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Productivity and Reallocation: Evidence from Ecuadorian Firm-Level Data

ABSTRACT Ecuador, a developing small open economy, serves as an important case study for aggregate productivity growth and input reallocation. Since little is known about the economic performance of Ecuador with its crisis and reforms between 1998 and 2007, this paper uses a comprehensive microdata set from Ecuador's National Statistics and Census Institute to study Ecuadorian firm dynamics in that period. We find that the 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 contributes to productivity growth only in the later recovery period (2002–04).

JEL Codes: D24, E25, L11, O11, O47

Keywords: Aggregate productivity growth, factor reallocation

Understanding firm productivity and the efficient reallocation of resources is a central issue in industrial economics. Reallocation of resources from low-productivity to high-productivity firms will increase aggregate productivity, but there may be frictions that prevent this reallocation from occurring. These frictions are common in developing countries, and their study is therefore of interest.

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Our study focuses on the case of Ecuador, a developing small open economy that faced a crisis in 1998–2000 and subsequently undertook deep structural reforms, about which little is known. In this paper, we study the determinants of aggregate productivity growth in Ecuador in the period 1998–2007, when the Ecuadorian government implemented various policies to promote economic growth by reducing market distortion and facilitating resource reallocation. Some of these policies aimed to improve the allocative efficiency of resources among incumbent plants, while others were launched to encourage the entry of efficient plants and the exit of inefficient ones.

Using Ecuadorian plant-level data and the methodology proposed by Petrin and Levinsohn, we estimate and decompose aggregate productivity growth (APG) into three components: a technical efficiency improvement, input reallocation by incumbent plants (intensive margin) based on labor and capital, and input reallocation due to the entry and exit of plants (extensive margin).[1] Quantifying and understanding the magnitude 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, 2000–02, 2002–04, and 2004–06. 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 played a role in the APG decrease. In later periods, however, 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 labor reallocation on productivity growth. This case study also suggests that understanding the underlying mechanism of APG, input distortions, and input reallocation is important for policymakers as it quantifies the benefits (if any) of targeting policies to the different margins. It also sheds light on the causes of slow productivity growth in Latin America emphasized by the Inter-American Development Bank.[2] Finally, the findings in this paper suggest the need to remove factor market distortions via labor or capital market reforms, whereas policies to encourage entry and minimize 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 small open economy. We compare and contrast

1. Petrin and Levinsohn (2012).
2. Pagés (2010).

our findings with 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 resources from less-productive firms to more-productive ones. For example, Petrin, Reiter, and White highlight the positive role of reallocation in the United States.[3] Eslava, Haltiwanger, Kugler, and Kugler find that deregulation in Colombia created a positive impact on productivity.[4] On the extensive margin, Davis and Haltiwanger, as well as Caballero and Hammour, point out that recessions, although painful, serve a cleansing effect, whereby inefficient firms are culled while efficient ones thrive, resulting in an increase in overall productivity.[5]

Our results also show that the reallocation effect is not definitive, and it may decrease productivity in an economic crisis. These findings are in line with the strand of literature arguing that reallocation may intensify market frictions and reduce productivity. On the intensive margin, Barlevy shows that low-quality matches of firms and workers during a recession creates an inefficient reallocation of labor, known as the sullying effect.[6] Chen and Irarrázabal, as well as Oberfield, find that misallocation has strong negative effects on productivity in the Chilean manufacturing sector.[7] Petrin and Sivadasan find that labor market immobility may explain the large gaps between marginal product and marginal cost in Chilean plant-level data.[8] Asker, Collard-Wexler, and De Loecker find that much of the dispersion in productivity is due to capital misallocation caused by dynamic adjustment costs.[9] On the extensive margin, Nishimura, Nakajima, and Kiyota point out that the entry and exit mechanisms may not lead to efficiently superior firms during their infancy.[10] Hallward-Driemeier and Rijkers document that financial market imperfections in Indonesia attenuate the relationship between productivity and firm survival.[11]

3. Petrin, Reiter, and White (2011).
4. Eslava, Haltiwanger, Kugler, and Kugler (2004, 2010).
5. Davis and Haltiwanger (1990); Caballero and Hammour (1994).
6. Barlevy (2002).
7. Chen and Irarrázabal (2015); Oberfield (2013).
8. Petrin and Sivadasan (2013).
9. Asker, Collard-Wexler, and De Loecker (2014).
10. Nishimura, Nakajima, and Kiyota (2005).
11. Hallward-Driemeier and Rijkers (2013).

This paper is organized in the following fashion. The next section describes the data used, offers some descriptive statistics, and investigates the reallocation and productivity patterns. The paper then discusses the APG decompositions and analyzes the input distortions, while the final section concludes.

Stylized Facts

The Ecuadorian economic crisis spans from 1998 to 2000, when the real exchange rate of the sucre (Ecuador's former domestic currency) depreciated 62.3 percent against the U.S. dollar, and sixteen out of the forty banks failed. Figure 1 illustrates the diffcult macroeconomic conditions faced by Ecuador over the sample period. A detailed description of the crisis and subsequent labor and capital market reforms is provided in online appendix A.1.[12]

The impacts of an economic crisis are highlighted by the volatile patterns of plant turnover and input reallocation over the sample period. Plant turnover (that is, entry and exit) is indicative of a 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.

Ecuadorian Annual Survey of Manufacturing and Mining

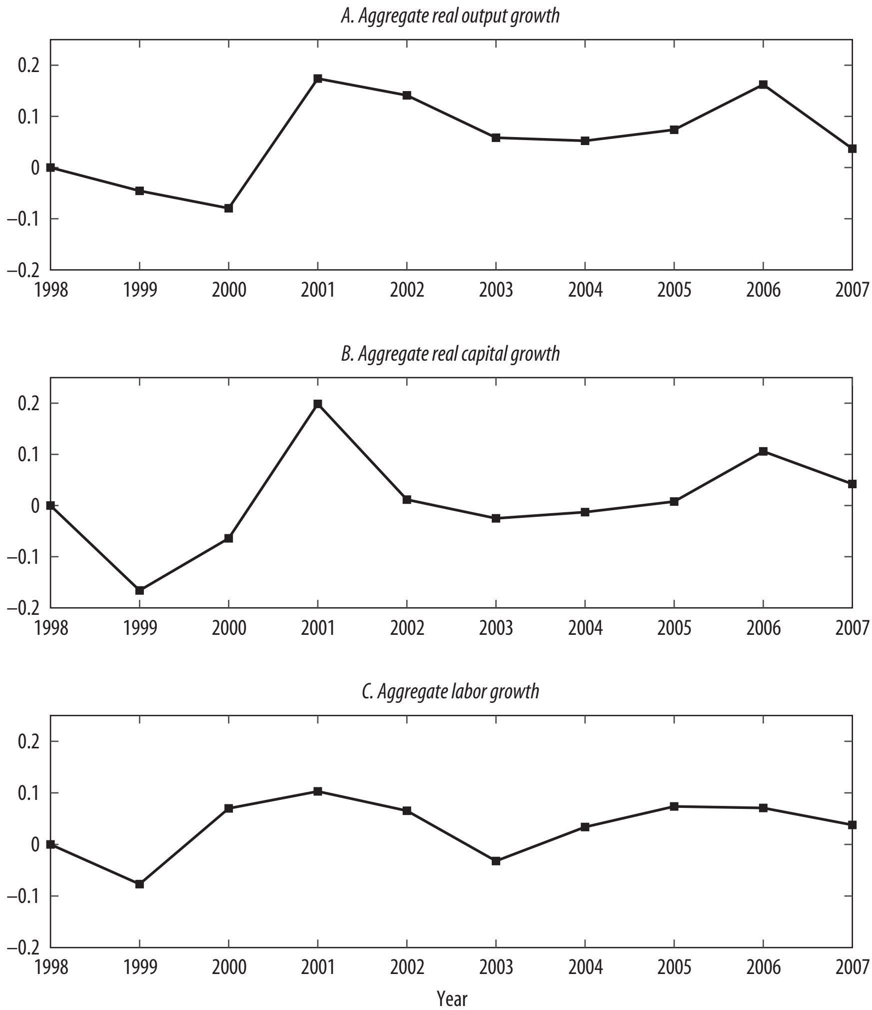
Our analyses are based on the Annual Manufacturing and Mining Survey prepared by the Ecuadorian National Institute of Statistics and Censuses (Instituto Nacional de Estadística y Censos, INEC). Construction of the data set is based on the list of plants identified in the 1984 Economic Census. The survey was launched in 1998 and aims to capture all manufacturing plants based on reported addresses and economic relevance. It covers plants with at least ten employees in the 1998–2007 period.[13] Each plant is assigned a unique taxpayer registration number (*Registro Único de Contribuyentes,* RUC).[14] New entrants are identified through tax records and added to the

12. See "Supplementary material for articles published since Spring 2017" on the journal's official website.

13. While it would be beneficial to include observations before 1998, compatible data are unavailable.

14. The survey potentially included informal plants that existed in 1984. However, these plants were unlikely to still be informal at the beginning of the survey in 1998.

FIGURE 1. Aggregate Output, Capital, and Labor Growth in the Ecuadorian Manufacturing Sector



Note: All monetary variables are expressed in 2000 U.S. dollars.

survey every year.[15] Plants are tracked over time and compelled by law to respond to the survey every year. Survey responses must follow official accounting standards and are cross-validated with the Ecuadorian Internal Revenue Service.[16]

We focus on plants' value added, which is the total value of sales and changes in inventory, minus the total value of intermediate inputs (that is, raw materials, parts and accessories, and packaging). 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 the sucre in 1999–2000.[17] Plants' value added and other monetary variables are deflated to 2000 U.S. dollars using the sector-specific producer price index (PPI) and the general PPI, respectively.[18] Monetary values reported in domestic currency (Ecuadorian sucres) before official dollarization are first adjusted to 2000 values using the PPI, and are then converted to U.S. dollars at the official exchange rate at the time of dollarization (25,000 sucres per U.S. dollar).[19]

Plants are classified into sectors by their two-digit International Standard Industrial Classification (ISIC Revision 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 in the top and bottom 1 percent for either the ratio of value added to labor or the capital-labor ratio to eliminate outliers. This results in 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 and exits.[20] Missing plant-year specific

15. 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 not have a significant influence on our analysis of resource reallocation and aggregate productivity growth because these plants are small and account for only a minor fraction of market share.

16. We thank Diego Rojas at the INEC for clarifying the technical details of the annual survey.

17. This is a conservative measurement of plant-level capital, because it decreased even more severely during the crisis if revaluation is not considered. A detailed explanation of the definition and measurement of capital is provided in online appendix A.2.

18. *Índices de Precios al Productor, Total (Nacional-Exportación*) and subcategories of the ISIC, revision 3.

19. The general PPI increased about four times from 1998 to 2000, which is roughly consistent with the depreciation of the sucre against the U.S. dollar in the same period.

20. A small fraction of plants (about 1 percent) temporarily exit and later re-enter the sample. For the effects on entry and exit, we ignored temporary exits and re-entries by treating a given plant's first entry and last exit as the only valid ones.

TABLE 1. Classification of Industries Based on Two-Digit ISIC Code

		Proportion of		
ISIC	*Industry*	*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 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

Notes: Plants are classified into sectors using their two-digit International Standard Industrial Classification (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 accounting for less than 0.5 percent of total observations were dropped from the sample.

observations due to temporary exits are linearly interpolated following Petrin and Levinsohn.[21]

For analyzing plant turnover, input reallocation, and aggregate productivity growth, we construct changes in four biennial windows.[22] This allows us to determine which time period contributed the most to the variation. Results are converted to annual values by dividing the biennial values by two.

Turnover and Reallocation Patterns

Plants' entry and exit patterns are reported in table 2. Entry is defined as the number of new plants in period t that did not exist in period t–1, where t is a two-year window. Similarly, exit is the number of plants that existed in period $t - 1$ but not in period t. Both are expressed as a fraction 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 subsequent recovery. As expected

21. Petrin and Levinsohn (2012).
22. Results at annual intervals are available in online appendix C.

TABLE 2. Resource Reallocation Patterns

Type of reallocation	*1998–2000*	*2000–02*	*2002–04*	*2004–06*
Entry and exit rates				
Entry rate (E)	0.040	0.072	0.101	0.053
Exit rate (X)	0.082	0.060	0.071	0.056
Net entry rate (NE)	–0.043	0.012	0.031	–0.003
Labor reallocation patterns				
Job creation (JC)	0.102	0.141	0.101	0.111
by entrants	0.030	0.045	0.050	0.033
by incumbents	0.072	0.096	0.050	0.079
Job destruction (JD)	0.104	0.062	0.089	0.046
by exiters	0.058	0.033	0.040	0.018
by incumbents	0.046	0.028	0.049	0.028
Job reallocation (JR)	0.206	0.203	0.190	0.157
l of entrants (no. workers)	29.5	23.0	25.0	22.0
l of exiters (no. workers)	21.0	20.0	18.0	16.0
Capital reallocation patterns				
Capital creation (KC)	0.094	0.167	0.096	0.106
by entrants	0.033	0.055	0.045	0.029
by incumbents	0.061	0.113	0.051	0.077
Capital destruction (KD)	0.216	0.070	0.108	0.058
by exiters	0.073	0.036	0.036	0.018
by incumbents	0.142	0.034	0.071	0.040
Capital reallocation (KR)	0.310	0.237	0.204	0.164
k/l of entrants (ratio)	2.412	3.228	4.180	4.249
k/l of exiters (ratio)	3.893	2.110	2.666	3.461

Notes: 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) and capital creation (KC) are defined as the sum of new jobs (capital) used by new entrants (E) and incumbent plants (I). Job destruction (JD) and capital destruction (KD) are defined as the sum of all lost jobs (capital) at exiters (X) and incumbent plants (I). Job reallocation (JR) and capital reallocation (KR) are the sum of jobs (capital) created and destroyed. JC, JD, and JR (KC, KD, and KR) are expressed as fractions of the average employment (capital) in periods t and $t-1$. The median number of workers employed and the median capital-labor ratio are denoted by l and k/l, respectively. All results are in annual values.

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 the entry rate. The net entry rate peaked in 2002–04 (3.1 percent), as the entry rate increased steadily to just over 10 percent while the exit rate remained low after the crisis.

The table also reports labor and capital reallocation patterns. We focus on the creation, destruction, and reallocation rates. Job (capital) creation is the sum of new jobs (capital) at new entrant and incumbent plants; destruction is the sum of lost jobs (capital) at exiter and incumbent plants; reallocation is the sum of jobs (capital) created and jobs (capital) destroyed. All job (capital) creation, destruction, and reallocation rates are expressed as a fraction of the average employment (capital) in periods t and t–1.

For labor, the reallocation rate was highest (20.6 percent) in 1998–2002 and gradually decreased to 15.7 percent in 2004–06. During the crisis, the job creation and destruction rates were both about 10 percent. Reallocation remained high in 2000–02, as job creation increased to 14.1 percent while job destruction decreased to 6.2 percent. Expanding incumbents contributed most of the job creation except in 2002–04, when plant entry was the highest. In contrast, exiters and incumbents had similar job destruction rates. Entrants were bigger than exiters in terms of the number of workers employed, but both were below the median level.[23]

In the case of capital, the crisis period had the highest reallocation rate (31 percent), when capital destruction (21.6 percent) was more than twice the rate of creation (9.4 percent). The trend immediately reversed in 2000–02, 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 2000–02. The incumbents generally account for the largest share of capital creation and destruction. In terms of the median capital-labor ratio, entrants were bigger than exiters except in the crisis years.

Aggregate Productivity Growth Decomposition

The role of resource reallocation in productivity growth is unclear for an economy in transition. Resource 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 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.

The existing macroeconomic literature largely focuses on measuring the effect of reallocation on total factor productivity (TFP). The conventional

23. The median size of employment increased from thirty-two in 1998 to thirty-five in 2006. See online appendix A.3 for details.

decomposition method is based on output-weighted aggregates of plant-level TFP.[24] 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 estimate TFP growth in Colombia due to market reforms and quantify the role of adjustment costs on resource reallocation.[25]

To measure the allocative efficiency of an economy in crisis, we adopted an alternative method developed by Petrin and Levinsohn to measure and decompose aggregate productivity growth (APG).[26] This approach explicitly measures productivity growth deriving from TFP improvements and resources reallocation, taking into account plant-level heterogeneity and returns to scale.[27] The 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.[28] APG improves when input is reallocated from a plant with a smaller marginal product–marginal cost gap to a plant with a larger gap. Technical details of the decomposition method are provided 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 to a lower-TFP plant may still improve productivity, provided that input reallocation sufficiently reduces misallocation. In contrast, such reallocation will show up as productivity loss in the conventional decomposition, as the higher-TFP plant loses market share to the lower-TFP plant. For example, Cubas, Ho, Huynh, and Jacho-Chávez use the Foster-Haltiwanger-Krizan decomposition method to analyze labor productivity in Ecuador, and they find that reallocation improves productivity while productive plants are losing market share.[29] Important differences between APG and conventional decompositions are further discussed in Petrin and Levinsohn.[30]

24. Olley and Pakes (1996); Baily, Hulten, and Campbell (1992); Foster, Haltiwanger, and Krizan (2001).

25. Eslava, Haltiwanger, Kugler, and Kugler (2004, 2010).

26. Petrin and Levinsohn (2012).

27. See 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.

28. See Restuccia and Rogerson (2008); Guner, Ventura, and Xu (2008); and Hsieh and Klenow (2009).

29. Cubas, Ho, Huynh, and Jacho-Chávez (2016); Foster, Haltiwanger, and Krizan (2001).

30. Petrin and Levinsohn (2012).

Methodology

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

$$Y_{it} = z_{it} K_{it}^{\alpha_j} L_{it}^{\gamma_j}, \tag{1}$$

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

Aggregate productivity growth (APG) is defined as the change in the 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 a continuous-time setting, APG at time t is

$$\text{APG}(t) = \frac{\sum_i dY_{it} - \sum_i r_{it} dK_{it} - \sum_i w_{it} dL_{it}}{\sum_i Y_{it}}. \tag{2}$$

By substituting production function (1) and $d\ell = \ell d\ln\ell$ for $\ell \in \{K, L\}$ into equation 2, we get

$$\text{APG}(t) = \sum_i D_{it} d\ln z_{it} + \sum_i D_{it}\left(\alpha_j - s_{it}^K\right) d\ln K_{it} + \sum_i D_{it}\left(\gamma_j - s_{it}^L\right) d\ln L_{it} \tag{3}$$

with

$$D_{it} = \frac{Y_{it}}{\sum_i Y_{it}},\ s_{it}^K = \frac{r_{it} K_{it}}{Y_{it}}, \text{ and } s_{it}^L = \frac{w_{it} L_{it}}{Y_{it}}, \tag{4}$$

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

The total APG from period t–1 to t is measured by taking the time integral of equation 2:

$$\text{APG}_{t-1,t} = \int_{t-1}^{t} \text{APG}(\tau)\, d\tau, \tag{5}$$

which can be empirically approximated in discrete time intervals. It can be decomposed by substituting equation 3 into equation 5 and further categorizing plants by their entry/exit status. The discrete time approximation is written as

$$(6)\quad \text{APG}_{t-1,t} \simeq \underbrace{\sum_{i\in I_t} \bar{D}_{it}\Delta \ln z_{it}}_{\text{TE}} + \underbrace{\sum_{i\in I_t} \bar{D}_{it}\left(\gamma_j - \bar{s}^{L}_{it}\right)\Delta \ln L_{it}}_{\text{APG}^{L}_{RE}} + \underbrace{\sum_{i\in I_t} \bar{D}_{it}\left(\alpha_j - \bar{s}^{K}_{it}\right)\Delta \ln K_{it}}_{\text{APG}^{K}_{RE}}$$

$$+ \underbrace{\sum_{i\in E_t} D_{it}\left(1 - s^{K}_{it} - s^{L}_{it}\right)}_{\text{Entry}} - \underbrace{\sum_{i\in X_{t-1}} D_{it-1}\left(1 - s^{K}_{it-1} - s^{L}_{it-1}\right)}_{\text{Exit}},$$

with

$$(7)\quad \bar{D}_{it} = \frac{D_{it} + D_{it-1}}{2}, \bar{s}^{L}_{it} = \frac{s^{L}_{it} + s^{L}_{it-1}}{2}, \text{and } \bar{s}^{K}_{it} = \frac{s^{K}_{it} + s^{K}_{it-1}}{2},$$

where I_t, E_t, and X_{t-1} denote the set of plants at period t that are incumbents, new entrants, and exiters, 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; and $\bar{s}^{L}_{it}$ and $\bar{s}^{K}_{it}$ are incumbent i's average value added shares for labor 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 changes in within-plant productivity affect the overall APG. Reallocation terms measure productivity changes coming from the reallocation of labor (APG^{L}_{RE}) and capital (APG^{K}_{RE}).

Productivity gains from reallocation depend on allocative efficiency and input flows. Typical factors affecting allocative efficiency include taxes, market frictions, and adjustment costs. The amount of input misallocation, that is, 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 a percentage of factor shares are equivalent to the notion of distortion taxes in the theoretical literature.[31] Reallocation improves productivity

31. 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 formally tests whether the distribution of distortions 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 and others (2016), and Chu, Huynh, Jacho-Chávez, and Kryvtsov (2018). See "Supplementary material for articles published since Spring 2017" on the journal's official website.

when factor inputs are directed to 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 where resources are efficiently allocated, plants' marginal product of inputs is equal to their marginal cost, and further reallocation will not improve productivity.[32]

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 operating 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 exiters operating in period t–1 and not in period t, as their disappearances represent a loss in the existing value added residuals. The net entry effect is positive when high-TFP entrants replace low-TFP exiters or when entrants with lighter distortions replace exiters with heavier distortions.

For our APG estimation, factor shares for each sector are estimated following Wooldridge, and results are reported in table 3.[33] Labor expenditure ($w_{it}L_{it}$) is taken from the data, which allow wages to vary across plants to reflect differences in labor quality. Since there are 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 eighty-four- to ninety-one-day U.S. dollar loans, reported by the Central Bank of Ecuador. This simplifying assumption ($r_{it} = r_t, \forall i$) is also used in Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sánchez.[34]

APG Results

Estimates from the APG decomposition are reported in table 4.[35] Results are expressed in annual values. Our results show that APG is the predominant

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

33. Wooldridge (2009). 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 ordinary least squares 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.

34. Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sánchez (2017).

35. Results for the APG decomposition in annual intervals are reported in online appendix C.

TABLE 3. Production Function Estimates

ISIC sector	$\hat{\alpha}_j$	*Std. error*	$\hat{\gamma}_j$	*Std. error*
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

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

TABLE 4. Aggregate Productivity Growth (APG) Decomposition

Component	*1998–2000*	*2000–02*	*2002–04*	*2004–06*	*Average*	*Std. deviation*
ΔY	–0.064	0.147	0.058	0.107	0.062	0.091
ΔL	–0.006	0.013	0.006	0.010	0.006	0.008
ΔK	–0.006	0.000	–0.002	0.002	–0.002	0.003
APG	–0.052	0.134	0.053	0.095	0.058	0.080
TE	–0.015	0.061	0.032	0.052	0.032	0.034
APG_{RE}						
Labor	0.013	0.016	0.006	0.014	0.012	0.004
Capital	–0.028	0.056	0.001	0.023	0.013	0.035
Total	–0.014	0.072	0.008	0.038	0.026	0.038
APG_{NE}						
Entry	0.016	0.019	0.028	0.013	0.019	0.007
Exit	0.038	0.019	0.014	0.008	0.020	0.013
Net entry	–0.022	0.000	0.014	0.006	–0.001	0.016

Notes: ΔY is value added growth; ΔL and ΔK are changes in the aggregate expenditure on labor and capital, respectively; TE is technical efficiency; APG_{RE} is the reallocation term; and APG_{NE} is the net entry effect, which equals entry minus exit. The TE and APG_{RE} terms are estimated from the production function following Wooldridge (2009). Results are in annual values.

contributor to the growth of value added. From 1998 to 2006, value added grew by 6.2 percent per year, on average, of which 5.8 percent was due to APG. Changes in aggregate labor and capital expenditures only contribute 0.6 percent and –0.2 percent of value added growth, respectively.

Improvements in technical efficiency (TE) and input reallocation (APG_{RE}) are the main drivers for APG. From 1998–2006, technical efficiency and input reallocation contributed, on average, 3.2 and 2.6 percent of APG, respectively. Capital and labor reallocation, in turn, increased APG by 1.3 percent and 1.2 percent, respectively. On the extensive margin, net entry only has a minor effect, with an average of –0.1 percent of 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 significant on the intensive margins, with technical efficiency (–1.5 percent) and reallocation (–1.4 percent), and on the extensive margin, with the net entry effect (–2.2 percent). APG strongly rebounds to 13.4 percent as the economy recovers in 2000–02, when it was mainly driven by the intensive margins, with technical efficiency (6.1 percent) and reallocation (7.2 percent). From 2002 onward, technical efficiency continues to be an important source of 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 2000–02, when capital reallocation contributes 5.6 percent of APG, which marks the strongest effect of input reallocation in all periods. APG from capital reallocation is close to zero in 2002–04 and then rises to 2.3 percent in 2004–06. In contrast, labor reallocation makes positive and stable contributions to APG, even during the crisis in 1998–2000 (1.3 percent), suggesting that labor market reforms during the crisis may have improved allocative efficiency. Productivity growth from labor reallocation in post-crisis periods remains above 1.0 percent, except for a notable drop in 2002–04, when the labor market reforms were partially reversed in 2003.[36]

Overall, the net entry effect is limited because the entry and exit effects roughly cancel each other out. Entrants and exiters are also smaller in size than incumbent plants and account for less weight in the APG.[37] Nonetheless, net entry still had economically sizable effects on APG during the crisis, when the net entry rate was negative and bigger plants exited the market. It also made a notable contribution to APG of 1.4 percent in 2002–04, when the net entry rate was the highest and entrants were substantially larger than the exiters.

Our findings provide an interesting comparison with existing studies on emerging economies. Relative to the 1982 Chilean crisis, the Ecuadorian crisis had a more moderate impact on APG.[38] The decline in technical efficiency was substantially smaller, and capital reallocation played a more important role in

36. See table A.1 in online appendix A for details.
37. See “Stylized Facts,” above, for entrants’ and exiters’ characteristics.
38. Nishida, Petrin, and Polanec (2014).

the post-crisis APG. Midrigan and Xu 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.[39] 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 also contrasts with Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sánchez, who show that capital inflows were increasingly misallocated in southern Europe from 1999–2012.[40] On the extensive margin, productivity loss from net exit during the Ecuadorian crisis is consistent with the exit of productive plants in the 1997–98 Indonesian crisis.[41] Our findings also suggest that net entry contributes to productivity growth only in later periods of recovery. In a broader sense, the decrease in technical efficiency during the Ecuadorian crisis is consistent with Gopinath and Neiman's findings on the 2001–02 Argentine crisis, when productivity decreased as a result of within-firm substitution of inputs.[42]

Source of APG from Reallocation

Since input reallocation by 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: more inputs are used in the aggregate economy, which reduces the average misallocation; and inputs are reallocated across plants in which inputs are disproportionately misallocated. Distinguishing the effects of these channels is important because an economic crisis is commonly associated with substantial changes in the level of aggregate inputs.[43] To separate these effects, APG_{RE}^{L} and APG_{RE}^{K} in equation 6 are rewritten as

$$\text{(8)} \qquad \begin{aligned} \text{APG}_{RE}^{L} &= \sum_{i \in I_t} \bar{D}_{it} \left(\gamma^{j} - \bar{s}_{it}^{L} \right) \Delta \ln L_{it} \\ &= \underbrace{\bar{\mu}_t^{L} \sum_{i \in I_t} \bar{D}_{it} \Delta \ln L_{it}}_{\text{AVG}_L} + \underbrace{\sum_{i \in I_t} \bar{D}_{it} \left[\left(\gamma^{j} - \bar{s}_{it}^{L} \right) - \bar{\mu}_i^{L} \right] \Delta \ln L_{it}}_{\text{DAVG}_L} \end{aligned}$$

39. Midrigan and Xu (2014).
40. Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sánchez (2017).
41. Hallward-Driemeier and Rijkers (2013).
42. Gopinath and Neiman (2014).
43. Calvo, Izquierdo, and Talvi (2006).

and

$$\text{(9)} \qquad \text{APG}_{RE}^{K} = \sum_{i \in I_t} \bar{D}_{it} \left(\alpha^j - \bar{s}_{it}^{K}\right) \Delta \ln K_{it}$$

$$= \underbrace{\bar{\mu}_i^K \sum_{i \in I_t} \bar{D}_{it} \Delta \ln K_{it}}_{\text{AVG}_K} + \underbrace{\sum_{i \in I_t} \bar{D}_{it} \left[\left(\alpha^j - \bar{s}_{it}^{K}\right) - \bar{\mu}_t^K\right] \Delta \ln K_{it}}_{\text{DAVG}_K},$$

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

$$\text{(10)} \qquad \bar{\mu}_t^L = \frac{\sum_{i \in I_t} \left(\alpha^j - \bar{s}_{it}^{L}\right)}{N_{it}}$$

and

$$\text{(11)} \qquad \bar{\mu}_t^K = \frac{\sum_{i \in I_t} \left(\gamma^j - \bar{s}_{it}^{K}\right)}{N_{it}}.$$

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, that is, $\bar{\mu}_t^{\ell} > 0$ 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 disproportionate 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 labor reallocation (APG_{RE}^{L}) predominantly derives from increases in the aggregate use of labor (AVG_L). From 1998–2006, this component contributes an average of 2.1 percent to APG per year. Productivity gains from the aggregate change in labor resemble the net job creation pattern in table 2. While the economy-wide net job creation is negative during the crisis, incumbents absorb the labor inputs released by exiters to ease their

TABLE 5. Aggregate Productivity Growth (APG) from Factor Reallocation

	APG_{RE}^{L}			APG_{RE}^{K}		
Period	AVG_L	$DAVG_L$	Total	AVG_K	$DAVG_K$	Total
1998–2000	0.024	–0.010	0.013	–0.008	–0.020	–0.028
2000–02	0.028	–0.012	0.016	0.002	0.054	0.056
2002–04	0.009	–0.003	0.006	–0.002	0.003	0.001
2004–06	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. deviation	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

Notes: APG_{RE}^{L} and APG_{RE}^{K} refer to APG from labor and capital reallocation, respectively. The total effect of reallocation equals $AVG_\ell + DAVG_\ell$ for $\ell = L, K$.

constraints, leading to a positive AVG_L (2.4 percent). For most years, AVG_L is over 2 percent, with the increase in aggregate labor input reflected in the net job creation. The negative $DAVG_L$ shows that the labor input flow is concentrated in incumbents with below-average misallocation instead of moving toward more labor-constrained plants. A plausible reason is that plants with below-average labor misallocation are 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 labor market reforms may have promoted employment through a more flexible labor market, there may also be other factors preventing labor inputs from moving toward more constrained plants.

Capital reallocation (APG_{RE}^{K}) shows a contrasting pattern to labor reallocation. The aggregate change in capital (AVG_K) has minimal influences on APG, with an average of –0.1 percent from 1998 to 2006. The main source of growth is the efficient reallocation of capital ($DAVG_K$), contributing 1.4 percent to APG per year. Taken together, the pattern of capital creation/destruction, AVG_K, and $DAVG_K$ 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 2000–02 is a reverse of the process. The combination of 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 disproportionately capital constrained.

Plant-Level Distortions and Productivity Growth

Our findings on aggregate productivity growth suggest that input reallocation among incumbent plants is an important channel. Thus, we conduct further analysis of the incumbents to understand the relationship between plant characteristics and input misallocation. The measures of input misallocation are taken from the reallocation terms in equation 6 and are normalized to be expressed as percentages of the value added share for factor input.[44] Specifically, denote the normalized labor (L) and capital (K) distortions for plant i in period t as τ_{it}^{ℓ} for $\ell \in \{L, K\}$:

$$\tau_{it}^{L} = \frac{\left(\gamma_j - \overline{s}_{it}^{L}\right)}{\overline{s}_{it}^{L}} \tag{12}$$

and

$$\tau_{it}^{K} = \frac{\left(\alpha_j - \overline{s}_{it}^{K}\right)}{\overline{s}_{it}^{K}}. \tag{13}$$

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-effects regression model on input distortion is specified as

$$\tau_{it}^{\ell} = \beta_i + \beta_j + \beta_t + I\left\{\tau_{it}^{\ell} \geq 0\right\} \times \left\{\beta_z^{+} \log z_{it-1} + \beta_k^{+} \log k_{it-1}\right\} + I\left\{\tau_{it}^{\ell} < 0\right\} \times \left\{\beta_z^{-} \log z_{it-1} + \beta_k^{-} \log k_{it-1}\right\} + u_{it}^{\ell}, \tag{14}$$

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-labor ratio. $I\{\bullet\}$ 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

44. As noted earlier, this measure is equivalent to the notion of an input distortion tax in the macroeconomic literature.

TABLE 6. Regression Analysis on Input Misallocation and APG Reallocation

Explanatory variable	$\ell = L$	$\ell = K$
$\ln z_{it} \mid \tau_{it} \geq 0$	0.507***	3.802***
	(0.03)	(0.40)
$\ln k_{it} \mid \tau_{it} \geq 0$	0.132***	−4.266***
	(0.02)	(0.26)
$\ln z_{it} \mid \tau_{it} < 0$	0.388***	2.156***
	(0.04)	(0.56)
$\ln k_{it} \mid \tau_{it} < 0$	0.087**	−1.124**
	(0.03)	(0.45)
Sector fixed effects	Yes	Yes
Time effects	Yes	Yes
Plant fixed effects	Yes	Yes
R^2	0.211	0.158
No. observations	4,063	4,063

Notes: 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 that had a higher capital-labor ratio; for plants with $\tau_{it}^{\ell} < 0$, $\beta_k^- < 0$ indicates that more misallocation occurs with those that had a higher capital-labor ratio.

** Statistically significant at the 5 percent level.

*** Statistically significant at the 1 percent level.

to capture the different relationship between the direction of input distortions and plant characteristics. The plant-level capital-labor ratio also reflects the extent of misallocation of a specific input and explains the extent to which APG is coming from a specific factor reallocation. The rationale for including the capital-labor ratio is that input adjustments are interdependent. As illustrated by Eslava, Haltiwanger, Kugler, and Kugler, plants' labor adjustments are conditional on their capital constraints, and vice versa.[45] Thus, we use plants' capital-labor ratios to reflect the relative tightness of their capital and labor constraints. Results are reported in table 6.

For input-constrained plants, that is, $\tau_{it}^{\ell} \geq 0$, productive plants are subject to more input distortions, and capital distortions are more sensitive to plant-level productivity. The positive β_z^+ implies that there is a barrier to the growth of the most productive plants, as they are constrained by resource allocation.[46] We estimated that a one percent increase in TFP is associated with 0.51 percent and 3.80 percent more labor and capital distortions, respectively. Various factors contribute to the higher sensitivity of capital distortion. The aggregate capital supply is more limited than the labor supply in Ecuador, so that plants

45. Eslava, Haltiwanger, Kugler, and Kugler (2010).

46. We thank Marcela Eslava for this comment.

are more restricted in capital use in general. Labor regulation reforms in response to the crisis may also provide greater flexibility to the labor market, which reduces the amount of labor distortions in productive plants.

The distortion estimates for the capital-labor ratio, that is, β_k^+, provide further evidence on the relatively flexible labor market. A 1 percent increase in the capital-labor ratio raises the labor distortion by only 0.13 percent, but it reduces the capital distortion by 4.27 percent. These results suggest that plants with a higher capital-labor ratio—and thus a higher marginal product of labor—are able to make labor adjustments, and have only a slightly higher labor distortion. These plants, while still undersized, face much less capital distortion, indicating that plant-level capital is more difficult to adjust.

For plants with surplus inputs, that is, $\tau_{it}^l < 0$, productive plants are associated with less input misallocation. The positive β_z^+ indicates that plants with a higher TFP are less oversized. Plants with a higher capital-labor ratio have less excess labor but more excess capital. This is in line with the economic intuition that high-TFP plants have a higher marginal product of inputs, so they should use more inputs and become larger in scale. Thus, conditional on being undersized, the extent of misallocation increases with higher TFP, while in oversized plants misallocation decreases with higher TFP. The coefficient on capital distortion is substantially higher than its labor 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 a low capital-labor ratio. Oversized plants with a higher capital-labor ratio are also associated with more misallocation, but they are notably less sensitive than undersized plants. On the other hand, plants with a higher capital-labor ratio have a higher marginal product of labor and are associated with more labor misallocation, conditional on being undersized.

Conclusion

Ecuador's economic performance in 1998–2007 provides an interesting case study for understanding aggregate productivity growth and input reallocation in a developing small open economy. Using Ecuadorian plant-level data, we documented stylized facts about plant turnover and input reallocation to illustrate the amount of friction in this economy. We estimated the effects of input misallocation on aggregate productivity growth using Petrin and Levinsohn's decomposition method.[47] Our results show that technical efficiency growth and input reallocation (intensive margin) are more important than the net entry of plants (extensive margin) for productivity growth. From 1998 to 2006, improvements in the technical efficiency and input reallocation of incumbent plants contributed 3.2 and 2.6 percent to average annual productivity growth, respectively, while net entry accounted for only –0.1 percent. During the crisis, technical efficiency, reallocation among incumbent plants, and net entry of plants played equally important roles in the plummeting APG. Reallocation among incumbent plants was particularly important during the immediate recovery period in 2000–02, while net entry contributed only moderately to APG in 2002–04. We also find that distortions are statistically significantly correlated with plant-level TFP and capital-labor ratios.

Our findings have important policy implications, as they highlight the need for removing distortions in factor markets via labor or capital market reforms. Policies to encourage entry and minimize exit may have a limited and lagged effect on aggregate productivity growth. Overall, our results point to technical efficiency growth and input reallocation as important margins for readjustment. Nonetheless, the concurrent policy reforms undertaken in the sample period make 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 for future research is the role of financial frictions in the capital adjustment process. For instance, Buera, Kaboski, and Shin show that financial frictions distort capital allocation and negatively affect productivity.[48] On the other hand, Midrigan and Xu suggest that efficient establishments can quickly accumulate internal funds and that financial frictions produce only modest TFP losses.[49] Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sánchez use the introduction of the euro and the decline in the real interest rate to explore how capital inflows to Spain resulted in lower productivity.[50] Dollarization may have a similar impact on plants' input reallocation by removing the balance-sheet effect. Quispe-Agnoli and Whisler find that dollarization improved the Ecuadorian banking sector.[51] Unfortunately, at the present time there are no detailed financial balance-sheet data for Ecuador that can be used to study this phenomenon.

47. Petrin and Levinsohn (2012).
48. Buera, Kaboski, and Shin (2011).
49. Midrigan and Xu (2014).
50. Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sánchez (2017).
51. Quispe-Agnoli and Whisler (2006).

Appendix: Aggregate Productivity Growth Decomposition Method

This appendix contains technical details of the decomposition method used in the paper.[52] To decompose the effects of entry and exit on aggregate productivity growth (APG) from period t–1 to t, plants are categorized as incumbents (I_t), entrants (E_t), and exiters (X_t–1), such that equation 5 can be reformulated as

$$\text{(A1)} \qquad \text{APG}_{t-1,t} = \sum_{i \in I_t} \int_{t-1}^{t} \text{APG}_i(\tau)\, d\tau + \sum_{i \in E_t} \int_{t-1}^{t} \text{APG}_i(\tau)\, d\tau + \sum_{i \in X_t} \int_{t-1}^{t} \text{APG}_i(\tau)\, d\tau,$$

where

$$\text{(A2)} \qquad \text{APG}_i(t) = \frac{\left(dY_{it} - r_{it} dK_{it} - w_{it} L_{it}\right)}{\sum_i Y_{it}}$$

is plant i's contribution to APG at time t. For the incumbents, equation 3 implies that

$$\text{(A3)} \qquad \sum_{i \in I_t} \int_{t-1}^{t} \text{APG}_i(\tau) d\tau = \underbrace{\sum_{i \in I_t} \int_{t-1}^{t} D_{it} d\ln z_{it}}_{\text{TE}} + \underbrace{\sum_{i \in I_t} \int_{t-1}^{t} D_{it} \left(\alpha_j - s_{it}^K\right) d\ln K_{it}}_{\text{APG}_{RE}^K} + \underbrace{\sum_{i \in I_t} \int_{t-1}^{t} D_{it} \left(\gamma_j - s_{it}^L\right) d\ln L_{it}}_{\text{APG}_{RE}^L}.$$

On the extensive margin, we follow the approach in Kwon, Narita, and Narita to approximate the effects of entry and exit.[53] For entrants, denote $\tau_i^E \in (t-1, t)$ as the time when plant i enters the sample:

$$\text{(A4)} \qquad \sum_{i \in E_t} \int_{t-1}^{t} \text{APG}_i(\tau)\, d\tau = \sum_{i \in E_t} \left[\int_{t-1}^{\tau_i^E} \text{APG}_i(\tau)\, d\tau + \int_{\tau_i^E}^{\tau_i^E} \text{APG}_i(\tau)\, d\tau + \int_{\tau_i^E}^{t} \text{APG}_i(\tau)\, d\tau \right],$$

52. Additional information is available in the online appendixes (economia.lacea.org/Forthcoming%20papers/Jacho-Chavez%20full%20version.pdf).

53. Kwon, Narita, and Narita (2015). See online appendix B.

where

$$Y_{it}^{R} = Y_{it} - r_{it}K_{it} - w_{it}L_{it}; \tag{A5}$$

$$\sum_{i \in E_t} \int_{t-1}^{\tau_i^E} \text{APG}_i(\tau)\, d\tau = 0; \tag{A6}$$

$$\sum_{i \in E_t} \int_{\tau_i^E}^{\tau_i^E} \text{APG}_i(\tau)\, d\tau = \frac{Y_{i\tau_i^E}^{R}}{\sum_i Y_{i\tau_i^E}}; \tag{A7}$$

$$\sum_{i \in E_t} \int_{\tau_i^E}^{t} \text{APG}_i(\tau)\, d\tau = \left.\frac{Y_{i\tau_i^E}^{R}}{\sum_i Y_{i\tau}}\right|_{\tau_i^E}^{t} - \int_{\tau_i^E}^{t} \frac{Y_{i\tau}^{R}}{\left(\sum_i Y_{i\tau}\right)^2} d\left(\sum_i Y_{i\tau}\right). \tag{A8}$$

The residual value added by plant i is defined in equation A5. The effect of entry on APG is the sum of equations A6, A7, and A8; equation A6 is equal to zero prior to plant *i's* entry; equation A7 is the difference between the left and right limits due to the jump in the value added residual; and equation A8 is the post-entry APG from entrants derived using integration by parts. Assuming that

$$Y_{i\tau}^{R} \ll \left(\sum_i Y_{it}\right)^2,$$

the entry effect on APG is approximated as

$$\begin{aligned} \sum_{i \in E_t} \int_{t-1}^{t} \text{APG}_i(\tau)\, d\tau &\simeq \sum_{i \in E_t} \frac{Y_{it} - r_{it}K_{it} - w_{it}L_{it}}{\sum_i Y_{it}} \\ &= \sum_{i \in E_t} \frac{Y_{it}}{\sum_i Y_{it}} \left(1 - \frac{r_{it}K_{it}}{Y_{it}} - \frac{w_{it}K_{it}}{Y_{it}}\right). \\ &\sum_{i \in E_t} D_{it}\left(1 - s_{it}^{K} - s_{it}^{L}\right). \end{aligned} \tag{A9}$$

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

$$\text{(A10)} \quad \sum_{i \in X_{t-1}} \int_{t-1}^{t} \mathrm{APG}_i(\tau)\, d\tau = \sum_{i \in X_{t-1}} \left[\int_{t-1}^{\tau_i^X} \mathrm{APG}_i(\tau)\, d\tau + \int_{\tau_i^X}^{\tau_i^X} \mathrm{APG}_i(\tau)\, d\tau + \int_{\tau_i^X}^{i} \mathrm{APG}_i(\tau)\, d\tau \right]$$

$$\simeq \sum_{i \in X_{t-1}} - \left(\frac{Y_{it-1} - r_{it-1}K_{it-1} - w_{it-1}L_{it-1}}{\sum_i Y_{it-1}} \right)$$

$$= - \sum_{i \in X_{t-1}} D_{it-1} \left(1 - s_{it}^K - s_{it}^L \right).$$

The APG is the sum of equations A3, A9, and A10. The continuous-time APG for incumbents in equation A3 is converted to discrete time using the Tornquist-Divisia approximation, to derive the APG decomposition in equation 6.

References

Ackerberg, Daniel A., Kevin Caves, and Garth Frazer. 2015. "Identification Properties of Recent Production Function Estimators." *Econometrica* 83(6): 2411–51.

Asker, John, Allan Collard-Wexler, and Jan De Loecker. 2014. "Dynamic Inputs and Resource (Mis)Allocation." *Journal of Political Economy* 122(5): 1013–63.

Baily, Martin N., Charles Hulten, and David Campbell. 1992. "Productivity Dynamics in Manufacturing Plants." *Brookings Papers on Economic Activity: Microeconomics* 23(1992): 187–267.

Barlevy, Gadi. 2002. "The Sullying Effect of Recessions." *Review of Economic Studies* 69(1): 65–96.

Buera, Francisco J., Joseph P. Kaboski, and Yongseok Shin. 2011. "Finance and Development: A Tale of Two Sectors." *American Economic Review* 101(5): 1964–2002.

Caballero, Ricardo J., and Mohamad L. Hammour. 1994. "The Cleansing Effect of Recessions." *American Economic Review* 84(5): 1350–68.

Calvo, Guillermo A., Alejandro Izquierdo, and Ernesto Talvi. 2006. "Sudden Stops and Phoenix Miracles in Emerging Markets." *American Economic Review* 96(2): 405–10.

Chen, Kaiji, and Alfonso Irarrázabal. 2015. "The Role of Allocative Efficiency in a Decade of Recovery." *Review of Economic Dynamics* 18(3): 523–50.

Chu, Ba, Kim P. Huynh, David T. Jacho-Chávez, and Oleksiy Kryvtsov. 2018. "On the Evolution of the United Kingdom Price Distributions." *Annals of Applied Statistics* 12(4): 2618–46.

Cubas, Germán, Anson T. Y. Ho, Kim P. Huynh, and David T. Jacho-Chávez. 2016. "Analysing Labour Productivity in Ecuador." In *Productivity and Efficiency Analysis*, edited by William H. Greene, Lynda Khalaf, Robin C. Sickles, and others, pp. 109–17. New York: Springer.

Davis, Steven J., and John Haltiwanger. 1990. "Gross Job Creation and Destruction: Microeconomic Evidence and Macroeconomic Implications." In *NBER Macroeconomics Annual 1990*, vol. 5, edited by Olivier J. Blanchard and Stanley Fischer, pp. 123–86. MIT Press.

Eslava, Marcela, John Haltiwanger, Adriana Kugler, and Maurice Kugler. 2004. "The Effects of Structural Reforms on Productivity and Profitability Enhancing Reallocation: Evidence from Colombia." *Journal of Development Economics* 75(2): 333–71.

———. 2010. "Factor Adjustments after Deregulation: Panel Evidence from Colombian Plants." *Review of Economics and Statistics* 92(2): 378–91.

Foster, Lucia, John Haltiwanger, and C. J. Krizan. 2001. "Aggregate Productivity Growth: Lessons from Microeconomic Evidence." In *New Developments in Productivity Analysis*, edited by Charles R. Hulten, Edwin R. Dean, and Michael J. Harper, pp. 303–72. University of Chicago Press.

Gopinath, Gita, Şebnem Kalemli-Özcan, Loukas Karabarbounis, and Carolina Villegas-Sánchez. 2017. "Capital Allocation and Productivity in South Europe." *Quarterly Journal of Economics* 132(4): 1915–67.

Gopinath, Gita, and Brent Neiman. 2014. "Trade Adjustment and Productivity in Large Crises." *American Economic Review* 104(3): 793–831.

Guner, Nezih, Gustavo Ventura, and Yi Xu. 2008. "Macroeconomic Implications of Size-Dependent Policies." *Review of Economic Dynamics* 11(4): 721–44.

Hallward-Driemeier, Mary, and Bob Rijkers. 2013. "Do Crises Catalyze Creative Destruction? Firm-Level Evidence from Indonesia." *Review of Economics and Statistics* 95(5): 1788–810.

Hsieh, Chang-Tai, and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China and India." *Quarterly Journal of Economics* 124(4): 1403–48.

Huynh, Kim P., and David T. Jacho-Chávez. 2010. "Firm Size Distributions through the Lens of Functional Principal Components Analysis." *Journal of Applied Econometrics* 25(7): 1211–14.

Huynh, Kim P., David T. Jacho-Chávez, Oleksiy Kryvtsov, and others. 2016. "The Evolution of Firm-Level Distributions for Ukrainian Manufacturing Firms." *Journal of Comparative Economics* 44(1): 148–62.

Huynh, Kim. P., David T. Jacho-Chávez, Robert J. Petrunia, and Marcel Voia. 2011. "Functional Principal Component Analysis of Density Families with Categorical and Continuous Data on Canadian Entrant Manufacturing Firms." *Journal of the American Statistical Association* 106(495): 858–78.

Kwon, Hyeog Ug, Futoshi Narita, and Machiko Narita. 2015. "Resource Reallocation and Zombie Lending in Japan in the 1990s." *Review of Economic Dynamics* 18(4): 709–32.

Levinsohn, James, and Amil Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables." *Review of Economic Studies* 70(2): 317–41.

Midrigan, Virgiliu, and Daniel Yi Xu. 2014. "Finance and Misallocation: Evidence from Plant-Level Data." *American Economic Review* 104(2): 422–58.

Nishida, Mitsukuni, Amil Petrin, and Saso Polanec. 2014. "Exploring Reallocation's Apparent Weak Contribution to Growth." *Journal of Productivity Analysis* 42(2): 187–210.

Nishimura, Kiyohiko G., Takanobu Nakajima, and Kozo Kiyota. 2005. "Does the Natural Selection Mechanism Still Work in Severe Recessions? Examination of the Japanese Economy in the 1990s." *Journal of Economic Behavior and Organization* 58(1): 53–78.

Oberfield, Ezra. 2013. "Productivity and Misallocation during a Crisis: Evidence from the Chilean Crisis of 1982." *Review of Economic Dynamics* 16(1): 100–19.

Olley, Steven, and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunication Equipment Industry." *Econometrica* 64(6): 1263–98.

Ouyang, Min. 2009. "The Scarring Effect of Recessions." *Journal of Monetary Economics* 56(2): 184–99.

Pagés, Carmen, ed. 2010. *The Age of Productivity: Transforming Economies from the Bottom Up*. Development in the Americas Series. Inter-American Development Bank. New York: Palgrave Macmillan.

Petrin, Amil, and James Levinsohn. 2012. "Measuring Aggregate Productivity Growth Using Plant-Level Data." *Rand Journal of Economics* 43(4): 705–25.

Petrin, Amil, Jerry Reiter, and Kirk White. 2011. "The Impact of Plant-Level Resource Reallocations and Technical Progress on U.S. Macroeconomic Growth." *Review of Economic Dynamics* 14(1): 3–26.

Petrin, Amil, and Jagadeesh Sivadasan. 2013. "Estimating Lost Output from Allocative Inefficiency, with Application to Chile and Firing Costs." *Review of Economics and Statistics* 95(1): 286–301.

Quispe-Agnoli, Myriam, and Elena Whisler. 2006. "Official Dollarization and the Banking System in Ecuador and El Salvador." *Economic Review* 91(3): 55–71.

Restuccia, Diego, and Richard Rogerson. 2008. "Policy Distortions and Aggregate Productivity with Heterogeneous Plants." *Review of Economic Dynamics* 11(4): 707–20.

Wooldridge, Jeffrey M. 2009. "On Estimating Firm-Level Production Functions Using Proxy Variables to Control for Unobservables." *Economics Letters* 104(3): 112–14.