The Dynamics of Development: Innovation and Reallocation

Francisco J. Buera* Roberto N. Fattal-Jaef†

November 15, 2015

Abstract

This paper investigates aggregate and firm-level properties of the dynamics of economic development. We investigate macro and micro features of successful growth take-offs in the data and find that, while every episode exhibits sustained growth in TFP and investment rates, there are substantial differences in the evolution of the firm size distribution between the experiences of post-communist economies and the rest of the successful accelerations. The pattern is that firms tend to get larger on average during a typical acceleration, while the average size of a firm is declining along a post-communist transition. To understand this behavior, we provide a quantitative theory of transitions featuring endogenous innovation, entry and exit, and the dismantling of idiosyncratic distortions. We construct reforms in which the rate of progress in the reversal of distortions is calibrated to the experiences of China and Chile. We find that the mechanisms in the model are able capture the salient features that we documented in the data.

1 Introduction

While elusive for many poor economies, economic development as defined by a persistent acceleration in the growth rate of per-capita income have been attained by a significant number of countries in the post-war period (Haussmann, Pritchett & Rodrik, 2005). Prominent examples are Asian economic miracles and the successful post-communist

*Federal Reserve Bank of Chicago; fjbuera@gmail.com.
†World Bank; rfattaljaef@gmail.com.
transitions. At the aggregate level, sustained development episodes are characterized by a gradual and sustained increase in their Total Factor Productivity (TFP) (Buera and Shin, 2013, 2015). At the disaggregate level, these episodes feature rich firm dynamics, which we document in this paper. Our purpose is to provide a quantitative theory connecting these phenomena.

Our baseline economy builds on Lucas (1978), which we extend to incorporate a theory of innovation along the lines of Atkeson and Burstein (2010). There is a large household populated by a continuum of individuals, who are heterogeneous with respect to the ability to operate a firm. Entrepreneurial ability evolves endogenously as a result of entrepreneurs’ investments in innovation, and exogenously as a result of productivity shocks. For workers, the arrival of entrepreneurial ideas is completely random. Agents commit to a risk-sharing agreement that insulates them from idiosyncratic fluctuations in income. The head of household, then, makes an occupational choice on behalf of its members, determining whether they work for a wage or operate a business, and makes decisions about aggregate consumption and physical capital accumulation.

We incorporate two distortions that account for the initial differences in TFP across countries and whose (partial) elimination triggers the onset of a growth accelerations. First, in the spirit of Hsieh and Klenow (2009) and Restuccia and Rogerson (2008), we consider idiosyncratic revenue taxes and subsidies affecting the allocation of resources across entrepreneurs and, more importantly, their incentive to innovate. We refer to these as allocative distortions. We use available measures of these distortions, and their dynamics in the aftermath of specific growth acceleration episodes, to discipline their magnitude. Second, as a simple device to model the incentive structure in a communist regime, we assume that entrepreneurial profits, gross of entrepreneurial innovation expenses, are subject to very progressive profit tax. As we document in this paper, the differential nature of distortions faced by these economies are important determinants of the evolution of the average size of firms. Post-communist transition are characterized by a decline in the average size of firm, while the average size of firms tend to increase for Asian miracles and other growth acceleration with available data.

To illustrate the quantitative working of the model, we consider two specific examples of growth accelerations: Chile in the 80s and China in the 90s. We assume that firms in Chile are only subject to allocative distortions. In particular, we use the level and dynamics of allocative distortions measured by Chen and Irarrazabal (2014). For China, we assume that the economy is subject to both allocative distortions and progressive profit taxes. We use the level and dynamics of allocative distortions mea-
sured by Hsieh and Klenow (2007). The curvature of the profit tax schedule is chosen to capture egalitarian nature of a communist regime and its scale to match the initial large average size of firms in the Chinese manufacturing sector.

We first illustrate the impact of allocative distortions and progressive profit taxes on the initial level of (under)development. Both distortions depress the incentive to innovate, generating losses in TFP of 25% for Chile and 50% for China. They also imply life-cycle profile for employment and productivity of firms that are flat, consistent with the evidence in Hsieh and Klenow (2014). We decompose the effect of distortion on TFP into two channels: (i) their effect holding fixed the distribution of productivity of firms, which we labeled static; (ii) their effect through the change in the distribution of productivity of firms, which we labeled dynamic. Interestingly, we find that the dynamic channel explains the majority of the negative impact of allocative distortions on TFP.

We then turn to the main goal of the paper, investigating the macro and firm-level features of development dynamics. As idiosyncratic distortions and the progresivity of profit taxes are eliminated, innovation investment rises, both on impact and further along the transition. This results in a sustained, but significantly protracted, rise in TFP. Over the sample period, the model account for over 30% of the TFP growth for Chile, and over 50% of TFP growth for China. An important implication of the quantitative theory is that the impact of reforms is very protracted. The half life of the transition is 25 and 11 years for Chile and China, respectively. Finally, consistent with the data, along the transition the average size of firms increases for Chile, while it decreases substantially for the case of China.

We conclude the analysis of the development dynamics by exploring the implications of the theory for evolution of the cross-sectional employment-age relationship. Along the transition, the cross-sectional employment-age relationship is the product of age and cohort effects, and, therefore, it is natural to ask about the relative importance of these forces. We find that the cross-sectional employment-age relationship converges slowly to its new stationary equilibrium. This result raises a word of caution when using a stationary model to make inferences about the nature of underlying distortions, specially when studying economies undergoing a growth acceleration episode.
2 Related Literature

Our study provides a unified framework for thinking about the long run implications of various types of allocative distortions, and for investigating the micro and macro behavior of the economy along development paths. It is therefore related to the large body of studies that has made contributions to each of these areas in isolation.

Our work is related to the burgeoning empirical and quantitative literature on misallocation and productivity, of which Hsieh and Klenow (2009), Bartlesman, Haltiwanger, and Scarpetta (2008), and Restuccia and Rogerson (2008) are salient examples. We connect to this literature from two dimensions. First, we appeal to it as motivation for assigning a prominent role to resource misallocation in the construction of an initial allocations with low productivity and income per capita in the model. We take direct summary statistics about the degree of resource misallocation in developing countries from the empirical branch of the literature, and use them to discipline the extent of misallocation in the model at the onset of our transition experiments. Secondly, we contribute to the quantitative side of it, investigating the extent to which the dynamic responses from firms, such as innovation, entry, and exit, complement with static allocative responses in shaping long run loses in productivity and in explaining the speed of transition to equilibrium with lesser degrees of distortions.

The second feature of our work connects us with the literature on neoclassical transition dynamics. Christiano (1989) and King and Rebelo (1993) were the first to emphasize the shortcoming of the frictionless neoclassical model when it came to reproducing features of transition dynamics in miracle economies. In the data, transition dynamics of fast growing economies are characterized by sustained growth in income per-capita and total factor productivity, delayed but protracted investment surges, and hump-shaped interest rate dynamics. These features cannot be jointly reproduced by the many extensions to the canonical neoclassical growth model, unless with the introduction of a exogenous path of TFP that accompanies the convergence in capital stocks, as shown for the case of Japan by Chen, İmrohoroglu, and İmrohoroglu (2006). Our contribution is to develop a model that can account endogenously for the joint dynamics of investment rates an TFP, at the same time it delivers rich firm-level implications that can be validated against firm-level data.

Two papers in the literature stand out for the proximity with ours. Buera and Shin (2013) develops a theory of transitions featuring heterogeneous entrepreneurs, entry and exit to production, and credit market imperfections. Motivated by the experience
of seven Asian economies, the authors show that in presence of financial frictions that delay capital reallocation, transition paths triggered by the removal of idiosyncratic distortions are characterized by investment and interest rate dynamics that are close to the data. The model also yields an endogenous path for TFP, although on this front the model’s convergence is faster than in the data. Our relationship to this paper is twofold. On one hand, we take the paper’s historical accounts of growth accelerations in fast growing economies as providing empirical support to the idea that reforms that removes allocative distortions occurred at the beginning of these growth accelerations. Secondly, our model provides a complementary mechanism through which macroeconomic dynamics can depart from those of the standard neoclassical model. Rather than emphasizing frictions to factor reallocation, we show that the interaction between the economy’s incentives to accumulate tangible capital, through household’s investment decisions, and intangible capital, from firms’ innovation efforts, can generate transition paths for output, investment, and TFP similar to those in the data in a frictionless setup. Furthermore, because innovation outcomes are risky, the productivity distribution of firms manifests sluggishly the increased innovation efforts by firms, which allows the model to generate sustained and protracted increases in TFP, a weakness of the theories based on barriers to factor reallocation.

The consideration of tangible and intangible forms of capital relates our paper to the work of Atkeson and Kehoe (2005). The authors develop a theory of development in which life-cycle dynamics are driven by age-dependent stochastic accumulation of organizational capital and in which entering firms embody the best available technology. The trigger of development in their model stems from a sudden permanent improvement in the technologies embodied in new plants. Despite the resemblance of our model to theirs, there are several points of departure. First, as in the data, life-cycle dynamics of firms in the frictionless steady state of our model are different from those of the distorted equilibrium. In turn, this differences are generated endogenously, from a theory of innovation that connects firm growth to allocative frictions. Secondly, the predictions about entry along the transition path in our model differ from those in Atkeson and Kehoe (2005). Entry is inefficiently encouraged by subsidies in the pre-reform steady state of our economy, which implies that our development paths are characterized by reductions in entrepreneurship, and increases in the average firm size. Lastly, because of our focus on growth accelerations, we follow a different strategy for parameterizing the pre-reform stationary equilibrium, appealing to firm-level data in low income countries to discipline the choice of distortions that hinder output and
productivity.

3 Motivating Facts

We set the stage for the quantitative model presenting a number of facts regarding macroeconomic and microeconomic features of transitions around the world. We consider separately two types convergence episodes: sustained growth accelerations in the post-war period, identified appealing to the methodology of Hausmann et.al. (2005), and post-communist transitions. As we shall explain in greater detail below, we proceed in this way because of the fundamental differences in the adjustments occurring at the micro-level between these episodes, differences that we want to carefully account for in the theory that we develop later.

Our interpretation about the triggers of development dynamics is that they arise as a result of large scale reforms that produce significant changes in the business environments in which firms operate. This view may sound more acceptable for the case of post-communist transitions than for accelerations since, by definition, a liberalization as dramatic as the adoption of a market-based allocation mechanism constitutes an evident change in the incentives of business formation, resource allocation, and firm growth. There is, however, substantial evidence supporting the view that large-scale economic reforms also help explain the beginning of the take-offs in growth accelerations. Buera and Shin (2013), for instance, summarize policy changes involved in the reforms underlying the most prominent examples of accelerations during the 1960-2000 period, and find that the dates in which these policy changes were implemented coincide with most of the take-off dates identified using statistical methods. To reinforce our interpretation, we present direct data on measures of resource misallocation for

\[\text{In Hausmann et.al. (2005) a growth acceleration starts in year } t \text{ only if the following three conditions are met: (1) the average growth rate in the seven ensuing years (years } t \text{ through } t + 6 \text{) is above 3.5 percent; (2) the average growth rate in the seven ensuing years is at least two percentage points higher than in the preceding seven years (years } t - 7 \text{ to } t - 1 \text{); and (3) the output per capita in the ensuing seven years is above the previous peak. If more than one contiguous years satisfy all three conditions, the start of the growth acceleration is chosen to be the one for which a trend regression with a break in that year provides the best fit among all eligible years, in terms of the F-statistic. A sustained growth acceleration is one for which the average growth rate in the decade following a growth acceleration (years } t + 7 \text{ through } t + 16 \text{) is above 2 percent. We use the growth acceleration data from Buera and Shin (2013) who apply Hausmann et al. methodology to an updated sample (Penn World Tables 8.0).}\]

\[\text{The complete list of post-communist countries and the list of acceleration episodes picked up by the methodology is presented in the appendix.}\]
two salient examples of accelerations and post-communist transitions, Chile and China, and show that these measures indeed decline throughout the period in which growth is taking place. We present this data when we discuss the calibration of reforms in the model.

3.1 Aggregate and Firm-Level Features of Accelerations and Post-Communist Transitions

Consider first the behavior of aggregate variables. Figure 1 shows the average behavior of TFP and investment rates in our selection of growth-accelerations and post-communist transitions. The left panel plots the average dynamics of TFP. In the vertical axis, units are measured relative to the average value of TFP in the 5 years preceding the take-off\footnote{Since accelerations occur a different dates in each country, we construct a measure the average TFP dynamics as follows. For each country, we construct the time series of TFP during the acceleration years and we express them relative to the average value of TFP in the 5 years preceding the start of the acceleration; and then average across countries.}. For post-communist countries, we date all transitions to start in 1990, so the corresponding line illustrates the ratio between the average of TFP across countries relative to the average value between 1985 and 1990.
The left panel plots TFP dynamics for the simple average of post-communist transitions and acceleration episodes. The right panel illustrates the average of investment rates. The horizontal axes measure years with respect to the beginning of each episode, which we label period 0. For post-communist transitions we date such period to be 1990, while for growth accelerations, period 0 is given by the country’s specific date in which we identify, using the Hausmann et.al. (2005) methodology, the start of the growth take-off. TFP dynamics are measures relative to the TFP level in period 0, while the investment rates are expressed as absolute deviations from the period 0 levels. A complete list of countries in each group is presented in the appendix.

Despite the initial slump in the case of post-communist transitions, both TFP and investment rate increase over time. This pattern of behavior has been noted before in the literature as a challenge for the standard neoclassical growth model, the workhorse model to study transitions, since it is model that is silent about TFP dynamics and one that predicts a decreasing path of convergence in the investment rate towards an equilibrium with a higher capital stock. In this context, one of the goals of our paper is to attempt to reconcile theory and data, developing a quantitative model of transitions.
with endogenous TFP and investment rate dynamics⁴.

While exhibiting similar characteristics in the aggregate, acceleration episodes and post-communist transitions differ notably in the adjustments taking place at the micro level, in particular regarding the size distribution of firms. To see this, the figure below reproduces the dynamics of the average firm size of a manufacturing firm, in terms of employment, for the subset of countries for which we were able to gather time-series average size data. We consider three post-communist cases, Hungary, Romania, and China, and four acceleration episodes, Singapore, Japan, Chile, and Korea. The former group of countries is plotted in the left panel, and the latter group in the right one.

Figure 2: Average Size Dynamics during Acceleration Episodes and Post-Communist Transitions

Left panel illustrates average size dynamics for post-communist countries. Acceleration episodes are plotted on the right. Horizontal axes measure years after the period 0, which corresponds to the year of reforms in the case of accelerations, and the first available year with firm level data in the case of post-communist transitions. Given the more substantial differences in average size dynamics across growth accelerations, we also plot the behavior of the simple average of average size dynamics across these episodes. In all cases, the vertical axes measure the ratio of the average size relative to period 0

⁴Christiano (1989), King and Rebelo (1993), Chen et.al. (2006), and Buera and Shin (2013) are salient examples of papers that have noted the conflict between the neoclassical growth model and macroeconomic data on transitions, and developed extensions of the neoclassical model to bridge the gap between the two. See the literature review for a more thorough explanation of how our paper relates to this literature.
The figure shows a divergence in the behavior of average firm size across episodes. While the average size increases by a factor of two 20 years into an acceleration path, the typical firm shrinks by almost 70% in the post-communist case.

Several authors studied the behavior of the industrial sector in post-communist economies and emphasized the declining role played by large state-owned enterprises in favor of small privately owned businesses. Maddison (1998) is perhaps the most eloquent of these explorations, showing data about the re-organization of production in China and the economies of former Soviet Union countries. Our contribution is to extend this analysis to a more recent period, and revisit the previous findings through the lens of newer datasets.

Similarly, the fact that average firm size tends to increase with development has also been noted before in the literature. In fact, our data for average size dynamics during accelerations draws exactly from that in Buera and Shin (2013). What has not been equally emphasized before, and we do so here, is the notion that divergences from this average behavior can be determined by the nature of the underlying transformations taking place in the economy and that one such transformation that differs from the average is a post-communist liberalization.

In short, in this section we presented facts regarding macroeconomic and microeconomic aspects of transition dynamics in the data. We showed that both in post-communist liberalizations and in acceleration episodes, aggregate dynamics follow a similar behavior, with TFP and investment rates increasing over time. At the micro level, the experiences of these countries are antagonic. While accelerations are characterized by a protracted increase in the average size of a firm, the behavior is reversed in post-communist transitions. Combined, these facts play two essential roles in the design and validation of our quantitative theory. First, they tell us that our recreation of initial conditions before reforms needs to take into account the fundamental differences in the distortions that detract economic development in each case. And it also sets the bar for the kind of dynamics that we should expect our model to deliver. We present the theory with which we confront these challenges in the section below.

5 The following quote from Maddison (1998) exemplifies greatly the eloquence of his investigation: "There has been a huge expansion in industrial activity outside the state sector. In 1978 there were 265,000 collectives. By 1996 there were 1.6 million. The number of private enterprises rose from zero to 6.2 million. The bulk of these are small scale operations, most of them in rural areas, and run by individuals, townships and village level governments. A major reason for the success of these new firms is that their labour costs are much lower than in state enterprises, their capitalization is much more modest, and they are freer to respond to market demand. Many benefit from special tax privileges granted by local authorities."
4 Model

We propose an economy populated by a single household composed of a continuum of agents. These agents are heterogeneous with respect to their ability to operate a production technology and run a business. The head of the household makes an occupational choice on behalf of each agent, choosing either to assign her to entrepreneurship and earn a risky profit, or make her participate in the labor force, in exchange for a fixed wage. Each individual commits to participate in a risk-sharing agreement that insulates individual consumption from fluctuations in idiosyncratic income. In addition to occupational choices, the head of household chooses aggregate consumption and investment in order to maximize lifetime utility.

There are endogenous and exogenous forces for firm dynamics and resource reallocation. The endogenous component stems from entrepreneur’s investments in a risky innovation technology that controls the expected evolution of entrepreneurial ability over time. The exogenous element results from idiosyncratic productivity shocks around the expected path. It is the endogenous decision of entrepreneurs to innovate together with the decision to enter and exit entrepreneurship that connects the life cycle and the size distribution of firms with policies and distortions to factor allocation.

We first present the details of the frictionless economy, which we take as reference for the calibration of parameter values. Then we introduce distortions.

4.1 Consumption and Savings Problem

The assumption of perfect sharing of idiosyncratic risk allows us to separate the consumption/investment decision from the choices about occupations.

Taking wages and occupational choices as given, the household chooses consumption and investment in order to solve the following problem:

\[
\max_{\{c_t,k_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}
\]

subject to

\[
c_t + k_{t+1} = w_t L_t^s + \Pi_t + (1 + r_t) k_t.
\]

Aggregate labor supply and aggregate profits, \(L_t^s\) and \(\Pi_t\) respectively, are defined as follows:

\[
L_t^s = \int (1 - o_t(z)) \, dM_t(z)
\]
and

\[ \Pi_t = \int o_t(z) \pi_t(z) dM_t(z) \]

where \( o_t(z) \) is the outcome of the occupational choice of a household member with productivity \( z \), being equal to 0 if she is a worker, and 1 if she is an entrepreneur; and \( M_t(z) \) denotes the endogenous distribution of agents over productivity levels. All these objects will be characterized in detail below.

### 4.2 Occupational Choice

We assume that the head of household chooses occupations for its members every period. Furthermore, we assume that movements in and out of entrepreneurship are costless. Therefore, the decision to allocate an individual into working for a wage or becoming an entrepreneur amounts to comparing the values associated with each activity.

When selected into entrepreneurship, agents produce the final good combining their own idiosyncratic productivity, \( z \), together with capital and labor into a Cobb-Douglas production function with decreasing returns to scale:\(^6\)

\[ y_t(z) = z^{(1-\alpha-\theta)} k_t(z)^{\alpha} l_t(z)^{\theta} \]

We assume that there are perfectly flexible labor and capital rental markets every period, so that both capital and labor can be adjusted freely in response to changes in aggregate or idiosyncratic conditions. It follows that capital and labor choices are determined by the following static maximization problem:

\[ \pi_t(z) = \max_{l,t,k} \left\{ z^{(1-\alpha-\theta)} k^{\alpha} l^{\theta} - w_t l - (r_t + \delta) k \right\} \]

which yields the following expressions for optimal capital and labor demands:

\[ l_t(z) = \left( \frac{\alpha}{r_t + \delta} \right) \left( \frac{\theta}{w_t} \right) \frac{1-\alpha}{1-\alpha-\theta} z \]

\(^6\)The introduction of the productivity term raised to the \((1 - \alpha - \theta)\) power is a normalization that simplifies the description of the stochastic process for productivity. As we will show below, firms’ capital and labor demands become proportional to \( z \) when productivity is introduced in this way in the production function. This allows us to map the space of productivity levels \( z \) directly into the space of labor and capital demands.
The indirect profit function associated with optimal capital and labor demands is given by:

\[
\pi_t(z) = \left( \frac{\alpha}{r_t + \delta} \right)^{\frac{1}{1 - \alpha - \theta}} \left( \frac{\theta}{w_t} \right)^{\frac{\theta}{1 - \alpha - \theta}} z
\]

Besides production decisions, entrepreneurs make investments in innovation. We adopt a process of technology upgrading and downgrading similar to that in Atkeson and Burstein (2010). Specifically, we assume that the growth rate of idiosyncratic productivity is normally distributed, with an expected rate of growth that is determined from the firm’s investments in innovation, and an exogenous standard deviation.

Let \( \Delta \) denote the change in the logarithm of productivity that a firm can experience from one period to the other. Entrepreneurs count with a research technology that yields a probability \( p \) of a technological upgrade (and probability \( 1 - p \) of a downgrade) in return to investing \( \chi(p, z) \) units of labor. We assume a convex function for the cost of innovation of the following form:

\[
\chi_t(p, z) = z \times \mu e^{\phi p}
\]

Notice that the innovation cost is scaled by the current productivity of the entrepreneur. As we will explain below, this is an important assumption that allows the model to be consistent with innovation patterns of large firms in the U.S, which is our target economy for the calibration. We will also explain the relevance of the scale parameter \( \mu \) and the elasticity parameter \( \phi \) to replicate of properties of the size distribution and firm life-cycle dynamics in the U.S.\(^7\)

Taking capital and labor demands from the static profit maximization problem, entrepreneurs’ innovation decision solves the following optimization problem:

\[
v_t^E(z) = \max_p \left\{ \pi_t(z) - w_t \chi(p, z) \right\}
\]

\[
+ \left( \frac{1}{1 + r_{t+1}} \right) \left[ pv_{t+1} \left( z e^\Delta \right) + (1 - p) v_{t+1} \left( z e^{-\Delta} \right) \right]
\]

\(^7\)We can also describe the process for idiosyncratic productivity as following binomial approximation to a geometric Brownian motion, with an exogenous standard deviation \( \Delta \), and endogenous drift \((2p_t(z) - 1)\Delta\)
with \( v_t^E(z) \) standing for the value of an entrepreneur with productivity \( z \) in period \( t \), and \( v_t(z) \) denoting the value of an individual in period \( t \) with productivity \( z \), facing the decision to become an entrepreneur or working for a wage. We will come back to this value below, once we characterize the value of a worker.

Unlike entrepreneurs, we abstract from modeling workers’ efforts and investments in developing entrepreneurial ability. We assume that while working for a wage, agents get a random draw of entrepreneurial ability from a known stationary distribution \( F(z) \) that they can exploit the following period if they find profitable to do so. In particular, we assume that an individual in the labor force with current entrepreneurial ability \( z \) gets to keep it for the following period with probability \( \psi \), and gets a random draw from the distribution \( F(z) \) with probability \( (1 - \psi) \). The same process governs the evolution of entrepreneurial ability of agents that join the labor force after having exited from operating a business. These agents will keep the accumulated stock of knowledge with probability \( \psi \), and will get random draws with probability \( (1 - \psi) \).

Our probabilistic representation of the arrival of entrepreneurial ideas among workers allow us to be consistent with two key properties about the behavior of entrants in the data: 1) the rate of establishment entry and exit, and 2) the average size of entrants relative to incumbents. We will see below that consistency with these facts is important for the properties of firm’s life-cycle dynamics, and for shaping the responses to reforms.

It follows from the above that the value of a worker is simply defined by the wage rate in the period, plus the discounted expected value of resetting occupations in the following period:

\[
v^\omega_t(z) = w_t + \left( \frac{1}{1 + r_{t+1}} \right) \left[ \psi v_{t+1}(z) + (1 - \psi) \int v_{t+1}(z') dF(z') \right]
\]

with the value of an agent before making an occupational choice given by

\[
v_t(z) = \max_{o_t(z)} o_t(z) v^E_t(z) + (1 - o_t(z)) v^\omega_t(z).
\]

### 4.2.1 Aggregation and Definition of Equilibrium

At any given point in time, all individuals in the economy will be distributed over the space of entrepreneurial productivities. We denote the fraction of individuals with productivity less than or equal to \( z \) with \( M_t(z) \). We need to characterize the evolution
of such distribution in order to be able to aggregate individual decisions and compute equilibrium prices.

Say we start with a given distribution \( M_t(z) \) at the beginning of period \( t \). Entrepreneurs move across productivity levels in accordance to their innovation decisions, while workers do so in response to the stochastic process of productivity. Combining these processes leads to the following law of motion for the distribution of agents across productivity levels:

\[
M_{t+1}(z) = M_t(z) + \int_{z}^{z+\Delta} (1 - p_t(x)) o_t(x) \, dM_t(x) - \int_{z}^{z-\Delta} p_t(x) o_t(x) \, dM_t(x) \\
- (1 - \psi) \int_{0}^{z} (1 - o_t(x)) \, dM_t(x) \\
+ (1 - \psi) F(z) \int_{0}^{\infty} (1 - o_t(x)) \, dM_t(x)
\]  

(1)

The second two terms refer to the individuals that worked as entrepreneurs in period \( t \) and transition to (remain in) the set with productivity in \([0, z]\) after a period. Those with productivity level \( x \in (z, z+\Delta] \) downgrade to \( xe^{-\Delta} < z \) with probability \( 1 - p_t(x) \), and those with productivity level \( x \in (z-\Delta, z] \) upgrade to \( xe^{\Delta} > z \) with probability \( p_t(x) \). The last two terms refer to workers. A fraction \( 1 - \psi \) of workers with ability less than \( z \) get a new productivity. Among all the workers that get a new productivity, a fraction \( (1 - \psi)F(z) \) their new draw is less than or equal to \( z \).

A competitive equilibrium in this economy is given by sequences of choices by the head of the household \( \{c_t, k_{t+1}, o_t(z)\}_{t=0}^{\infty} \); sequences of entrepreneurs’ decisions \( \{l_t(z), k_t(z), p_t(z)\} \); sequences of interest rate and wage rates \( \{r_t, w_t\} \); and a distribution of agents over productivities \( \{M_t(z)\} \); such that given an initial capital stock \( K_0 \) and a given distribution of talent draws for workers \( F(z) \), household’s and firm’s decision solve their dynamic optimization problems and capital and labor markets clear

\[
\int \left[ l_t(z) + z\mu e^{\phi q_t(z)} \right] o_t(z) \, dM_t(z) = \int (1 - o_t(z)) \, dM_t(z)
\]

and

\[
\int k_t(z) o_t(z) \, dM_t(z) = K_t,
\]

and the distribution of entrepreneurial productivity evolves according to (1).

Similarly, a long run equilibrium of this economy is one where individual decisions,
aggregate quantities, and prices are constant, and the distribution of productivities are stationary.

**Output and Productivity** A well known property of our model with decreasing returns to scale and frictionless factor markets is that the production side of the economy aggregates into the following aggregate production function:

\[ Y_t = \left[ \int o_t(z) z dM_t(z) \right]^{(1-\alpha-\theta)} (K^s_t)^\alpha \left( L^s_{p,t} \right)^\theta \]

where \( L_{p,t} \) stands for aggregate labor demands for the production of the final good only:

\[ L_{p,t} = \int l_t(z) o_t(z) dM_t(z) \]

Measured TFP, in turn, can be computed from the following expression:

\[ TFP_t = \left[ \int o_t(z) z dM_t(z) \right]^{(1-\alpha-\theta)} \frac{(K^s_t)^\alpha \left( L^s_{p,t} \right)^\theta}{(L_t)^{1-\alpha}} \]

Notice that we have made an adjustment to our measure of \( TFP_t \) so as to make it comparable with that in income accounting studies. The expression reflects that output is deflated using the entire labor force in the data, regardless of occupations, while in the model only a subset of the agents are involved in the production of goods. The other fraction, entrepreneurs and workers in innovation, make intangible contributions that go unmeasured in GDP.

### 4.3 Introducing Distortions

The goal of the paper is to study transitions from low to high levels of economic development. To do this, we first need to take a stand about the forces that drag economic development in the initial allocation and the changes in the economic environment that revert them. Motivated by the empirical literature on misallocation, our approach is to give a prominent role to allocative distortions in understanding the former and to interpret the latter as an outcome of reforms that liberalize the economy from these distortions. A second decision we need to make refers to the specific type of distortions that we shall feed into the model in order to generate allocations similar to those of acceleration economies prior to take-off and resembling those of communist regimes.
Lastly, we must identify a strategy to discipline the parameterization of these distortions from the data.

We interpret the initial condition of an economy prior to engaging in an acceleration episode as an equilibrium in which factors of production are misallocated across firms due to distortions in the labor, capital, and product markets. The burgeoning literature that we summarized before provides robust evidence about the pervasiveness of resource misallocation in under-developed countries. To fully account for this feature, we introduce a distribution of idiosyncratic wedges that we calibrate to replicate properties of the distribution of wedges in the data. That is, we do not take a stand on what the specific friction is, whether it operates more predominantly through labor, capital, or product markets, but we rather follow the tradition of the literature in modeling the distortion in reduced form, through a productivity-dependent revenue tax. The upside of this abstraction is that we are able to honor the true degree of misallocation that we observe in economies before taking off.

Constructing an initial allocation representing a communist regime is more challenging given the inherent differences in the process of decision making and in the optimization goals between a central planner and utility and profit maximizing agents in a market economy. Given our goal of understanding transitions out from communism, we side-step this difficulty by focusing on recreating an allocation that resembles that of a communist regime within the context of a market economy with distortions, rather than doing so within a fully-specified model of a communism.

There are three distinguishing features of a centrally planned economy that we ought to take into account when constructing a communist allocation: apprehension towards income inequality, misallocation of production factors across production units, and limits to private entrepreneurial initiatives. The first and the last ones follow almost by definition, while the second one is a manifestation of the distortions to management practices and production goals from the central planning authorities. The joint consideration of these features, which are essential in accounting for the differences in the size distribution of firms between acceleration and post-communist economies that we documented in an earlier section, requires that we complement the misallocation frictions with a second distortion that discourages inequality and distorts entry. We show below that a parsimonious mechanism to achieve this is by feeding a profile of progressive

---

8See Roland (2000), chapter 1, for a detailed explanation of the organization of production and exchanges by the central administration, and for a description of how these production plans interfered with managerial incentives to operate firms efficiently.
taxes to the profits of the firms net of innovation costs.

Formally, let $\tau_t(z)$ and $\tau^\pi_t(z)$ denote the revenue and profit tax rates corresponding to a firm with productivity $z$ in period $t$. Then, the revenue and profit tax schedules are related to physical productivity in the following fashion:

$$[1 - \tau_t(z)] = \left(\frac{z}{z_{I,t}}\right)^{-\nu_t(1-\alpha-\theta)} \quad (2)$$

$$[1 - \tau^\pi_t(z)] = \tau^\pi_t(0) z^{-\xi_t(1-\alpha-\theta)} \quad (3)$$

The slope parameter in the misallocation schedule $\nu_t$ controls the degree of linear relationship between the logarithm of the marginal revenue product of the firm ($TFPR$) and the logarithm of physical productivity ($TFPQ$). As explained in greater detail in the calibration section, we appeal to Chilean and Chinese estimates for the regression coefficient between these variables to discipline its parameterization. The productivity index $z_{I,t}^{(1-\alpha-\theta)}$ separates firms into those that get a revenue subsidy from those that get a revenue tax. It is easy to show that flat revenue taxes have a neutral effect on aggregate productivity, so its introduction is innocuous for labor, capital, innovation, and occupational allocations. However, $z_I$ is useful since it gives us a degree of freedom to neutralize secondary effects of distortions on the investment to output ratio in the model.

In terms of the profit tax schedule, the key elements are the parameter determining its degree of progressivity $\xi_t$ and the flat component $\tau^\pi_t(0)$. It can be shown that unlike a flat revenue tax, a flat profit tax has a direct effect over occupational choices, innovation, and, thereby, the average size of a firm. We appeal to data on the latter for former communist countries to determine its value in the quantitative analysis.

We now turn to incorporating the profit and revenue taxes into the optimization problems of the agents. Consider first the value of an entrepreneur with productivity $z$ and associated revenue and profit taxes $\tau_t(z)$ and $\tau^\pi_t(z)$. This is given by the following expression:

$$v^E_t(z) = \max_{p_t} \left\{ [1 - \tau^\pi_t(z)] \pi_t(z, \tau_t(z); w_t, r_t) - w_t \chi_t(p, z) + \left(1 - \frac{1}{1+r_t}\right) p_t v_{t+1} \left(z e^\Delta\right) + (1 - p_t) v_{t+1} \left(z e^{-\Delta}\right) \right\} \quad (4)$$

Profit taxes have a direct effect over the firm’s incentives to innovate but have no implication for the entrepreneur’s choice of labor and capital demands. Revenue taxes,
on the other hand, do interfere with factor demand and profitability, as reflected by the firm static profit maximization problem:

\[
\pi_t(z, \tau_t(z); w, r) = \max_{l_t(z), k_t(z)} \left\{ (1 - \tau_t(z)) z^{(1 - \alpha - \theta)} k_t^{\alpha} l_t^{\theta} - w_t l - (r_t + \delta) k \right\}
\]

\[
l_t(z) = \left( \frac{\alpha}{r_t + \delta} \right)^{\frac{1}{1 - \alpha - \theta}} \left( \frac{\theta}{w_t} \right)^{\frac{1}{1 - \alpha - \theta}} z [1 - \tau_t(z)]^\frac{1}{1 - \alpha - \theta}
\]

\[
k_t(z) = \left( \frac{\alpha}{r_t + \delta} \right)^{\frac{1}{1 - \alpha - \theta}} \left( \frac{\theta}{w_t} \right)^{\frac{1}{1 - \alpha - \theta}} z [1 - \tau_t(z)]^\frac{1}{1 - \alpha - \theta}
\]

\[
\pi_t(z, \tau_t(z); w, r) = \left( \frac{\alpha}{r_t + \delta} \right)^{\frac{1}{1 - \alpha - \theta}} \left( \frac{\theta}{w_t} \right)^{\frac{1}{1 - \alpha - \theta}} (1 - \alpha - \theta) [1 - \tau_t(z)]^\frac{1}{1 - \alpha - \theta}
\]

A feature of the value of entrepreneurship worth highlighting is that profit taxes affect the operational profits of the entrepreneur net of the expenditure on innovation. In the context of the theory, this assumption is necessary in order to ensure that the profit tax indeed distorts the innovation decision of the entrepreneur. To the extent that the profit taxes are intended to capture the distortions to managers’ incentives to invest in technology under a communist regime, it is necessary in the theory these taxes have a non-neutral effect over the rate of return to innovation relative to the marginal cost of innovation expenses. It is to accomplish this goal that we set the tax to affect operational profits net of innovation expenses.

We conclude the section presenting the definitions of aggregate output and productivity in the version of the economy with distortions:

\[
Y_t = \left[ \int z (1 - \tau_t(z))^{\frac{\alpha + \theta}{1 - \alpha - \theta}} o_t(z) d M_t(z) \right]^{\alpha + \theta} (K_{s,t}^\alpha) \left( L_{s,t}^\theta \right)\theta
\]

and

\[
TFP = \left[ \int z (1 - \tau_t(z))^{\frac{\alpha + \theta}{1 - \alpha - \theta}} o_t(z) d M_t(z) \right]^{\alpha + \theta} \left( L_{s,t}^\theta \right)\theta
\]

The misallocation-effect of revenue taxes is manifested in the aggregation of individual productivities, which now reflects the inefficiency in the distribution of capital and labor across producers. The dynamic effects of revenue and profit taxes, which operate through distortions to innovation, are captured in the distribution of firms across
5 Quantitative Exploration

In this section we start with the quantitative exploration of our theory. Our first set of results pertain to the long run properties of the model economy and its ability to replicate macro and firm level features of countries before accelerations and while under communism. Some of these features, such as the relative average firm size, will be replicated as part of the calibration strategy while others, such as the life-cycle dynamics of firms, will used as tests of the internal mechanics of the model. In the case of the communist allocation, we offer a decomposition of the results isolating the contribution from each of the two type of distortions at play.

Then we turn to the main focus of the paper, the analysis of transitions. We model accelerations triggered by a reform that smoothly dismantles allocative distortions. We appeal to time series data for the evolution of misallocation around the reform years in Chile to discipline the path reforms. For post-communist transitions, we assume that communist features (i.e. the profit taxes) are withdrawn once and for all, while we assume, as with Chile, a smooth reversal of misallocation taxes disciplined by time series summary statistics of misallocation in China.

5.1 Calibration

Parameters related to technology, shocks, and preferences will be calibrated to match features of the USA economy, while distortions will be disciplined by Chilean and Chinese firm-level data.

5.1.1 Parameters Common Across Economies

There are 7 parameters that remain invariant across the types of economies that we consider: the coefficient of relative risk aversion $\sigma$, the labor and capital shares in production $\alpha$ and $\theta$, the subjective discount factor $\beta$, the scale and the convexity parameters in the innovation cost function $\mu$ and $\phi$, and the capital depreciation rate $\delta$. In addition, we must specify and parameterize the distribution of entrepreneurial ability types among workers.

For the coefficient of relative risk aversion, we set $\sigma = 1.5$, which is standard in the macroeconomics literature. We set $\beta = 1 / (1 + 0.04)$, to target a 4% yearly interest
rate, and set the annual capital depreciation rate at \( \delta = 0.06 \). In terms of factor shares in the production technologies, given a value of the span of control \( 1 - \alpha - \theta \), we calibrate \( \alpha / (\alpha + \theta) = 1/3 \), so that 1/3 of the income going to non-entrepreneurial factors is paid to in return to capital.

The span of control \( \alpha + \theta \) is calibrated jointly with the parameters of the innovation cost, \( \mu \) and \( \phi \), and the innovation step \( \Delta \), to match the concentration of income in the top 1% of the population, the employment share in the top 10% of the firm size distribution, the average employment ratio between 30 and less than 5 year old firms, and the log dispersion of the distribution of employment growth rates for large firms. Finally, we assume that the distribution of entrepreneurial abilities is Log-normal, with a mean equal to zero and a variance that we calibrate to match the ratio between the average employment of entrants relative to the average employment of incumbents. This strategy leads to the following parameter values:

<table>
<thead>
<tr>
<th>Table 1: Calibration of Common Parameters across Economies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Top 1% Earnings Share</td>
</tr>
<tr>
<td>Top 10% Employment Share</td>
</tr>
<tr>
<td>Std Dev. Employment Growth rate</td>
</tr>
<tr>
<td>Empl. Ratio Entrants to Incumbents</td>
</tr>
</tbody>
</table>

Note: Top 1% earnings share for the US is taken from Diaz-Gimenez, Glover, and Rios-Rull (2011). The top 10% employment share and the average employment ratio between entrants and incumbents were computed from Business Dynamics Statistics database for the year 2007. Standard deviation of employment growth rates for large firms follows from Atkeson and Burstein (2010).

Besides calibrating the variance of the distribution to match moments of the entrants distribution in the data, we can further explore the goodness of fit of the Log-normal assumption by comparing the entire distribution of entrants with the data. We plot these distributions, both unweighted and weighted by employment shares in figure 3.
The figure shows that while the Log-normal distribution tracks closely the un-weighted empirical distribution of entrants, it under-predicts the share of employment accounted for by the largest firms. There are two features of the equilibrium that are affected by the properties of the distribution of entrants: the dynamics of employment over the life-cycle and the speed of convergence along transitional dynamics. Since large firms innovate more intensively, a smaller share at the top decreases the speed of employment growth over the life-cycle and delays the speed of convergence. As a robustness, we experimented with a Pareto distribution of entrants, which delivers the exact opposite prediction regarding the share of employment in the right tail. We found that, as long as both distributions are calibrated to match the ratio between the average size of employment of entrants and incumbents, the implications for the life-cycle and
the speed of convergence are almost identical.

A last feature of the calibration that is worthwhile to be discussed concerns the parameters of the innovation cost function. These parameters were calibrated to target the share of employment at the top of the size distribution of firms in the US, but the parameterization also has implications for the evolution of employment over the life-cycle, for which there also are empirical references\(^9\). Although we explore the model’s implications for the evolution of employment size over the life-cycle in more depth once we get to the quantitative analysis, we can look ahead into figure 6 and evaluate the implications of the calibration along this dimension. Focusing on the line corresponding to the frictionless economy, we see that the model does a reasonable job at reproducing the life-cycle dynamics of firms in the data, generating more than a duplication of the average size of the cohort by age 20, and a multiplication by almost 5 by age 40, virtually in line with the empirical counterparts\(^{10}\).

### 5.1.2 Parameterizing Distortions

We now turn to the discussion of our calibration strategy for the parameter values governing the distribution of distortions. As mentioned earlier in the text, both the pre-acceleration equilibrium and the communist allocation are affected by factor misallocation, so we need two targets for the relationship between revenue distortions and productivity in the model. Furthermore, our representation of the communist regime requires that we identify a target for the parameters of the distribution of profit taxes, the flat component of the schedule and the degree of progressivity. Lastly, we must identify a strategy to discipline the speed of reversal of the distortions, which is the definition of reform that triggers a transition path in the model.

In terms of the initial level and the path of reversal of misallocation frictions, we appeal to time series data for the regression coefficient between the logarithm of TFPR, which captures distortions, and the logarithm of TFPQ, which stands for the physical productivity of the firms. Despite the lack of availability of publicly accessible datasets

---

\(^9\)Our empirical reference comes from Hsieh and Klenow (2014), figure 1

\(^{10}\)Luttmer (2010) discusses the life-cycle properties of models with stochastic properties calibrated to match features of the firm size distribution, and argues that these models tend to predict implausibly slow life-cycle dynamics. One feature of our theory that allows us to circumvent this shortcoming is that we work with a theory of entry based on occupational choices which generates a distribution of entrants arriving to entrepreneurship from an entire distribution. This contributes to the life-cycle growth of the entering cohort by exhibiting more selection over time, and by having firms already at the top of the size distribution and hence innovating at higher pace.
that allow for these calculations, we were able to assemble a time series of these objects for two representative countries in the post communist and the acceleration groups: China and Chile.

Regarding Chile, the data comes from the work of Chen and Irarrazabal (2014), who study the evolution of allocative efficiency in the decade of recovery in Chile between 1983 and 1996. The authors report the regression coefficient between the logarithm of TFPR and the logarithm of TFPQ across firms for the years between 1980 and 1996, appealing to Chile’s manufacturing census covering all firms with 10 or more employees. We take the value of this coefficient in 1980, arguably a year that witnessed, or gave start to, a period of large-scale reforms in the Chilean economy, as the parameter value for the schedule of distortions that characterizes the initial steady state representing Chile in the model.

In terms of the dynamics of the distortion parameter along the reform path, we use the observed improvement in the degree of distortions in the Chilean economy to discipline a path or reform in the model. From the Penn World Tables version 8.1, which is our data source for the cross country analysis of accelerations and post-communist dynamics, we can gather aggregate data up until the year 2011. Since we only have actual data about the evolution of the regression coefficient for the years between 1980 and 1996, we fit a linear trend to this data and come up with a forecast for the regression coefficients for the remaining years between 1996 and 2011. In this way, we are interpreting Chile’s trend dynamics between 1980 and 2011 as resulting from a linear process of dismantlement of distortion that makes the economy transition from an initial steady state with the distortions observed in such economy in 1980 to a steady state exhibiting the degree of distortions implied by our forecast for 2011.

We proceed in similar fashion in disciplining the initial, terminal, and transitional levels of distortions in China. Our data source in this case is Hsieh and Klenow (2007), who report regression coefficients between the objects of interest for the years 1998, 2001, and 2005. Like we did with Chile, we use these three data points to construct a forecast of evolution of the coefficient for the remaining years between 1998 and 2005 and moving forward to 2011. Like before, the interpretation that we are giving to China’s trend dynamics between 1998 and 2011 is that of a transitional path resulting from a linear process of dismantlement of allocative distortions and profit taxes (in this case, yet to be specified) to a stationary allocation featuring the degree of misallocation we forecast for 2011, and a schedule of profit taxes that we specify below.

We can visualize our calibration strategy of misallocation frictions \( \left\{ \nu_t^{\text{Chile}}, \nu_t^{\text{China}} \right\} \).
in figure 4. The left panel illustrates the dynamics of the elasticity between the logarithm of TFPR and the logarithm of TFPQ between 1980 and 1996 (dots) together with our fitted estimate for the extended period until 2011 (solid line). The right panel illustrates the same objects for China, between 1998 and 2011.

Figure 4: Misallocation Frictions Chile 1980-2011 and China 1998-2011

Note: The plots reproduce the evolution of the coefficient of regression between \( \log(TFPR_i) \) and \( \log(TFPQ_i) \) for repeated cross sections in Chile and China. Data points come from Chen and Irarrazabal (2014) and Hsieh and Klenow (2007) for the case of Chile and China respectively. The dashed line results from fitting a linear trend to the data points.

A last feature regarding the parameterization of the path of allocative distortions refers to the scaling parameter \( Z_{I,t} \). We have a clear disciplining target for its value in the initial and terminal steady states, since we are introducing this degree of freedom to neutralize any effect of distortions on the capital to output ratio in the long run. However, we have no clear target for its parametrization along the transition. Against
a clear best practice, we proceed as with the parameterization of the slope parameter. That is, we fit a linear trend between the initial and terminal values and use it to predict values for every period in between.

It remains to be specified a strategy to pin down parameters governing the profile of profit taxes in the communist allocation. As argued above, we appeal to this instrument to introduce communist features into the model. To capture the strong equalizing forces inherent to the distribution of earnings in these regimes, we set the slope parameter in the profit tax schedule to $\xi_t = 0.9$. Both this parameterization and the calibration of misallocation frictions create a strong depressing force over the average firm size in the economy. This prediction is opposition to the fact documented earlier that firms are relatively larger on average in communist regimes. Thus, to regain consistency with this feature, we appeal to the scale parameter $\tau_{\pi t} (0)$ in the profit tax function. This parameter governs the scale of the profit taxation scheme, and is primarily intended to capture distortions to entry into entrepreneurship. Even though $\tau_{\pi t} (0)$ also contributes to discouraging innovation, this effect is dominated by the progressivity of the profit and revenue taxes. The major contribution of $\tau_{\pi t} (0)$ is to discourage entry and to increase the average firm size. We calibrate this parameter to target the average size of a firm in a communist regime relative to the US$^{11}$, which we find to be equal to 3.3. This gives a parameter value of $\tau_{\pi 0} (0) = 0.836$.

Having specified a strategy to characterize a communist stationary allocation, we move on to describing the behavior of the economy during the liberalization. We view post-communist transitions as a process of transformation in which countries completely and permanently liberalize communist elements in the environment and ignite a transition with distorted but steadily improving product and factor markets. In terms of the evolution of parameters of distortions in the model, we are assuming that $\xi_t = 0$ and $\tau_{\pi t} (0) = 0$ for all $t$ after liberalization, while $\nu_{t}^{China}$ evolves according to the right panel in figure 4.

---

$^{11}$The firm-level datasets to which we had access for computing the dynamics of the average firm size in the motivation section, albeit sufficiently comprehensive to capture trends in the dynamics of this object, showed different degrees of biases in the coverage that makes the actual levels of the average size less trustworthy. Among these datasets, we find the data for Romania to be the most reliable of all, so we use the average size of this country relative to the US to come up with a target for calibration. The average size of a manufacturing firm in Romania in 1993, the earliest in the sample, was 170 employees, 3.3 times the average size in the US manufacturing sector between 1977 and 2011.
5.2 Long Run Analysis

We start with the exploration of the long run implications of distortions in the model. Firstly, we explore micro-implications, such as changes in innovation expenditures, the productivity distribution of firms, and the dynamics of employment over the firms' life-cycle. Then, we move on to exploring macroeconomic outcomes, emphasizing the effects on GDP, TFP, entrepreneurship rates, and average firm sizes.

5.2.1 Micro-Implications

The following figure illustrates the implications of the theory with respect to the profile of innovation intensities as a function of firm productivity and the resulting equilibrium distribution of firms. The left panel shows the ratio of employment in innovation activities relative to the labor demanded in production for three stationary equilibriums of the model: the frictionless, the distorted one calibrated to Chile in 1980, and the distorted one calibrated to China in 1998. The right panel plots the corresponding productivity distributions.
One salient feature of the profile of innovation intensities is that, in accordance with Gibralt’s law, the share of labor devoted to innovation in large firms is independent from productivity, and hence size, in the frictionless economy. This is not surprising, since it is precisely the goal we sought to achieve with scaling of the innovation cost function by the firm’s productivity. The independence between firm growth and firm size does not hold for entrepreneurial abilities that are close to the exit cutoff, region in which innovation intensities are lower than but increasing towards the level for large firms. For entrepreneurs that are close to the cutoff, the rate of return to innovation is challenged by the value of selecting into the labor force, which gives the agent the opportunity to work for a period and get a new entrepreneurial ability from the entrant’s distribution in the following period.

Innovation patterns and occupational choices are notably different depending on the type of distortions affecting the economy. With misallocation frictions only, calibrated
to Chile in 1980, the structure of subsidization and taxation is such that it encourages entrepreneurship among the lowest productivity types in the population. This can be seen by the set of productivities for which innovation intensity was equal to zero in the frictionless economy but have a positive value in the distorted one.

Innovation decisions are also heavily distorted. Because the revenue tax rates are increasing in productivity, the rate of return to innovation expenditures is hindered relative to the marginal cost, which remains unaffected by the idiosyncratic distortion. The result is that innovation declines in all ability levels except those that are new to entrepreneurial activity. In China, the disincentives to innovate are magnified by the combination of misallocation frictions with progressive profit taxes, bringing the innovation intensities almost all the way to zero for every type of firm in the economy.

The distortionary effect of distortions on innovation and occupational choices manifests in the distribution of firms across productivity levels (right panel). In Chile in 1980, there’s a larger fraction of firms in the lower end of the entrepreneurial ability spectrum and the whole distribution is shifted to the left relative to the frictionless. In China in 1998, the flat component of the profit tax profile counteracts this force so we do not obtain a magnification of the left tail. Combined with virtually no innovation across firms, the distribution is concentrated closer to the exit cutoff.

A second dimension along which we can evaluate the micro-implications of the theory is with respect to the life-cycle dynamics of employment and productivity. This is an interesting dimension since there are concrete empirical references in the literature against which to compare the predictions of the theory. Hsieh and Klenow (2014), for example, document a notable flatness in the behavior of employment and physical productivity across firms of different ages in Mexico and India relative to the US. A similar conclusion, albeit less dramatic, is reached by Ayyagari et.al. (2013) for a larger sample of developing and low income countries. We plot the model counterparts of these objects in figure 6.
The left panel of the figure illustrate employment over the life-cycle, while the right panel illustrates productivity. The frictionless economy shows that the calibration of the innovation cost parameters and the choice of a log-normal distribution of entrants delivers a reasonable match between the life-cycle evolution of employment in the model and in the data. In Hsieh and Klenow (2014), a typical 20 year old US firm is more than twice as large than the group of firms between the ages of 1 and 5, and is almost 5 times larger by the age 39. A similar growth is experienced by a typical cohort of entrants in the theory. The distortions underlying the model’s equilibrium for Chile 1980 and China 1998, on the other hand, generate a substantially flatter pattern of employment and productivity growth over the life cycle, which is consistent with the findings from Hsieh and Klenow (2014) and Ayyagari et.al (2013). Also, notice that because revenue and profit taxes increase with productivity, the life-cycle differences in productively translate less markedly into differences in the life-cycle of employment.

In summary, we have characterized the micro-implications of allocative distortions and profit taxes in our theory and we have described how they map into observable
empirical counterparts. The next goal is to assess the aggregate implications of these firm level responses.

5.2.2 Aggregate Implications

Having characterized the implication of distortions for firm-level decisions we now focus on the ability of the economies with distortions to account for the income and productivity gaps that were observed between acceleration and communist economies relative to the US prior to the reforms.

To do so, we compute the ratio between the variables of interest in the calibrated economies of Chile in 1980 and China in 1998 relative to their values in the frictionless allocation. In the case of China, since there are the two distortions at play, we complement the analysis turning off the profit taxes and considering misallocation frictions only. The goal is to understand the interaction between the two.

Table 2: Steady State Analysis: Chile 1980 and China 1998 vs Frictionless

<table>
<thead>
<tr>
<th></th>
<th>Pre-Acceleration</th>
<th>Communist (China 1998)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chile 1980</td>
<td>Benchmark</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Misallocation Only</td>
</tr>
<tr>
<td>GDP</td>
<td>0.68</td>
<td>0.43</td>
</tr>
<tr>
<td>TFP</td>
<td>0.75</td>
<td>0.52</td>
</tr>
<tr>
<td># of Entrepr. (diff.)</td>
<td>0.21</td>
<td>-0.02</td>
</tr>
<tr>
<td>Av. Size</td>
<td>0.14</td>
<td>3.3</td>
</tr>
<tr>
<td>Wage</td>
<td>0.74</td>
<td>0.34</td>
</tr>
</tbody>
</table>

The calibrated distortions for Chile in 1980 is capable of generating a TFP contraction of 25% and a decline in output of 30%. Consistently with the data presented above, the pattern of taxation and subsidization increases the rate of entrepreneurship and induces a contraction in the average size of the firm, which shrinks to just 14% of the size in the frictionless equilibrium. Low productivity firms are benefited by the distortions relative to high productivity ones. This increases the profitability of marginal agents and favors their selection into entrepreneurship.

The combination of allocative distortions and profit taxes, as in the communist regime, magnifies the decline in output and productivity, reaching almost 60% for the former and 50% for the latter. The two distortions reinforce each other in discouraging innovation, which results in a stronger decline in productivity and output. Furthermore, as anticipated in the calibration, the profit tax profile reverts the depressing forces of
the misallocation frictions over the average size, generating an increase in the average size of 3.3 times the size in the undistorted allocation, which is the factor of increase we targeted in the calibration.

The third column shows that had misallocation frictions been the only distortion in the communist regime, the reduction in output and productivity would have been less than half of what they were in the benchmark. This suggests that the barriers to entrepreneurship and apprehension to income inequality represented in the profit tax schedule are a fundamental ingredient of communist regimes that help understand the sources of their development and technological gaps. Furthermore, the last two columns already hint a non-trivial behavior of the firm size distribution along the transitional path. On one hand, the removal of profit taxes pushes the average firm size downwards, while the reversal of misallocation generates the opposite effect. Which of these forces prevails in the model’s dynamics will be important for its ability to replicate the dynamics of the average size in post-communist transitions.

The steady state analysis gives us an idea of the type of adjustment that would have to take place along a full transition path to development. The economies have to close significant development gaps, especially for communist regimes, and are expected to exhibit substantial reorganizations at the micro-level, in light of the differences in innovation, entrepreneurship rates, and the firm size distribution.

5.3 Development Dynamics

Here we turn to the main goal of the paper, investigating the macro and firm-level features of development dynamics. As explained in the calibration section, we interpret transitional growth as a consequence of a set of reforms, which in the case of Chile entails a protracted process of dismantlement of misallocation frictions, and in the case of China entails a similar process of removal of allocative distortions combined with a sudden removal of the communist features embedded in profit tax schedule. The calibrated paths of distortions in the two economies are in figure 4.

Even though the table in the previous section gave us an idea of the detrimental power of allocative distortions and communist regimes, the development gaps were measured relative to the frictionless allocation. In the transition exercises below, however, the economies do not attain the frictionless level of development. This is because in our benchmark experiments we assumed that the progress of reversion of misallocation stalls and remains stagnant at the level forecasted for the latest year in our sample
of aggregate data, namely 2011. In order to get a sense of the long run changes in productivity, entrepreneurship, and average firm sizes that our calibrated reforms are able to achieve, we report the steady state ratios between the terminal and the initial values of each variable in the table below.

Table 3: Development Dynamics: Terminal vs Initial Allocations

<table>
<thead>
<tr>
<th></th>
<th>Chile 2011 relative to 1980</th>
<th>China 2011 relative to 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>1.15</td>
<td>1.95</td>
</tr>
<tr>
<td>TFP</td>
<td>1.11</td>
<td>1.65</td>
</tr>
<tr>
<td># of Entrepr. (diff.)</td>
<td>-0.06</td>
<td>0.14</td>
</tr>
<tr>
<td>Av. Size</td>
<td>1.37</td>
<td>0.07</td>
</tr>
<tr>
<td>Wage</td>
<td>1.12</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Note: Chile 2011 relative to 1980 refers to ratios of the corresponding variables in stationary equilibrium with regression coefficients between TFPR and TFPQ equal to $\nu^{Chile}_{Chile} = 0.6$, relative to a stationary equilibrium with $\nu^{Chile}_{2011} = 0.4$. China 2011 vs 1998 refers to ratios between stationary equilibriums with $\{\tau^{\pi}_{1998} (0) = 0.84, \xi_{1998} = 0.9, \nu^{China}_{1998} = 0.5\}$ and $\{\tau^{\pi}_{2011} (0) = 0, \xi_{2011} = 0, \nu^{China}_{2011} = 0.3\}$ respectively.

For our calibrated path of distortions, Chile experiences a transition that increases TFP by 11% in the long run. The increase in productivity combined with a contraction in the number of entrepreneurs translates into a 37% increase in the size of an average plant. In China, removing communist forces and withdrawing distortions induces a productivity increase of 65%. At the micro level, the depressing effect of abolishing communist features outweighs the enhancing effect exerted by the improvement in allocative efficiency over the average size.

5.3.1 Acceleration Episode: Chile 1980-2011

Here we start with the analysis of transitions. Consider first the acceleration episode of Chile between 1980 and 2011, presented in figure 7. The solid black line corresponds to the model and the light gray line corresponds to the data. In the case of the investment rate, the units of the data are measured on the right axis. TFP is reported as a ratio with respect to the initial steady state, while the investment rate, the average size, and the innovation expenditure rates are expressed as absolute differences from the initial steady state level.
Figure 7: Transition Dynamics Acceleration Episode: Chile 1980-2011

Note: The data for TFP corresponds to the trend component of HP filtered (smoothing parameter of 100) Chilean data between 1980 and 2011. The investment rates is the raw data for the period. The average size data is the same as in section 3. TFP and the average size are expressed as ratios with respect to 1980 values, where, in the case of the model, 1980 stands for the calibration of the economy to the distortions in that year. The investment rate and the ratio of innovation expenditure over GDP are expressed as absolute differences.

The figure shows that the model is able to capture the qualitative features of the dynamics of TFP, investment, and average firm size in the data. Aggregate productivity increases protractedly, both as a result of the reallocation gains that accrue in each period due to the improvement in allocative efficiency, and because of the returns to innovation investments which, as shown in the lower right panel also increase steadily over time. The investment rate is, by construction, starting and finishing at the same level between the two steady states. However, along the transition, it declines in the onset of the reform and increases smoothly until it reverses back to the steady state, reversal that materializes beyond 2011. Physical capital investment declines in response
to the economy’s allocation of resources towards the financing of innovation expenses. As innovation pays off and productivity starts to increase, the rate of return to capital goes up and so does the rate of tangible capital investment in the economy.

Quantitatively, the model cannot account for about half of the productivity gains experienced by Chile between 1980 and 2011. Making a more complete comparison of the behavior of the model and the data during this period is complicated by the fact that Chile suffered and recovered from a deep recession in the very same years it was reforming its economy and liberalizing distortions. Part of this cycle still feeds into the HP-filter trend. Of course, there is no force in the model than can track this cyclicality. Similarly, the model cannot account for the magnitudes of fluctuations in the investment rates, although it does replicate its increasing pattern. However, a fair conclusion to be made at this stage, one that we shall validate below when studying post-communist transitions, is that the predicted recovery of aggregate productivity in the model is slower than the one observed in the data.

The model also captures the adjustments in the size distribution of firms, as manifested by the dynamics of the average firm size. Although less abruptly than in the data, the average size of firm increases by 30% between 1980 and 2011. In the last period with available firm-level, the average firm size had increased by 50% in the Chile and about 20% in the model. As argued in the context of steady state analysis, the increase in the average firm size responds, on one hand, to the progressive dismantlement of distortions, which eliminates subsidies at the bottom of the productivity distribution and discourage low-productivity entrepreneurship, and on the other hand to the increase in innovation investment by productive firms, which concentrates employment and production into fewer and more productive entrepreneurs.

Although we have taken Chile as the reference country for the evaluation of the model, we can also compare the theory with respect to the more general patterns that come out from the broader sample of acceleration episodes. In this sense, the model captures the monotone upwards trajectory of TFP, the hump-shaped behavior of investment rates, and the increasing dynamics of the average firm size that are typical of these episodes.

5.3.2 Post-Communist Transition: China 1998-2011

We now present the results for our representation of China’s transition between 1998 and 2011. The results are illustrated in figure 8, where the solid black line corresponds
to the model, and the light gray line corresponds to the data. Investment rates and the average firm size are measured on the right axis.

Figure 8: Post-Communist Transition Dynamics: China 1998-2011

Note: The data for TFP corresponds to the trend component of HP filtered (smoothing parameter of 100) Chinese data between 1998 and 2011. The investment rates is the raw data for the period. The average size data is the same as in section 3. TFP and the average size are expressed as ratios with respect to 1998 values, where, in the case of the model, 1998 stands for the calibration of the economy to the distortions in that year. The investment rate and the ratio of innovation expenditure over GDP are expressed as absolute differences.

The model is also able to replicate the similarity between acceleration episodes and post-communist transitions from an aggregate point of view, at the same time it accounts for the differential behavior of firms at the micro level. This can be noted in that, contrary to Chile, the average firm size declines for a number of periods along the transitions, while TFP and investment rate display the same increasing pattern. Of course, the two experiments differ in the magnitudes, which is not surprising in light of
the different development gaps to be bridged by each economy.

Even though aggregate productivity increases substantially in the model, gaining 40% in 2011 relative to 1998, it can account for about half of the gain experienced by China between 1998 and 2011. Recall that the only source of technological progress in the model stem from resource reallocation gains and expansions in innovation investments from the withdrawal of distortions. The data suggests other forces are having a significant role as well.

Like in the case of acceleration episodes, investment in physical capital declines upon reform, and does so more abruptly in light of the larger productivity gaps that needs to be closed by investing in technology. The flip-side of the deeper contraction in investment is the greater increase in the innovation expenditure rate, which is twice as large as in the acceleration episode upon reform, and almost three times as large by 2011. Relative to the data, however, the extent of decrease and increase in the investment rate is orders of magnitude smaller.

The dynamics of the average size warrants a closer inspection. The steady state analysis already anticipates that the calibrated reform for China generates a contraction in the average firm size. However, the figure shows that these opposing forces manifest at different stages of the transition, generating a non-monotone path of convergence. Upon reform, misallocation is dismantled smoothly, while profit taxes are eliminated abruptly. This creates a severe decline in entrepreneurship which more than compensates for the incipient expansion in productivity, reducing the average firm size to just about 14% of the initial steady state value. Thereafter, the exit from entrepreneurship and the decline in average size persists for a few periods, until the expansionary effect from undoing misallocation starts to prevail. The average size flattens out and eventually increases gradually towards the new steady state value. The increasing part does not materialize until later than 2011 so, in a sense, it constitutes a forecast from the model about what we should expect to happen with the dynamics of the average size in China in the near future.

Lastly, notice that the degree of contraction in the average size exceeds largely the one observed in China. Part of this divergence can be attributed to the incomplete coverage of the universe of manufacturing firms in our dataset, which leaves out enterprises and businesses with sufficiently low level of sales. In the context of the theory, an important factor underlying the results is the abruptness with which we withdraw the communist features in the model, which had happened at a similar pace in many of the post-communist countries but certainly not in China.
We conclude the analysis of post-communist transitions performing an experiment that would allow us to disentangle the relative contribution of each ingredient of a post-communist reform in shaping development dynamic. To achieve this, we compute a counterfactual reform in which only the communist features, embedded in the profit taxes, are dismantled, while resource misallocation persists as the same level than in the initial allocation. We overlay the results form this experiment, which we label partial, with those of the benchmark, which we label full in figure 9 below\textsuperscript{12}.

Figure 9: Decomposition of Post-Communist Transitions: Full Reform vs Removing Profit Taxes Only

It follows from the figure that the fundamental force driving the dynamics of China during the liberalization years is the withdrawal of the profit distortions. Removing

\textsuperscript{12}To be clear about the meaning of “full”, it does not refer to fully removing all type of distortions, as in a frictionless economy, but rather to contemplating both of the reforming forces that we are allowing to happen in the model, namely the protracted reversion of misallocation and the abrupt withdrawal of profit distortions.
this friction allows China to reap almost all of the productivity gains from the more comprehensive reform. The figure also reinforces the intuition that the contribution of improvements in allocative efficiency for the average size manifest later in the transition process, pushing the average size upwards. As shown in the lower-left panel of the figure, the average size is below the benchmark level throughout the partial transition. Lastly, the bottom right figure shows that even though the productivity gains from the partial reform are, by 2011, very similar to the complete reform, they require a slower investment in innovation to achieve them.

6 Conclusion

In this paper we presented a quantitative model of economic transitions to aid in the understanding the macro and micro patterns of development dynamics in post-war acceleration episodes and post-communist transitions.

Our model builds upon the most recent theories of firm-level innovation, with entry and exit, and a stationary firm size distribution. We innovated upon these theories interacting the built-in mechanisms of the models with two types of allocative distortions, misallocation wedges and progressive profit taxes, and characterizing transition dynamics. Furthermore, our analysis exploits the time-series dimension in existing empirical studies of misallocation in developing countries to come up with a novel strategy to discipline reforms. This allowed us to explore the quantitative behavior of the model in the context of a calibrated path dismantlement of distortions.

Our findings suggest that our theory can account for the salient features of development dynamics in acceleration episodes and post-communist transitions. A property of our findings is that, despite dispensing from frictions to resource reallocation, the model can deliver a protracted path of growth in the rate of investment and in TFP in the economy. A key feature for the sustained growth in these variables is our theory of innovation, and the co-existence of heterogeneous incentives to invest in intangible capital along transition paths. There, the incentives to spur innovation from new and previously taxed entrepreneurs interact with a decline in innovation incentives from older cohorts of firms with relatively low productivity. As a result of this tension is that it takes several years for TFP to attain its new steady state level.

Our work also provides results that feedback into the empirical literature. In particular, our analysis of the evolution of the life-cycle of firms and the cross-sectional
distribution of employment across ages along the transition path can be of help in the growing interest in the literature to understand cross-country differences in the life-cycle of firms and its repercussion on cross-country differences in productivity. Our results suggest that inferences about life-cycle behavior drawn from cross-sectional characterizations of employment across ages maybe misleading with respect to capturing the actual patterns of firm growth over the life-cycle, specially so in countries that are undergoing a growth acceleration.

References

[1]


