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Investment Decisions and Capital Accumulation: Firm-Level Evidence from Brazil

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Abstract

Using firm-level data from an administrative Brazilian dataset, I document a few stylized facts regarding capital stock accumulation patterns and investment decisions. Finding evidence largely in favor of micro-level lumpiness of investment as it was found for American firms, I document that there are a few particularities in the behavior of Brazilian firms. First, I document that the distribution of the growth rate of capital is more dispersed, with "fatter" tails. Second, I also show that, as economic activity, the volume of investment and capital stock are more concentrated on a small number of firms, micro-level lumpiness might have a bigger role in understanding aggregate movements. Third, I show that the observable characteristics of Brazilian firms explain a lot more of sudden movements in capital growth when compared to the U.S., after controlling for industry specific characteristics and other variables. Fourth and last, I compute statistical measures related to the investment rate distribution, which show that investment at the firm-level seems to be even "lumpier" in Brazil, with firms investing less on average, while experiencing more episodes of investment spikes and periods of inaction.

KEYWORDS: *Investment Decisions, Lumpy Investment, Capital Stock, Capital Growth*

Contents

1 Introduction

Understanding investment has long been a fundamental question for macroeconomists, as it plays a fundamental role both in the long-run and in the short run. First, and most importantly, investment is the link between the present and the future in an economy, as it allows to accumulate capital which is the key production factor to induce growth in the long-run, even though productivity growth is the main driver. Second, investment is the most variable component of output and, as such, understanding what generates this variation is of key importance to understand the business cycle.

Even though this is a primarily macroeconomic question, economists, over the last 20 years, have increasingly turned themselves to microeconomic data in order to better understand aggregate dynamics. The failure of the first modeling attempts and the accumulation of new data, econometric methods and theoretical models have been the main drivers of this process, which has been somewhat successful in providing useful insights. Unfortunately, however, such progress has been mainly focused on developed economies, in particular the United States economy.

As such, there is a gap in the investment literature with regard to developing economies and it is exactly this gap that this articled intends to to fill, taking advantage of a comprehensive administrative dataset of Brazilian firms. This dataset allows me to catalog the stylized facts regarding firm-level investment decisions in a similar way to the work of Doms and Dunne (1998), who studied American establishment-level data for the period between 1973 and 1988.

More precisely, first I show that the tails of the distribution of the growth rate of capital are "fatter" in Brazil, when compared to the U.S, with firms experiencing, on average, periods of both more intense investment and disinvestment of capital. Second, I also show that these large sudden adjustments in capital stock and in investment seem to matter even more to understand aggregate movements in the economy, as economic activity, the volume of investment and capital stock are more concentrated on small number of firms in Brazil. Third, I show that the observable characteristics of Brazilian firms explain a lot more of sudden movements in capital growth when compared to the U.S., after controlling for industry specific characteristics and other variables. Fourth and last, I compute statistical measures related to the investment rate distribution, which show that investment at the firm-level seems to be "lumpier" in Brazil, with firms investing less on average, while experiencing more episodes of investment spikes and periods of inaction.

This article is organized as follows. In the next section, I present an extensive review of the literature, in an attempt to provide a historical link between the most relevant contributions. In the third section, I present the dataset used in this article, detailing its collection, the selection of my final sample and the definition of the most important variables . In the fourth section, I present the steps needed in order to build a capital stock series for each firm. The fifth section presents the analysis of firm-level capital accumulation patterns. Finally, the sixth section presents concluding remarks.

2 Literature Review

2.1 Related Articles

This subsection presents a review of the most important works regarding investment theories and stylized facts about investment, both at the macro and micro levels. The first serious attempt to model investment in a optimizing framework dates back from the beginning of the 1960's, when Jorgenson (1963) proposed "a theory of investment behavior based on the neoclassical theory of optimal accumulation of capital". In such framework, a perfectly competitive firm maximizes its expected net revenue facing constant returns to scale, no adjustment costs and no uncertainty. However, as Jorgenson (1972) himself pointed out, without such costs the scale of output and the optimal level of investment are indeterminate[1] if no other hypothesis were made. In order to solve such problem, the author explicitly included installation costs in his 1972 article.

Almost simultaneously, Tobin and Brainard (1968) and Tobin (1969) proposed another way to model investment decisions. The authors argued that a firm should invest in a project if and only if such investment increased the value of the firm's shares. As such, the investment rate should only depend on q, the ratio between the value of capital and its replacement cost[2]. If q was above 1, then the firm should invest, as it would be able to more than compensate one unit of money spent capital expenditure if it sold one of its shares. Evidently, it should desinvest if q was below 1.

At first, the neoclassical investment theory and the q-theory seem to be at odds with one another, as many authors would argue. However, in the late 1970's and early 1980's, different authors - Abel (1979), Yoshikawa (1980) and Hayashi (1982) - found ways to reconcile both theories. Among these three contributions, Hayashi (1982) has the biggest impact, as it generalizes the previous results and provides a direct connection between the neoclassical model with convex adjustment costs and a q-model. However, Hayashi's q is different from the one proposed by Tobin: q, in this framework, is "the ratio of the market value of an *additional* unit of capital to its replacement cost"[3]. Not only this changes somehow the economic interpretation of the model but this also imposes an econometric difficulty to economists as the "marginal q" is not observable under general conditions and

[1] One should also note, as Hayashi (1982) highlights, that output is taken as given in Jorgenson's seminal article, an hypothesis that is inconsistent with perfect competition.

[2] This q should be interpreted as an "average q".

[3] This q should be interpreted as a "marginal q".

using average q as a proxy usually leads to measurement error[4].

These models, however, have a poor empirical performance, as Chirinko (1993) and Caballero (1999) emphasize in different manners[5]. The former presents a survey regarding the pre-1990 investment literature, both theoretical and empirical, and notes that investment tends to respond more to quantity variables, i.e. cash flow and sale's growth, rather than price variables, i.e. the cost of capital, what was not predicted by the theories presented above. Going further, the latter analyzes the shift from aggregate to microeconomic data and the attempt to exploit natural experiments in order to measure more accurately changes in the cost of capital and q. Even though he notes that some improvements were achieved, there still was a large unexplained component of the variation in aggregate and disaggregate investment when such models were confronted with higher-frequency data.

This dissatisfying performance of the earlier models led to a renewed and simultaneous effort in the beginning of the 1990's, both theoretically and empirically. The scarcity of comprehensive datasets meant, in practice, that the first advancements were made in the theoretical literature, even though the empirical literature soon caught up with the former. For the ease of exposition and also of motivating the theoretical developments, I will first delve into the seminal work of Doms and Dunne (1994, 1998), who were the first to catalog the stylized facts regarding investment at the establishment level[6] . The authors who analyzed data from the Longitudinal Research Database (LRD)[7], covering the period between 1972 and 1988. They document several important regularities in the data, but they highlight two of them:

1. Most of the establishments adjust their capital stocks in a "lumpy" fashion. In their sample, more than 50% of the plants experienced an adjustment of at least 37% in a single year. Another important feature is the fact that, at any given year, around 80% of the plants change their net capital stock by less than 10%.

[4]Hayashi provides sufficient conditions for both q's to be equal but, as Caballero (1999) highlights, many authors refrain from observing such conditions, incurring, as such, in the risk of making a serious econometric mistake.

[5]Another important empirical evaluation of these theories is provided by Abel and Blanchard (1986).

[6]One can not ignore the also seminal work of Rust (1987) and Cooper and Haltinwanger (1993), who also studied machine replacement at the micro level. However, these authors focused on specific sectors.

[7]The LRD is a panel dataset produced by the U.S. Census Bureau that "includes information on R&D spending and company characteristics, and data collected under both mandatory and voluntary survey response conditions". The sample is small (about 13000 establishments) when compared to the to population of manufacturing firms (around 350000 establishments), but it accounts for most of the manufacturing employment, investment and output of the population. Another important feature of this dataset is that it allows researchers to construct a balanced panel dataset, ensuring that the perpetual inventory method can be used to construct the capital stocks for each establishment.

2. These investment spikes at the disaggregate level have aggregate consequences as they represent a large fraction of the aggregate investment. To be more precise, in their sample, 25% of expenditures on new equipment and structures was made by plants that were increasing their real capital stock by more than 30%, even though they represented only 8% of the sample. This pattern was also observed when the whole manufacturing population was taken into account[8].

As I have highlighted above, the theoretical developments in the early 1990's preceded the empirical ones. This was largely due to a dissatisfaction with "potentially unrealistic assumptions of convex adjustment costs and reversibility", hypotheses that were first questioned by Rothschild (1971) that argued that convex adjustment costs implied no distinction between fixed and variable factors of production and that firms would always alter their capital stock if market conditions changed. Abel and Eberly (1994, 1996) and Dixit (1997) provide conditions for the capital adjustment cost function in order to induce discontinuities or non-linearities in the investment decision function of the firm. Broadly, one can create such traits by including fixed costs to investment, a wedge between the purchase and sale prices of capital and the possibility of irreversible investment, which precludes firms from downsizing their capital stock and can be seen as a rather extreme hypothesis[9]. These hypotheses induce firms to make less frequent adjustments and, when they choose to do so, to make them in a concentrated fashion[10]. Most importantly, the empirical evidence, as Cooper and Haltiwanger (1999, 2006) show, is largely in favor of a model that mixes both convex and non-convex adjustment costs in order to explain the establishment-level data patterns.[11]

The apparent success of the non-convex adjustment function at the micro level and the empirical observation that investment spikes at the disaggregate level seem to matter to explain aggregate movements led to different attempts to model how this channel would work and to different empirical tests of the theory. Caballero and Engel (1993, 1999), Bertola and Caballero (1994) and Caballero, Engel and Haltiwanger (1995) provide

[8] This fact was reported in the years of 1977 and 1987 when the LRD coincided with the manufacturing census.

[9] Caballero (1999) argues in favor of the irreversibility hypothesis by stating that it is possible to induce irreversibility if there is a large but not necessarily infinite cost to disinvestment.

[10] While the smaller frequency is due to the fact that the cost of adjusting the stock of capital increases a lot around the point of no adjustment (irreversibility), the bunching of investment is due to the increasing returns in the adjustment function that arise after the introduction of fixed costs.

[11] Another theoretical source of micro-level investment lumpiness is to model uncertainty in a more precise manner, an approach pursued by Bloom, Blond and Van Reenen (2007) and Bloom (2009). Uncertainty shocks make firms less prone to smooth adjustments as it increases the real option value of waiting before investing or desinvesting.

different sources of microeconomic distortions that, in the presence of some kind of heterogeneity across establishments[12], have a direct influence to the aggregate dynamics and variation of investment. For an example, Bertola and Caballero (1994) build and solve a model of sequential irreversible investment at the microeconomic level that make such irreversibility constraints important to explain the aggregate dynamics due to the presence of idiosyncratic uncertainty. Despite the different sources of distortions in each model, the connection between microeconomic adjustment and aggregate dynamics is done through the same two channels:

1. How much each establishment responds to aggregate shocks by adjusting their capital stock (what is known as the *intensive margin*);

2. The number of establishments actually doing these adjustments in their capital stock (what is known as the *extensive margin*).

These models seem to perform "substantially better" than their predecessors, as they present a clear theoretical connection between micro-level distortions and aggregate behavior of investment that, upon econometric analysis, seems to be empirically relevant. Unfortunately, however, all of them demonstrate and estimate the impact on aggregate investment of microeconomic distortions at the plant-level without imposing general equilibrium. As firms investment decisions are related to the cost of capital which in turn is connected to the aggregate savings of the households, there may be equilibrium effects that, in the end, lead to a correction of the distortions, ie a smoothing of aggregate investment. In order to take this fact into account, many authors imposed microeconomic distortions at the firm-level in otherwise standard Real-Business-Cycle models. So far, this strand of the literature still has to provide definite conclusions, as there are articles presenting evidence both in favor and against the importance of modeling micro-level lumpiness to understand movements in aggregate investment. At this point, I will not go further into this (large) literature as this framework is not developed here. For the interested reader, I highlight, among numerous articles, Thomas (2002), Khan and Thomas (2003, 2008), Bachmann, Caballero and Engel (2013) and Winberry (2016) as the most important references.

2.2 Contributions

My contributions are threefold. First, this is, to my knowledge, the first attempt to compute firm-level capital stocks for Brazilian firms using the perpetual inventory method

[12]For an example, it could be idiosyncratic uncertainty about individual productivity.

while accounting for a possible heterogeneity in sectoral capital depreciation rates. Not only this approach has become the standard in the literature, but also it is methodologically more solid than assuming a single exogenous depreciation rate for all sectors, once it allows for the possibility that all sectors actually have the same depreciation rate and it is an actual estimation of different decay rates, which are fundamental in capital stock estimation, a point made by Nehru and Dhareshwar (1993), with clear hypotheses.

Previous work regarding capital stock estimation took different paths in comparison to the approach presented above. Among these works, there are two that should be highlighted: Alves and Silva (2008) and Alvarez et. al. (2018). While Alves and Silva (2008) provide estimates for firm-level capital stocks for Brazilian firms using the same original dataset, they follow a different method. Instead of directly applying the perpetual inventory method, which requires the exclusion of firms that do not appear at some point in the period of study, they apply an imputation method called propensity score matching to substitute missing values in the dataset. After this procedure, they compute the aggregate investment in the Brazilian industry, without giving many details on the micro-level behavior of capital stock and investment, which is the focus of this article. On the other hand, Alvarez et. al. (2018) compute capital stock series at the firm-level also using the PIA dataset for the period between 1996 and 2012, assuming a single depreciation rate. However, as in the end they decided not to use the capital stock to compute their productivity measure, they do not present any details on their computational methods and treat it as a mere intermediate step.

Second, I contribute to the long-standing literature that documents lumpy behavior of investment decisions at the firm-level (or at the establishment-level), with infrequent and large adjustments of capital stock, as it was documented by Doms and Dunne (1998) for American establishments and by Carlsson and Laséen (2005) for Swedish firms.

Third, this article gives a first step to a different attempt in understanding how firm dynamics differ in developing countries when compared to developed countries, providing a possible new direction on the literature that followed Hsieh and Klenow (2009) and Restuccia and Rogerson (2008), such as Akcigit, Alp and Peters (2016) which focus on managerial aspects and lack of selection rather than capital stock and investment decisions.

3 Data

This paper analyzes data from the *Pesquisa Industrial Anual*[13] (PIA), a confidential dataset maintained at IBGE[14]. This survey has the goal of identifying the structural characteristics of the Brazilian industrial sector, its changes through time and providing annual information about the volume and value of sales in each sector. Even though the first PIA survey was published in 1967 and the last meaningful methodological change happened in 1996, we will restrict the analysis to the period between 2000 and 2015 for two reasons: the first one is to analyze the same time span as Doms and Dunne (1998) and the second one is to avoid possible consequences of macroeconomic crisis that Brazil went through in the end of the 90's.

3.1 Collection

To construct the dataset, IBGE uses two different questionnaires: a "complete" model and a "simplified" model. Both questionnaires gather information from six major areas (labor, revenue, costs and expenditures, acquisitions and write-offs of assets and sectoral information), but the first one allows for a more detailed description of firms. The complete model is filled by all firms with more than 30 employees and/or all firms with revenue of more than a threshold value[15] in the year before the reference year of the survey[16], while the simplified version is filled by a random sample of firms with less than 30 employees. As such, when taking into consideration the population of firms in Brazil, the PIA sample tends to overrepresent larger firms.

3.2 Sample Selection

The ultimate goal of this paper is to analyze how firms make their investment decisions and what are the consequences of such decisions to their capital stock accumulation. To do so, we apply the perpetual inventory method, which requires that we have a balanced panel of firms for the period between 2000 and 2015. As such, our final dataset contains 7530 firms[17], which is a rather small number when compared to a total of 144666 firms that appear in at least one of the years during this period. Even though the coverage in terms of number of firms is small, the establishments present in the final dataset account for a

[13] Annual Manufacturing Survey – Direct translation from Portuguese.

[14] Instituto Brasileiro de Geografia e Estatística – Brazilian Bureau of Geography and Statistics, in a direct translation from Portuguese.

[15] This value changes from year to year. In 2015, it was R$ 12.8 millions.

[16] The completion of the questionnaire is mandatory for these firms.

[17] This means 120480 observations.

Table 1: Sample Coverage by Year

Year	Investment Coverage (%)	Labor Coverage (%)	Production Coverage (%)	Average Employment
2000	60.5%	46.1%	60.1%	248.3
2001	63.7%	46.2%	58.9%	255.1
2002	65.8%	46.4%	60.2%	267.2
2003	61.8%	46.6%	61.8%	279.8
2004	65.5%	47.0%	62.4%	310.9
2005	69.9%	46.4%	63.4%	320.4
2006	71.8%	46.1%	63.5%	335.0
2007	64.4%	47.2%	64.3%	363.1
2008	70.2%	47.4%	65.0%	378.2
2009	74.9%	47.8%	65.0%	383.9
2010	71.5%	48.0%	65.8%	413.4
2011	69.3%	47.7%	66.3%	428.1
2012	67.0%	47.4%	65.0%	435.8
2013	68.1%	47.9%	65.1%	445.1
2014	61.9%	48.1%	64.1%	438.8
2015	64.8%	48.9%	64.1%	411.0

large share of investment, labor and production and are quite large, as one can observe from Table 1.

The natural benchmark for this study is the work of Doms and Dunne (1998). For the same time span, the balanced panel of Brazilian firms provides a better coverage in the three dimensions mentioned above[18], even though these firms tend to be smaller than American manufacturing establishments studied by these authors.

3.3 Variable Definitions

As stated above, the original PIA dataset portrays a very broad picture of each firm, but here we focus on employment, investment, output and sector. The employment measure is given by the average of employees in the reference year of the survey. Investment is defined as the sum of the net acquisition of assets and the changes in stocks. Output is given by the industrial transformation value, which is the gross value of industrial production net

[18] Doms and Dunne (1998): Less than 60% Investment Coverage, Around 40% Labor Coverage and around 50% Production Coverage, all of these in averages of the 16 years.

of production costs. All nominal values are deflated to 2015 values using IPCA[19] data also released by IBGE.

Finally, to identify each firm's sector, I use the industry identification provided by the 3-digit CNAE[20] Number that is assigned yearly to each firm present in the dataset. To correct for possible measuring mistakes in the survey and also due to the manner in which the sectoral depreciation is performed, I assume that the prevalent sector between 2007 and 2015, i.e. the mode of the CNAE Number for each firm between 2007 and 2015, is the CNAE Number for all the analyzed time span.

[19]Índice Nacional de Preços ao Consumidor Amplo – Broad National Consumer Price Index, in a direct translation from Portuguese.

[20]CNAE is an acronym for Classificação Nacional de Atividades Econômicas - National Economic Activity Classification, in a direct translation from Portuguese -, the Brazilian equivalent of NAICS used by the United States Census Bureau.

4 Building Firm-Level Capital Stock Series

In this section, I detail the steps needed to build a capital stock series for each firm present in the balanced panel. Following Doms and Dunne (1998), I use the perpetual inventory method to build the capital stock, $K_{i,t}$, in period t for each firm i in a given sector j:

$$K_{ijt} = K_{ij(t-1)} \left(1 - \delta_j\right) + I_{ijt}$$

where δ_j represents the depreciation rate of sector j and I_{ijt} is firm i's current period investment.

Consequently, before we can apply this method, it is necessary to solve two simultaneous problems. The first one is estimating the capital depreciation for each sector. The second one is finding a plausible guess for the initial capital stock of each firm as the PIA data does not include the book value of capital for all firms. As solving this problem simultaneously would be rather complicated, I proceed sequentially.

4.1 First Guess of Initial Capital Stocks

To guess the initial capital stock of each firm, I follow the work of King and Levine (1994). The following steps are repeated after the estimation of the depreciation rates, but, as this is the only difference, I will only present them once.

These authors compute initial capital by using a steady-state method:

$$K_{ij2000} = \underline{\kappa}_{ij} Y_{ij2000}$$

where Y_{ij2000} is firm i's output in the initial period and $\underline{\kappa}_{ij}$ is the steady-state capital-output ratio, which is given by $\underline{\kappa}_{ij} = \underline{i}_{ij} / \left[\delta_j + \underline{\gamma}_{ij}\right]$, where $\underline{i}_{ij}$ is firm i's steady-state investment rate and $\underline{\gamma}_{ij}$ is firm i's steady-state growth rate.

For the first guess, I assume a single depreciation rate of $\delta = 0.05$ across all sectors, i.e. $\delta_j = \delta = 0.05, \forall\, j$. I also assume that the steady-state investment rate is the same for all firms and it is given by $\underline{i} = \underline{i}_{ij} = 10.4\%, \forall\, i, j$, the average investment rate of American firms in the sample of Zwick and Mahon (2017).

On the other hand, to compute the steady-state growth rate of firm i, I use a weighted average growth rate. To be more precise, I define the steady-state growth rate of firm i as

$$\underline{\gamma}_{ij} = \lambda\gamma_{ij} + (1-\lambda)\,\gamma_w$$

where γ_i is firm i's growth rate over the period of 2000-2015, γ_w is the average growth rate in the panel of firms and λ is a parameter that measures how much weight each firm has on the steady-state. Following King and Levine (1994), I set $\lambda = 0.25$.

4.2 Estimating Depreciation Rates

After setting a first guess for the initial capital stock for each firm, I proceed with estimation of each sector's depreciation rate following the work of Doms (1996) with a few modifications. First of all, I assume a Cobb-Douglas production function[21]. Second, I constrain the estimates of δ_j to the interval [0.03, 0.15] for each sector j. At last, I only estimate the depreciation rate for sectors where at least 30 firms appear, setting the depreciation rate at 0.05 for sectors with a number of firms that is smaller than this threshold.

As such, for each sector j that has at least 30 firms, I estimate using Nonlinear Least Squares the following equation:

$$\ln Y_{ijt} = \beta_0 + \beta_L \ln L_{ijt} + \beta_K \ln\left(\underbrace{(1-\delta_j)^{t-2000} K_{ij2000} + \sum_{\tau=2000}^{t} (1-\delta_j)^{j-2000} I_{ij\tau}}_{K_{ijt}}\right) + \gamma_t D_t + \varepsilon_{jt}$$

where Y_{ijt} is output, L_{ijt} is labor, I_{ijt} is investment and ε_{jt} is an i.i.d error term, with the subscript i referring to firm i in sector j. The term $\gamma_t D_t$ is meant to capture technical change that might have happened in each year. In total, the final sample has 107 sectors identified through 3-digit industry codes (3-digit CNAE number). As a matter of illustration, I present the results of the regression for sector 25 in the next page.

[21] Doms (1996) estimates a translog production function. Due to time constraints and computational difficulties, I decided to estimate a simpler production function.

Table 2: Efficiency Schedule: Estimating a Cobb-Douglas Production Function with Geometric Efficiency for Sector 25

Dependent Variable = ln(output)			
β_0	8.188***	γ_{2006}	0.265***
	(0.0796)		(0.0720)
β_L	1.140***	γ_{2007}	0.338***
	(0.0136)		(0.0720)
β_K	0.0702***	γ_{2008}	0.333***
	(0.00334)		(0.0720)
δ_{25}	0.0511***	γ_{2009}	0.511***
	(0.00176)		(0.0720)
γ_{2001}	0.149**	γ_{2010}	0.499***
	(0.0719)		(0.0720)
γ_{2002}	0.00308	γ_{2011}	0.515***
	(0.0719)		(0.0720)
γ_{2003}	0.113	γ_{2012}	0.535***
	(0.0719)		(0.0721)
γ_{2004}	0.0978	γ_{2013}	0.570***
	(0.0720)		(0.0720)
γ_{2005}	0.124*	γ_{2014}	0.544***
	(0.0720)		(0.0720)
		γ_{2015}	0.491***
			(0.0720)
R^2	0.591		
Observations	7,504		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 Final Step: Capital Stock Series for each firm

At last, in possession of each sector's depreciation rate and recalculating the initial capital stock for each firm, I build each firm's capital stock using the perpetual inventory method. Computationally, I proceed in an iterate manner.

1. Using the new guess of initial capital stock for each firm and each firm's investment in the year 2000, I compute its capital stock in 2001.

2. In possession of this value and the investment in 2002, I compute the capital stock in 2002.

3. This procedure is repeated until I compute the capital stock in 2015.

5 Firm-Level Capital Accumulation Patterns

After computing each firm's capital stock series, we can proceed to analyzing their behavior across time. As we are not only interested in gathering stylized facts regarding investment decisions in Brazil, but also in comparing these facts with those of the American economy, I compute statistical measures following definitions from Doms and Dunne (1998) and Zwick and Mahon (2017)[22].

Doms and Dunne (1998) use plant-level data from the Longitudinal Research Database (LRD), which was maintained by the U.S. Census Bureau, containing plant-level production data from the Annual Survey of Manufactures (ASM) for the period between 1973 and 1988. On the other hand, Zwick and Mahon (2017) drew their firm-level data from annual IRS corporate tax returns, which covers all sectors of the economy and not only manufacturing firms, for the period between 1998 and 2010.

5.1 Growth Rate of Capital

Following Doms and Dunne (1998), the growth rate of capital for firm i of sector j at time t is given by

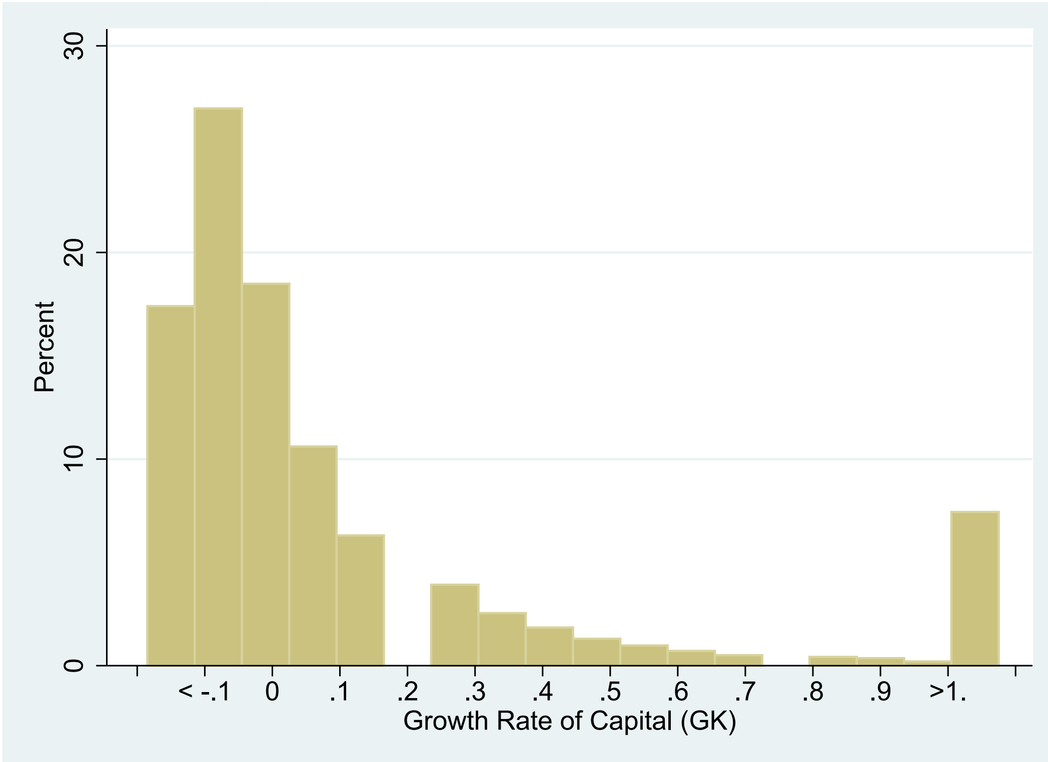
$$GK_{ijt} = \frac{I_{ijt} - \delta_j K_{ij(t-1)}}{0.5 \cdot \left(K_{ij(t-1)} + K_{ijt}\right)}$$

One should note that this measure is bounded below by -2, in the case where a firm decides to desinvest all of its remaining capital stock. As my first measure of capital is given by the guess for the year 2000, I compute GK_{ijt} for each plant for every year from 2001 to 2015.

Figure 1 presents the distribution of GK_{ijt}. It shows that the majority of firms, around 70%, increases its capital stock by less than 10%, while more than 20% of firms increase their capital stock by more than 20%. These numbers resemble those of the American distribution, but the percentages of firms at the left tail and at the right tail of distribution are strikingly higher in Brazil. On the left hand side of the distribution, more than 30% of firms exhibit negative capital growth rates against slightly more than 10% in the U.S. On the right hand side of the distribution, close to 10% of firms exhibit growth rates above 100% in Brazil while this number is smaller than 5% in the U.S. This suggests that aggregate investment movements in Brazil might depend even more on smaller number of firms than in the U.S.

[22] These are the measures presented by Winberry (2016).

Figure 1: Capital Growth Rate Distribution



To give a sense of this concentration on a smaller number of firms, I constructed table 3, which presents a snapshot of the shares of investment, employment, output and capital stock that are held by the biggest firms in each category in 2007 and 2015. Even though it is not directly comparable as Doms and Dunne (1998) present the concentration across plants, table 3 indicates that not only capital and investment are concentrated on a small number of firms, but also that economic activity is concentrated on a small number of firms. Anyway, as in the U.S., the bottom-line is that a small number of firms account for a substantial fraction of aggregate investment.

Also following Doms and Dunne (1998), I created a rank to examine within-firm capital accumulation patterns. For each firm in the final balanced dataset, I rank, in descending order, the annual capital growth rates from highest to lowest considering each year between 2001 and 2015. Also as in the aforementioned article, the rank 1 growth rate is denoted by MaxGK. In Figure 2, I present the means and medians of these ranked growth rates. While 9 of the 15 ranks possess means or medians between -10% and +10%, MaxGK is significantly higher for Brazilian Firms, with means exceeding 50% and medians exceeding 40% against 46% and 36% in the U.S. It is also striking that, on average, firms tend to

Table 3: Share of Investment, Employment, Output and Capital Accounted for by the Top Firms in Each Category (7530 Firms)

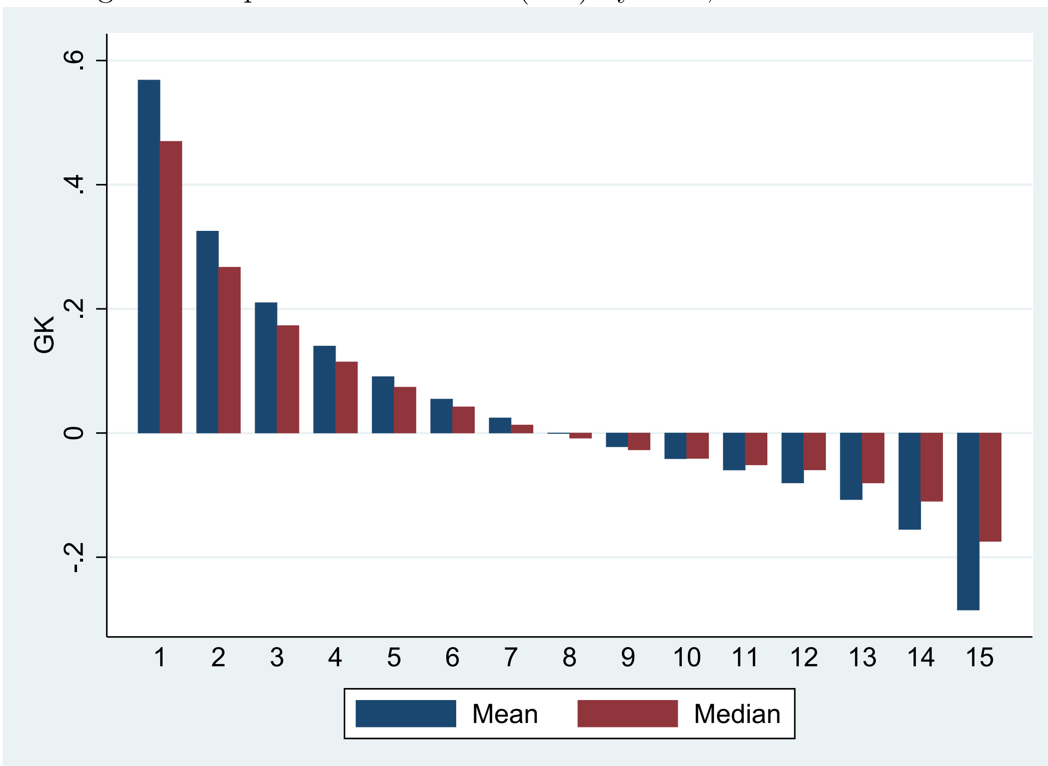
	2007			
	Investment	Employment	Output	Capital Stock
Top 10 Firms	53.5%	8.3%	35.6%	43.8%
Top 50 Firms	68.9%	20.5%	50.5%	59.2%
Top 100 Firms	76.1%	28.1%	58.5%	66.4%
Top 200 Firms	83.5%	37.4%	67.0%	73.9%
Top 500 Firms	92.1%	53.2%	77.9%	83.4%
Top 1000 Firms	97.6%	65.9%	85.8%	90.0%
Top 1500 Firms	100.0%	73.6%	90.1%	93.3%
	2015			
	Investment	Employment	Output	Capital Stock
Top 10 Firms	59.4%	10.5%	34.5%	55.1%
Top 50 Firms	73.9%	23.3%	50.7%	66.6%
Top 100 Firms	81.1%	31.3%	59.1%	72.7%
Top 200 Firms	88.3%	41.0%	67.2%	79.0%
Top 500 Firms	96.8%	56.9%	78.4%	87.0%
Top 1000 Firms	101.8%	69.5%	86.6%	92.2%
Top 1500 Firms	103.9%	76.8%	90.8%	94.8%

experience way larger disinvestment periods when compared to the American establishments, where the mean and the median never go lower than -10%.

As such, Figures 1 and 2 try demonstrate the lumpy behavior of investment and that the distribution of investment in the Brazilian economy is at least as skewed as in the American economy. with a small number of firms being responsible for a large of aggregate investment.

As in the U.S., the analysis demonstrates meaningful variation across Brazilian firms in terms of capital growth rates. While the analysis also indicates that some firms experience sizable changes in their capital stock, such variation does not allow us to discard that some firms might experience smoother changes in their capital stocks. A possible explanation of the differences in such changes is that for some industries investment is inherently lumpy due of the nature of the capital goods which could arise due to the indivisibility of large machines, while for other industries it may be easier to adjust capital more smoothly. To examine this possibility, I model MAXGK for a firm as a function of size, number of local units, controlling for industry and other effects, in a very similar way as in the Doms and Dunne article.

Figure 2: Capital Growth Rates (GK) by rank, means and medians



I estimate a regression model using all firms in the balanced panel. My firm-level measure of capital lumpiness is the maximum single year capital growth rate MAXGK. The regression also includes controls for firm size, which is modeled using a set of dummy variables representing plant-size quartiles. The quartiles go from smallest to largest, with the quartile representing the largest firms omitted. Finally, the regression is run with three-digit industry dummy variables, controlling for sectoral idiosyncrasies in the . I also include a dummy variable indicating whether the firm made the choice to be part of the special tax regime designed for micro and small firms. Unfortunately, PIA does not provide any information regarding firm age, so I do not include any proxies on this dimension. The results are exhibited in Table 4.

As in the U.S., smaller firms tend to have larger spikes, even after controlling for industry and other firm characteristics. Accordingly, as larger firms tend to have a larger number of local units, this fact is reinforced by the slightly negative coefficient relative to the number of local units. On another hand, in Brazil, these firm characteristics seem explain a lot more of the size of MaxGK when compared with the study of Doms and Dunne ($R^2 = 0.679$ vs. $R^2 = 0.211$).

Table 4: Capital Growth Rate Regression: MaxGK is the DependentVariable

Variables	
Firm Size Quartile (Smallest to Largest)	
1st Quartile	0.111***
	(0.0146)
2nd Quartile	0.0723***
	(0.0136)
3rd Quartile	0.0522***
	(0.0131)
Mean of Dependent Variable	0.714
	(0.508)
Number of Local Units	-0.00204***
	(0.000752)
Simples Dummy	-0.000675
	(0.0177)
Observations	7,530
R^2	0.679
4th Quartile	No
106 3-Digit Industry Controls	Yes
15 Year Dummies in which MAXGK occurs	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2 Investment Rate Statistics

In this subsection, I characterize the investment rate, defined as the ratio between investment and capital stock, distribution in Brazil, presenting also a comparison the findings for the American firms found in Zwick and Mahon (2017) and Winberry (2016). To do so, I compute a few statistical measures that try to capture not only the usual moments of interest - average and standard deviation - for any distribution, but also a few moments related to lumpiness of investment.

There are three statistical measures of investment lumpiness: inaction rate, spike rate, positive investment rate. The inaction rate is defined as the fraction of observations with investment rate less than 1%. The spike rate is the fraction of observations with investment rate greater than 20%. Finally, positive investment rate is the fraction of observations with investment rate between 1% and 20%.

Table 5 exhibits these measures, pooled over firms and time, both for Brazil and United States. They indicate that there are important differences in investment dynamics in Brasil vis-à-vis the U.S. First, investment rates are lower and the dispersion is significantly higher in Brazil than in the U.S, a result that might have different interpretations. On one hand, it could be the case, as argued by Hsieh and Klenow (2009) in a completely different setting, that inefficient firms tend to survive more in Brazil relate to the United States and, as inefficient firms are unlikely to grow much over time, they would, on average, invest less, accumulating less capital and also diminishing the average investment rate. On the other hand, it is also possible that other constraints, of either financial or physical adjustment nature, are tighter in Brazil, what could also be related to the other important difference of the investment rate distribution in Brazil and in the U.S.

The second important difference between the Brazilian and the American investment rate distributions Two other important differences are that Brazilian firms experience, on average, more episodes of investment spikes and they also tend to, on average, have more periods without any investment. This finding is in line with the higher standard deviation of investment rates and with the findings of subsection 5.1, where I showed that the growth rate of capital distribution has fatter tails and exhibits higher dispersion than in the U.S.

Table 5: Micro Lumpy Investment Statistics

	Brazil (2000-2015)	United States (1998-2010)
Statistic	Value	Value
Inaction Rate (%)	32.2%	23.7%
Spike Rate (%)	22.8%	14.4%
Positive Investment Rate (%)	45.0%	61.9%
Average Investment Rate (%)	5.3%	10.4%
S.D. of Investment Rates	6.35	0.16

Statistics drawn from distribution of investment rates pooled over firms and time. Inaction rate is fraction of observations with investment rate less than 1%. Spike rate is fraction of observations with investment rate greater than 20%. Positive investment is fraction of observations with investment rate between 1% and 20%

When taking into consideration these measures on a year to year basis, the most striking fact is the variation in the distribution of investment rates across years, as one can see in table 6.

Table 6A: Yearly Micro Lumpy Investment Statistics

	Value				
Statistic	2000	2001	2002	2003	2004
Inaction Rate (%)	25.9%	26.9%	29.0%	30.0%	29.4%
Spike Rate (%)	29.9%	28.2%	24.5%	23.4%	26.1%
Positive Investment Rate (%)	44.2%	44.9%	46.5%	46.6%	44.5%
Average Investment Rate (%)	12.8%	-19.6%	9.7%	8.4%	6.5%
S.D. of Investment Rates	0.7	24.4	0.5	0.8	2.7

Table 6B: Yearly Micro Lumpy Investment Statistics

	Value				
Statistic	2005	2006	2007	2008	2009
Inaction Rate (%)	31.5%	32.0%	29.0%	30.2%	37.6%
Spike Rate (%)	23.9%	22.2%	25.0%	26.4%	18.9%
Positive Investment Rate (%)	44.6%	45.8%	46.0%	43.4%	43.5%
Average Investment Rate (%)	9.4%	8.5%	7.8%	10.7%	6.7%
S.D. of Investment Rates	0.5	0.6	1.9	0.4	0.3

Table 6C: Yearly Micro Lumpy Investment Statistics

	Value					
Statistic	2010	2011	2012	2013	2014	2015
Inaction Rate (%)	31.0%	31.4%	33.5%	34.6%	39.2%	43.4%
Spike Rate (%)	24.8%	23.5%	20.0%	19.1%	16.1%	12.8%
Positive Investment Rate (%)	44.3%	45.0%	46.5%	46.2%	44.8%	43.8%
Average Investment Rate (%)	8.7%	8.5%	0.8%	6.9%	1.4%	-2.3%
S.D. of Investment Rates	1.0	0.6	4.7	0.5	2.5	2.4

6 Final Remarks

In this article, I take advantage of a comprehensive Brazilian administrative firm-level dataset to fill a void in the investment related literature with regard to the understanding of firm-level investment decisions in developing countries. Even though the broad picture is similar to the one regarding the U.S economy, i.e. evidence of micro-level lumpiness of investment, I document that there are some important differences in this panel of Brazilian firms.

I show that the tails of the distribution of the growth rate of capital are "fatter" in Brazil, when compared to the U.S, with firms experiencing, on average, periods of both more intensive investment and disinvestment of capital. Second, I also show that these large sudden adjustments in capital stock and in investment seem to matter even more to understand aggregate movements in the economy, as economic activity, the volume of investment and capital stock are more concentrated in Brazil. Third, I show that the observable characteristics of Brazilian firms explain a lot more of sudden movements in capital growth when compared to the U.S., after controlling for industry specific characteristics and other variables. Forth and last, I compute statistical measures related to the investment rate distribution, which show that investment at the firm-level seems to be "lumpier" in Brazil, with firms investing less on average, while experiencing more episodes of investment spikes and periods of inaction.

In terms of future areas of research, there are a few different paths that could be followed. Methodologically, it could be important to generalize the production function estimation, allowing for a more general functional form. In terms of our understanding of developing economies, there are two main paths that could be followed:

1. Using other variables available in the PIA dataset, we can build proxies for cash flow, financial expenditures, profit measures and other financial related variables allowing us to relate investment decisions and financial conditions of firms, providing a stronger link with the misallocation literature and/or with the literature that relates financial constraints and growth such as Rajan and Zingales (1998).

2. Another important area of research would be to solve and and structurally estimate a dynamic general equilibrium model taking into account the patterns observed in the microeconomic data presented above, what could be particularly useful to understand the Brazilian business cycle in the spirit of Winberry (2016). Such framework would also allow us to perform counterfactual exercises to understand

the macroeconomic effects of different economic policies that try to change micro-level behavior of economic agents, such as the investment incentive policies pursued by the Brazilian government mostly between 2008 and 2014.

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