capital. All monetary terms are measured in thousands of US dollars.

Table C.4: Aggregate Productivity Growth (APG) Decomposition

						APG_{RE}			APG_{NE}		
Year	ΔY	ΔL	ΔK	APG	TE	Labour	Capital	Total	Entry	Exit	Net
1999	-0.045	-0.033	-0.016	0.005	0.072	-0.012	-0.015	-0.027	0.013	0.054	-0.040
2000	-0.083	0.015	-0.006	-0.092	-0.106	0.032	-0.016	0.015	0.019	0.020	-0.001
2001	0.160	0.025	0.018	0.117	0.059	0.031	0.021	0.052	0.029	0.022	0.006
2002	0.134	0.021	0.000	0.112	0.073	0.032	0.011	0.043	0.011	0.015	-0.004
2003	0.058	-0.007	-0.003	0.067	0.051	-0.003	0.009	0.006	0.024	0.012	0.011
2004	0.058	0.008	-0.001	0.051	0.024	0.013	0.003	0.016	0.026	0.015	0.011
2005	0.072	0.015	0.000	0.057	0.031	0.021	0.000	0.021	0.012	0.007	0.005
2006	0.142	0.021	0.004	0.117	0.075	0.028	0.007	0.035	0.016	0.009	0.007
2007	0.034	0.006	0.002	0.026	0.005	0.015	0.009	0.024	0.029	0.033	-0.003
Average	0.059	0.008	0.000	0.051	0.031	0.017	0.003	0.021	0.020	0.021	-0.001
Std. Dev.	0.082	0.018	0.009	0.067	0.057	0.016	0.012	0.023	0.007	0.015	0.016

Note: ΔY is value-added growth. ΔL and ΔK refer to changes in the aggregate expenditure on labour and capital respectively. TE refers to technical efficiency, APG_{RE} is the Reallocation term, and APG_{NE} is the effect of Net Entry, which is Entry minus Exit. The TE and APG_{RE} terms are estimated from the production function following Wooldridge (2009).

D. Alternative Setup: Monopolistic Competition

In this section, we assume the economy has a monopolistic competition structure. Allowing for monopolistic competition addresses possible concerns of differential markups in the plant specific price of value-added relative to the sectoral average. This setup builds on the work of Levinsohn and Melitz (2003) and is similar to the approach used in Hsieh and Klenow (2009) analysing input misallocation. We estimate the production function allowing for markups using the strategy proposed by Tomlin (2014).

D.1. Plant-Level Revenue Production Function

The value-added by plant i in sector j is produced via a Cobb-Douglas production function in which capital (K) and labour(L) are used. Let Z_{it} denotes plant i's TFP at time t. The production function can be written as

$$Y_{it} = Z_{it} K_{it}^{\alpha_j} L_{it}^{\gamma_j} \exp(\mu_{it}^s), \tag{D.1}$$

where α_j and γ_j are the capital and labour shares of value-added in sector j, respectively, and μ_{it}^s is a normal independent and identically distributed (i.i.d.) shock to production. The demand for Y_{it} is defined as

$$Y_{it} = Y_{It} \left(\frac{P_{it}}{P_{It}} \right)^{-\eta} \exp(\mu_{it}^d), \tag{D.2}$$

where Y_{It} is the total value-added in sector j, P_{it} is the price charged by plant i at time t, P_{It} is the sectoral price index, η is the elasticity of substitution between different products, and μ_{it}^d is an i.i.d demand shock. The logarithm of equation (D.1) and (D.2) are

$$\begin{aligned} y_{it} &= z_{it} + \alpha_j k_{it} + \gamma_j l_{it} + \mu_{it}^s, & \text{(D.3)} \\ y_{it} &= y_{It} - \eta \left(p_{it} - p_{It} \right) + \mu_{it}^d, & \text{(D.4)} \end{aligned}$$

where variables in logs are represented by lower case variables.

Plant i's revenue in period t is defined as $R_{it} = P_{it} Y_{it}$. The log of revenue is

$$r_{it} = p_{it} + y_{it}. \tag{D.5}$$

Equation (D.2) and (D.5) show plant i's market revenue as

$$\begin{aligned} r_{it} &= p_{it} + y_{It} - \eta \left(p_{it} - p_{It} \right) + \mu_{it}^d, \\ r_{it} - p_{It} &= \widetilde{r}_{it} = \left(\frac{\eta - 1}{\eta} \right) y_{it} + \frac{1}{\eta} y_{It} + \frac{1}{\eta} \mu_{it}^d, & \text{(D.6)} \end{aligned}$$

where $\widetilde{r}_{it}$ is log of revenue deflated by sectoral price index P_{It}. Substituting log production function in (D.3) for y_{it} in (D.6), the estimating equation is the revenue production function

$$\widetilde{r}_{it} = \beta_l^j l_{it} + \beta_k^j k_{it} + \beta_\eta^j y_{It} + \beta_z^j z_{it} + \mu_{it}, \tag{D.7}$$

where $\beta_l^j = \left(1 - \frac{1}{\eta}\right)\gamma_j$, $\beta_k^j = \left(1 - \frac{1}{\eta}\right)\alpha_j$, $\beta_\eta^j = \frac{1}{\eta}$, $\beta_z^j = \left(1 - \frac{1}{\eta}\right)$, and $\mu_{it} = \frac{1}{\eta}\mu_{it}^d + \left(1 - \frac{1}{\eta}\right)\mu_{it}^s$. Equation (D.7) is estimated using the method developed in Wooldridge (2009), with z_{it} treated as observable by the plant but not the researcher.

Estimation results are reported in Table D.1. Although the underlying model structure is different, our estimates show that input elasticity of revenue in the monopolistic competition setting are similar to those in perfect competition in Table 3. In general, estimates from monopolistic competition slightly lower capital elasticity and similar labour elasticity when compared with those in perfect competition.

D.2. Aggregate Productivity Growth Decomposition

We define aggregate productivity as the aggregate residual *revenue*, calculated by subtracting aggregate expenditure from aggregate revenue. As described in the main text, Aggregate Productivity Growth (APG) from time $t-1$ to t, as a percentage of aggregate value-added, can be expressed as:

$$\text{APG}_{t-1,t} \;=\; \left(\sum_i dR_i - \sum_i q_t dK_i - \sum_i w_t dL_i\right) \Big/ \sum_i R_i. \tag{D.8}$$

With the revenue production function specified in equation (D.7), APG from time $t-1$ to t can be decomposed as

$$\begin{aligned}
\text{APG}_{t-1,t} \;=\; & \underbrace{\sum_{i\in I_t} \bar{D}_{it}\Delta \log A_{it}}_{\text{TE}_R} + \underbrace{\sum_{i\in I_t} \bar{D}_{it}\beta_z^j \Delta \log Z_{it}}_{\text{TE}_Q} \\
& + \underbrace{\sum_{i\in I_t} \bar{D}_{it}\left(\beta_l^j - \bar{s}_{it}^L\right)\Delta \log L_{it}}_{\text{APG}_{RE}^L} + \underbrace{\sum_{i\in I_t} \bar{D}_{it}\left(\beta_k^j - \bar{s}_{it}^K\right)\Delta \log K_{it}}_{\text{APG}_{RE}^K} \\
& + \underbrace{\sum_{i\in E_t} D_{it}\left(1 - s_{it}^K - s_{it}^L\right)}_{\text{Entry}} - \underbrace{\sum_{i\in X_{t-1}} D_{it-1}\left(1 - s_{it-1}^K - s_{it-1}^L\right)}_{\text{Exit}},
\end{aligned} \tag{D.9}$$

where

$$\bar{D}_{it} = \left(\frac{R_{it}}{R_t} + \frac{R_{it-1}}{R_{t-1}}\right) \Big/ 2, \tag{D.10}$$

$$\bar{s}^K_{it} = \left(\frac{q_{it}K_{it}}{R_{it}} + \frac{q_{it-1}K_{it-1}}{R_{it-1}}\right) \Big/ 2, \tag{D.11}$$

$$\bar{s}^L_{it} = \left(\frac{w_{it}L_{it}}{R_{it}} + \frac{w_{it-1}L_{it-1}}{R_{it-1}}\right) \Big/ 2. \tag{D.12}$$

Set I_t, E_t, X_{t-1} denote the set of plants at time t that are incumbents, new entrants, and exitors, respectively. $\bar{D}_{it}$ is the average of plant i's revenue (R_{it}) Domar weights from period $t-1$ to t, Δ is the first difference operator, $\log A_{it}$ is the log of TFPR, $\log Z_{it}$ is the log of TFPQ, $\{\beta^j_z, \beta^j_k, \beta^j_l\}$ are elasticities of revenue for TFPQ, capital (K), and labour (L) respectively, $\bar{s}^K_{it}$ and $\bar{s}^L_{it}$ are the average over period $t-1$ to t revenue shares for capital and labour respectively. Change in APG due to technical efficiency (TE) is the sum of technical *revenue* efficiency TE_R and technical *quantity* efficiency TE_Q.

Results for APG decomposition is shown in Table D.2. By construction, APG and APG_{NE} are the same across model specifications. APG from TE and reallocation are almost identical to those in perfect competition setting. A further decomposition of TE into TE_R and TE_Q shows that APG from TE is predominantly contributed by revenue efficiency growth (2.7 percent) and quantity efficiency growth (0.5 percent) is small.

Table D.1: Revenue Production Function Estimates

Sector	$\widehat{\beta}_l^j$	s.e.	$\widehat{\beta}_k^j$	s.e.	$\widehat{\beta}_\eta^j$	s.e.
15	0.655	0.039	0.198	0.033	0.523	0.049
17	0.540	0.054	0.048	0.054	0.291	0.193
18 & 19	0.932	0.072	0.047	0.045	0.481	0.074
20	0.916	0.075	0.075	0.047	0.030	0.145
21 & 22	0.664	0.087	0.237	0.043	0.553	0.075
24	0.644	0.071	0.253	0.059	0.324	0.099
25	0.624	0.070	0.101	0.056	0.616	0.167
26	0.716	0.071	0.104	0.050	0.503	0.159
27 & 28	0.767	0.120	0.163	0.053	-0.068	0.153
29 & 31	0.703	0.089	0.158	0.058	0.351	0.100
34	0.799	0.193	0.159	0.108	0.290	0.105
36	0.597	0.088	0.110	0.040	0.797	0.198

Note: The revenue production function is estimated using the framework described in Tomlin (2014) using the production function estimator of Wooldridge (2009).

Table D.2: Aggregate Productivity Growth (APG) Decomposition

					TE			APG_{RE}			APG_{NE}		
Year	ΔY	ΔL	ΔK	APG	TE_R	TE_Q	Total	Labour	Capital	Total	Entry	Exit	Net
1998-2000	-0.064	-0.006	-0.006	-0.052	-0.021	0.004	-0.017	0.013	-0.026	-0.013	0.016	0.038	-0.022
2000-2002	0.147	0.013	0.000	0.134	0.063	0.001	0.063	0.016	0.054	0.070	0.019	0.019	0.000
2002-2004	0.058	0.006	-0.002	0.053	0.027	0.005	0.032	0.006	0.001	0.007	0.028	0.014	0.014
2004-2006	0.107	0.010	0.002	0.095	0.041	0.011	0.052	0.015	0.023	0.038	0.013	0.008	0.006
Average	0.062	0.006	-0.002	0.058	0.027	0.005	0.033	0.013	0.013	0.026	0.019	0.020	-0.001
Std. Dev.	0.091	0.008	0.003	0.080	0.035	0.004	0.035	0.004	0.034	0.036	0.007	0.013	0.016

Note: ΔY is value-added growth. ΔL and ΔK refer to changes in the aggregate expenditure on labour and capital respectively. TE refers to technical efficiency, APG_{RE} is the Reallocation term, and APG_{NE} is the effect of Net Entry, which is Entry minus Exit. The TE and APG_{RE} terms are estimated from the production function following Wooldridge (2009).

E. Theoretical Framework for Factor Input Distortions

This section outlines the theoretical framework to shed light on the relationship between plants' production decisions and the allocative efficiency of factor inputs. We illustrate that the misallocation measure in Aggregate Productivity Growth (APG) decomposition (Section 3) is equivalent to the notion of distortion taxes in the theoretical framework. Further understanding on plant specific TFP and plant level distortion is important for understanding productivity growth, because they represent two important sources for growth. Studying the distributions of TFP and input distortions allow us to understand the role of the crisis and market reforms.

We follow the model framework originated from Hopenhayn and Rogerson (1993) in which plants make their entry/exit decisions and their scale of production based on their plant specific total factor productivity (TFP). Restuccia and Rogerson (2008) and Guner, Ventura, and Xu (2008) show that the existence of friction distorts plants' use of inputs, and such distortions can be quantified in forms of idiosyncratic taxes. We assume perfect competition as in the aforementioned studies.

E.1. Measuring Total Factor Productivity

As in Section 3, plants produce value-added (Y) via a Cobb-Douglas production function in which capital (K) and labour (L) are used as inputs. It follows the same specification as equation (3.1) that

$$Y_{it} = z_{it} K_{it}^{\alpha_j} L_{it}^{\gamma_j},$$

where z_{it} is plant i's TFP at time t, α_j and γ_j are the capital and labour elasticities of value-added in sector j.

Plant level TFP are constructed by using the production function estimates in Table 3, with

$$\ln z_{it} = \ln Y_{it} - \alpha_j \ln K_{it} - \gamma_j \ln L_{it}. \tag{E.1}$$

These TFP estimates are identical to the technical efficiency identified in APG decomposition in equation (3.6). Medians of the estimated log TFP are reported in the first column of Table E.1. In general, changes in TFP reflect the trend of labour productivity in Table A.4. A moderate drop in TFP is observed from 1998-2000. Since then, the median TFP has been increasing and higher than the pre-crisis level.

The TFP distributions are illustrated on the bottom right panel of Figure E.1. From 1998 to 2000, the TFP distributions have lower modes. Between 2000 and 2004, there is a significant increase in the mode and a decrease in the dispersion of TFP distributions due to the trimming of inefficient plants. Since then, TFP has maintained similar distributions. In general, there has been a positive shift of the TFP distributions over the sample periods.

E.2. Measuring Plant-Level Distortions

We assume plant i decides the amount of capital and labour inputs to maximise profits π_{it}, given the marginal cost of inputs. The profit maximisation problem is

$$\max_{K,L} \pi_{it} = \max_{K,L} \left\{ \left(1-\tau_{it}^{Y}\right) Y_{it} - \left(1+\tau_{it}^{K}\right) r_{it} K_{it} - \left(1+\tau_{it}^{L}\right) w_{it} L_{it} \right\}, \tag{E.2}$$

where r_{it} is the interest rate, w_{it} is the wage rate, τ_{it}^{Y} is the value-added distortion tax, τ_{it}^{K} and τ_{it}^{L} are the input distortion taxes on capital and labour, respectively. These input distortion taxes are generic measures for idiosyncratic distortions to plant's decisions. Distortions can be capital-specific (τ_{it}^{K}), labour-specific (τ_{it}^{L}), or affecting both the capital and labour decisions of a plant (τ_{it}^{Y}). For example, Asker, Collard-Wexler, and De Loecker (2014) suggest that capital distortion is due to dynamic adjustment costs, and Guner, Ventura, and Xu (2008) show that size-dependent policies can be a source of distortions.

The decisions of plant i are characterised by the following first order conditions (FOCs)

$$\gamma_j Y_{it} = \left(\frac{1+\tau_{it}^{L}}{1-\tau_{it}^{Y}}\right) w_{it} L_{it} = \left(1+\tilde{\tau}_{it}^{L}\right) w_{it} L_{it}, \tag{E.3}$$

and

$$\alpha_j Y_{it} = \left(\frac{1+\tau_{it}^{K}}{1-\tau_{it}^{Y}}\right) r_{it} K_{it} = \left(1+\tilde{\tau}_{it}^{K}\right) r_{it} K_{it} \tag{E.4}$$

where $\tilde{\tau}_{it}^{L}$ and $\tilde{\tau}_{it}^{K}$ are labour and capital distortion taxes weighted by the value-added distortion tax.[2] The FOCs are used to identify labour specific and capital specific distortions, such that the distortions in labour and capital markets are relative to any value-added distortions.

From equation (E.4) and (E.3), the input distortion tax rates can be rewritten as

$$\tilde{\tau}_{it}^{L} = \left(\gamma_j - s_{it}^{L}\right) / s_{it}^{L}, \tag{E.5}$$

$$\tilde{\tau}_{it}^{K} = \left(\alpha_j - s_{it}^{K}\right) / s_{it}^{K}, \tag{E.6}$$

where

$$s_{it}^{L} = \left(\frac{w_{it} L_{it}}{Y_{it}}\right), \tag{E.7}$$

$$s_{it}^{K} = \left(\frac{r_{it} K_{it}}{Y_{it}}\right) \tag{E.8}$$

The misallocation terms τ_{it}^{ℓ} for $\ell \in \{L, K\}$ in equation (4.1) and (4.2) are the continuous time approximation of average $\tilde{\tau}_{it}^{\ell}$ for $\ell \in \{L, K\}$ in (E.5) and (E.6) between time $t-1$ and t.

[2]Empirically, we cannot separately identify τ_{it}^{Y} from τ_{it}^{L} and τ_{it}^{K}. We focus on input distortion taxes because identifying these wedges is important for an economy that went through substantial reallocation of resource. Alternatively, distortion taxes can be rewritten as relative to capital or labour distortions following Hsieh and Klenow (2009).

Without input distortions, i.e., $\tilde{\tau}_{it}^{L} = \tilde{\tau}_{it}^{K} = 0$, (E.5) and (E.6) will become the typical FOCs that the factor shares of value-added equals to the elasticities of factor inputs under a Cobb-Douglas production function. If plant i's input is below its optimal level, resources allocation is distorted as if the plant is facing an input tax $\{\tilde{\tau}_{it}^{\ell}\}_{\ell=L,K} > 0$; if plant i's input is beyond its optimal level, allocation is distorted as if the plant receives an input subsidy $\{\tilde{\tau}_{it}^{\ell}\}_{\ell=L,K} < 0$.[3]

E.2.1. Distortion Results

The time series of $\tilde{\tau}_{it}^{L}$ and $\tilde{\tau}_{it}^{K}$ are constructed from (E.5) and (E.6), using $\hat{\alpha}_j$ and $\hat{\gamma}_j$ estimates in Table 3. The median distortion taxes are reported in Table E.1.

Labour market frictions are the highest during the crisis period. The estimated labour distortion tax is 0.51 in 1998, meaning that a plant with the median labor distortion uses less labour input than its optimal level as if it is facing a labour input tax of 51%. It further increases to 0.73 in 2000 as the crisis deepened, and it falls back to 0.56 in 2003 after reforms aimed at labour market liberalisation were implemented. There is an increase in labour distortion in 2004, and since then the median had remained at similar levels.

Compared with labour distortions, the median capital distortion tax shows that plants' use of capital are more heavily distorted. Capital flight during the crisis substantially restricted plants' use of capital. The median capital distortion tax increases from 0.83 in 1998 to 0.99 in 2000. It remains at similar levels in 2000-2002, before it further increases in 2002-2004 and since then stabilises at higher levels. In general, capital distortions has increased over the sample periods, indicating that plants' use of capital are more constrained.

E.2.2. Distributional Analysis

The distribution of labour distortion tax shows that the majority of plants are undersized and being restricted in their labour use. During the economic crisis, the overall labour distortion increases with a greater dispersion. After implementing reforms on labour regulations (see Table A.1), labour distortion slowly decreases from 2000 to 2002 with a more compact distribution. Since then, the distribution of labour distortions mostly remains stable with some changes in the tails.

In contrast to labour distortions, the distribution of capital distortions is more dispersed and volatile. For all the sample years, the majority of plants are undersized in terms of capital use. The distribution significantly increases from 1998 to 2000 with higher modes and shorter but fatter tails. It remains mostly the same between 2000 to 2002 and with longer tails. From 2002-2004, capital distortion further increases with a higher mode and trimming of the left tail.

[3] The model implies that the lower bound of input tax is -1 because plants will expand their scales to infinity if the after-distortion-tax factor prices are less than or equal to zero.

Table E.1: TFP and Distortions on Factor Inputs

Year	log TFP	$\tilde{\tau}^L$	$\tilde{\tau}^K$
1998	2.224	0.509	0.829
1999	2.161	0.685	0.759
2000	2.176	0.730	0.989
2001	2.336	0.594	0.973
2002	2.457	0.577	1.089
2003	2.499	0.559	1.232
2004	2.541	0.604	1.413
2005	2.551	0.568	1.591
2006	2.608	0.583	1.590
2007	2.634	0.576	1.497

Note: Median values are reported. Distributions of these variables are displayed in Figure E.1. Input distortion taxes on labour and capital are denoted by $\tilde{\tau}^\ell > 0$ for $\ell = L, K$.

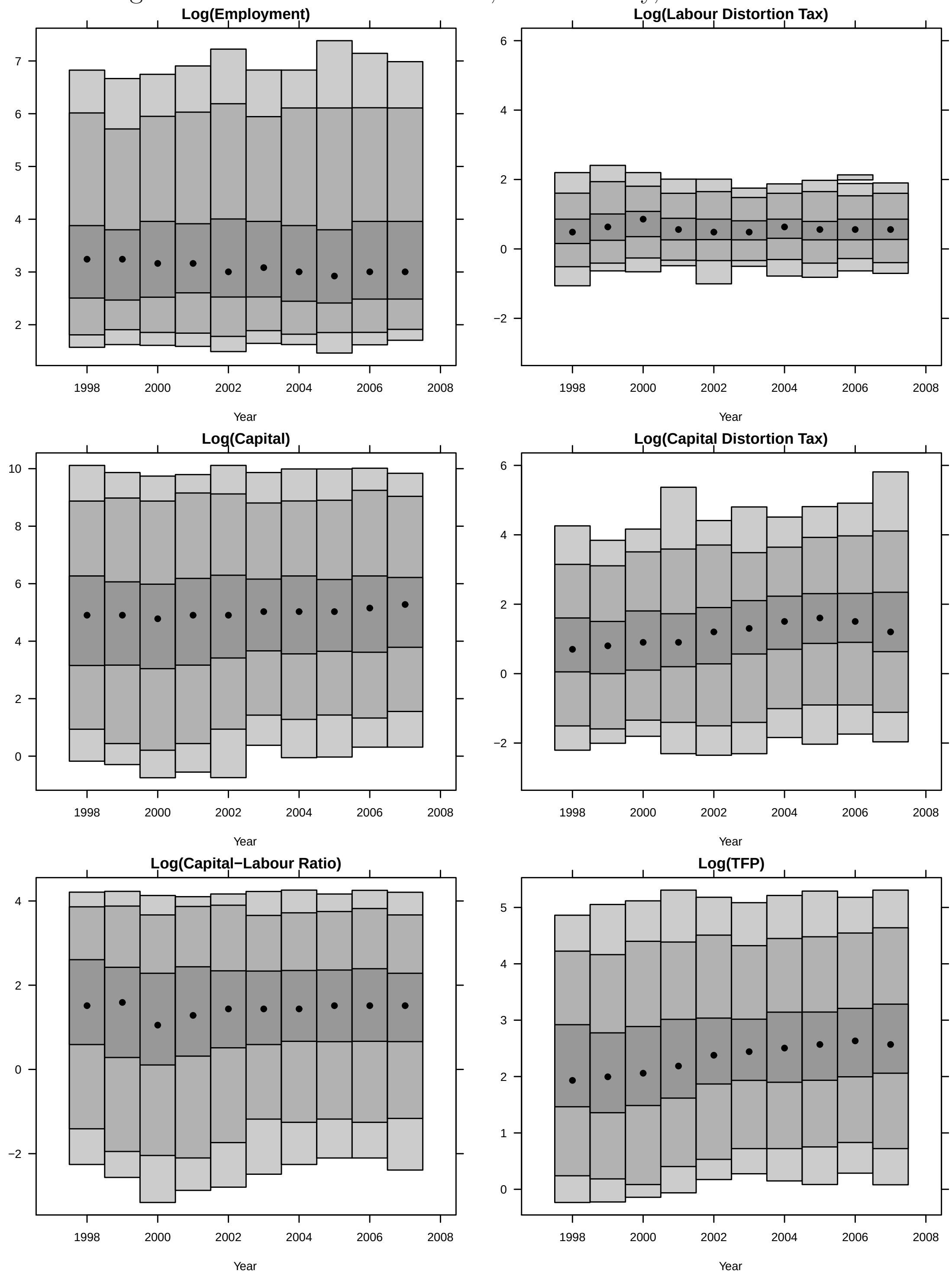
Since then, the distribution remains similar.

We formally tested if the distributions of distortion has changed over time.[4] These tests are important because distributions may dynamically vary from year to year in ways not fully captured by simply comparing sample medians, variances, or eye-balling. In particular, we test the null hypothesis $H_0 : f_t = f_s$ almost surely, for $t \neq s = 1998, \ldots, 2007$. Table E.2 shows the p-values based on 399 bootstrap replications of Li, Maasoumi, and Racine's (2009) test statistics for H_0, where f represents the probability density function of the log of capital distortion tax (upper triangular section), and the log of labour distortion tax (lower triangular section).

For labour distortions, the results show that all yearly distributions differ from each other prior to 2002. For capital distortions, pairwise comparison shows that most yearly distributions differ from each other, except in 1998-2001 where one cannot reject the null hypothesis of no distributional changes. Nonetheless, the importance of capital distortions during the crisis period is illustrated by the increase in the median capital distortion in Table E.1 and the mode of the distribution in Figure E.1.

[4] The time evolution of distributions is analysed using Functional Principal Component Analysis (FPCA). Results are available upon request. See Huynh and Jacho-Chávez (2010), Chu, Huynh, Jacho-Chávez, and Kryvtsov (2018) for applications on British data, and Huynh, Jacho-Chávez, Petrunia, and Voia (2011), Huynh, Jacho-Chávez, Kryvtsov, Shepotylo, and Vakhitov (2016) for applications on Canadian and Ukrainian data respectively.

Figure E.1: Distributions of Size, Productivity, and Distortions



Note: Bandwidths chosen by Silverman's rule-of-thumb with a second-order Gaussian kernel. The graph displays "highest density regions," i.e. the smallest region of the sample space containing 50% (darkest gray), 95% (medium gray), and 99% (lightest gray) probabilities (Hyndman, 1996). This graph also marks (by •) the empirical modes for each estimated density. Distortion taxes are expressed in gross terms, $\log(1+\tilde{\tau}^{\ell})$ for $\ell = L, K$.

Table E.2: Test of Equality of Probability Density Functions: Capital & Labour Distortion Taxes

$t\backslash s$	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1998	·	0.930	0.231	0.180	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	·	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.003	·	0.662	0.095	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	·	0.328	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.000	0.000	0.556	·	0.035	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.000	0.248	0.619	·	0.063	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.291	0.657	0.431	·	0.033	0.020	0.190
2005	0.000	0.000	0.000	0.023	0.291	0.579	0.286	·	0.970	0.125
2006	0.000	0.000	0.000	0.649	0.937	0.980	0.950	0.717	·	0.341
2007	0.000	0.000	0.000	0.130	0.739	0.449	0.649	0.692	0.617	·

Note: p-values based on 399 bootstrap replications of Li, Maasoumi, and Racine's (2009) test statistics for $H_0 : f_t = f_s$ almost surely, where f represents the probability density function of the log of capital distortion tax (upper triangular section), and the log of labour distortion tax (lower triangular section).

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