Capital-Reallocation Frictions and Trade Shocks*

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Abstract

What are the short-term effects of an import-competition shock on capital reallocation and aggregate productivity? To address this question, we develop a quantitative model with heterogeneous firms and capital-reallocation frictions. We discipline the model with micro data on investment dynamics of Peruvian manufacturing firms and trade flows between China and Peru. Because of large frictions in firm downsizing and exit, an import-competition shock induces a temporary aggregate-productivity loss and larger dispersion in marginal products, due to investment inaction and exit of some productive firms. Empirical evidence on the effects of trade shocks on capital reallocation supports the model mechanism.

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1 Introduction

Understanding the effects of trade liberalizations on domestic production is a key question both for the academic literature and in policy institutions. There is wide consensus that, in the long run, international trade leads to higher aggregate productivity by inducing selection and reallocation of factors across firms and industries. Moreover, trade allows consumers to expand their consumption bundle and increases their real income.

Less is known, however, about the consequences of accounting for transitional dynamics after trade shocks and to what extent frictions in the reallocation of factors may delay aggregate productivity gains. This gap in the literature is surprising, given that a large and influential body of empirical evidence points to the presence of substantial frictions in capital reallocation, especially in emerging economies, as shown by the persistent dispersion in returns from capital across firms.

In this paper, we ask the following question: What are the short-term effects of an import-competition shock on capital reallocation and aggregate productivity in the domestic economy? We show that the answer depends importantly on the size of frictions in capital reallocation. Large, unproductive firms find it costly to disinvest or to exit. Thus, the transitional dynamics that follow an import-competition shock feature gradual gains in productivity over several years. In fact, in the short run, trade liberalization may induce a productivity loss by temporarily taking the economy further from a frictionless allocation of resources.

To analyze quantitatively the effects of trade shocks on capital reallocation and productivity, we combine a novel general-equilibrium model of firm dynamics and trade with rich investment data on manufacturing firms in Peru during 2000-2014. The Peruvian economy is an ideal subject for our study, for two main reasons. First, it features a large manufacturing industry that was hit by a substantial import-competition shock after China gained accession to the World Trade Organization. Because the bilateral trade between Peru and China can be approximated by a balanced relation—with Peru importing manufacturing goods from China and mainly exporting commodities—this is a clear case of a trade shock that induces the downsizing of several manufacturing industries in the domestic economy. Second, firm-level data from Peru are uniquely detailed in terms of their information on capital composition and dynamics, and we leverage this feature in our empirical analysis.

We begin our analysis by developing a quantitative general-equilibrium model of firm dynamics, investment, and trade. Monopolistically competitive firms face idiosyncratic productivity shocks, hire workers, and adjust their capital stock subject to partial investment irreversibility and convex adjustment costs. Fixed operations costs determine firms' decisions to continue producing or exit their industry. Partial irreversibility generates an inaction region, where firms wait and see before adjusting their capital in response to productivity shocks. Moreover, irreversibility affects the patterns of selection: Large firms tend to survive even if they have low productivity.

We exploit our micro data to identify the presence of capital-reallocation frictions and quantify their importance in the stationary equilibrium of our model. In the data, returns from investment in physical capital are highly dispersed among manufacturing firms (within industries), consistent with many prior studies on several countries. Moreover, the adjustment of capital to firm-level shocks is asymmetric: Firms with high returns from capital (measured by marginal revenue product of capital - MRPK) tend to invest and grow, while firms that have low returns, because their productivity is low relative to their capital stock, do not disinvest and let their capital depreciate gradually over time. Furthermore, we find that the level of capital plays an important role for firms' survival, conditional on their productivity. We leverage detailed information about capital composition at the firm level to connect this evidence to the underlying role of investment irreversibility.

Starting from the calibrated stationary equilibrium of the model, we simulate an import-competition shock—i.e., the availability of low-cost imported varieties—and compute the transition path of the economy in general equilibrium. To highlight the role of capital-reallocation frictions, we compare our results to the ones that we obtain in a counterfactual economy without frictions.

When the trade shock hits, output prices drop and overshoot their long-run level, because imported goods compete with an initially large domestic manufacturing industry. Because of tough competition in the short run, many firms postpone their investment decisions and enter the inaction region. Furthermore, some small and relatively productive firms choose to exit. As a result of these short-run dynamics on the intensive and extensive margin of reallocation, the cross-sectional dispersion of MRPK increases temporarily and the economy experiences an aggregate-productivity loss of over one percent, relative to the frictionless counterfactual model without irreversibility and convex adjustment costs.

Over time, however, reallocation takes place, the domestic manufacturing industry downsizes, and the efficiency of the allocation of capital gradually increases above its initial level. In contrast, welfare gains from trade are realized early in the transition of our model, because households benefit from low output prices. Thus, our analysis implies that import competition is overall beneficial for both productivity and welfare, but these gains are not synchronized, with productivity improvements significantly lagging welfare gains due to reallocation frictions.

Finally, we return to the micro data to validate the main aspects of our model mechanism. In the data, we measure a trade shock as faster growth in imports from China within each industry. Consistent with the predictions of our model, we find that a high degree of import competition is associated with (i) a temporary increase in the dispersion of MRPK; (ii) a drop in the fraction of firms that expand their capital stock and an associated increase in inaction; (iii) higher exit, based on both productivity and capital levels.

Our paper proceeds as follows. Section 2 discusses our contributions to the literature. Section 3 presents our model. Section 4 describes data sources and measurement. Section 5 provides evidence on reallocation frictions and discusses the model calibration. Section 6 describes our main quantitative findings on the effects of trade shocks on productivity. Section 7 analyzes the empirical effects of trade shocks on capital reallocation and validates the model mechanism. Section 8 discusses additional counterfactual analyses. Section 9 concludes.

2 Related Literature

This paper contributes to three main strands of literature: the literature on the effects of international trade on firm dynamics and productivity; the literature on investment irreversibility; and the literature on aggregate productivity in the presence of frictions in the allocation of capital.

The literature on international trade with heterogeneous firms, starting from the influential work of Melitz (2003), often focuses on steady-state comparisons, i.e., long-term outcomes, and abstracts from investment dynamics. Our contribution is to analyze investment frictions and transitional dynamics.[1] By casting a model of trade with heterogeneous firms into a macro general-equilibrium framework and computing aggregate dynamics, we build on the seminal contribution of Ghironi and Melitz (2005). Moreover, we follow the business-cycle analysis of Clementi and Palazzo (2016) in modeling capital adjustment frictions jointly with entry and exit. We also apply computational tools from the literature on macro models with heterogeneous agents to keep track of the joint distribution of capital and productivity, the key aggregate state variable (as in Khan and Thomas, 2008), along the general-equilibrium transition path of the economy.[2]

[1]A growing body of work in the international trade literature analyzes financial and labor market frictions to understand trade patterns (Antràs and Caballero, 2009; Helpman, Itskhoki, and Redding, 2010; Chor and Manova, 2012; Cuñat and Melitz, 2012; Manova, 2013; Foley and Manova, 2015). Manova (2010) provides a survey of this literature. Relatedly, Bai, Jin, and Lu (2019) study the long-run effects of trade liberalization with heterogeneous firms and factor misallocation. Federico, Hassan, and Rappoport (2019) provide an empirical analysis of the reallocation of bank credit in response to trade shocks.

[2]Our results on the effects of capital-reallocation frictions on the gains from trade appear consistent

A related literature studies other frictions and adjustment dynamics in models of trade. In an early contribution, Chaney (2005) characterizes the transitional dynamics in a Melitz model. Several papers focus on the gradual *expansion* of exporting firms facing frictions such as sunk costs—e.g., Impulliti, Irrazabal, and Opromolla (2013), Alessandria and Choi (2014) and Alessandria, Choi, and Ruhl (2021)—or financing constraints—e.g., Caggese and Cuñat (2013), Chaney (2016), Brooks and Dovis (2020).[3] Our contribution is complementary to this body of work: We analyze the *downsizing* process of domestic firms induced by an import-competition shock.

The emphasis on import competition and downsizing motivates our focus on capital-reallocation frictions, and specifically investment irreversibility. In their seminal paper, Ramey and Shapiro (2001) provide direct evidence of the slow and costly downsizing of the US aerospace industry in the 1990s. Similar frictions in reallocation of used capital play an important role in several macro studies on business cycles (e.g., Veracierto, 2002; Eisfeldt and Rampini, 2006; Bloom, 2009; Khan and Thomas, 2013; Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry, 2018; Lanteri, 2018).[4] Our paper studies the role of these frictions in the context of trade liberalization. To this end, our model combines irreversibility with three relevant margins: monopolistic competition; endogenous entry and exit; and an open-economy dimension.

Finally, since the work of Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), a large literature documents the dispersion in firm-level returns from capital (or MRPK) and the associated aggregate-productivity losses. Asker, Collard-Wexler, and De Loecker (2014) show that a model of firm dynamics subject to idiosyncratic profitability shocks and

with the recent analysis of Berthou, Chung, Manova, and Charlotte (2021), who analyze the role of factor misallocation for the calculation of the gains from trade in response to the "China shock". Furthermore, consistent with our findings on slow adjustment, recent empirical work highlights the role of slow capital dynamics to explain labor-market transitions after trade liberalizations (Dix-Carneiro, 2014; Dix-Carneiro and Kovak, 2017), as well as the effect of capital specificity on the change in product mix and quality upgrading following import-competition shocks (Medina, 2021). Relatedly, Artuc, Brambilla, and Porto (2017) study the impact of capital adjustment costs and costs in labor reallocation across sectors on labor-market dynamics following trade shocks.

[3]Relatedly, Buera and Shin (2013) show that financial frictions also lead to gradual transitional dynamics after other types of reforms, which they model as removal of factor-markets distortions. Guren, Hemous, and Olsen (2015) study the role of sector-specific human capital for trade dynamics. Ravikumar, Santacreu, and Sposi (2019) emphasize the role of capital accumulation for gains from trade in a dynamic multi-country model. Caliendo, Dvorkin, and Parro (2019) analyze the labor-market effects of the China trade shock in a spatial general-equilibrium model of the US economy. Collard and Licandro (2020) study the role of selection and investment irreversibility for welfare in the transitional dynamics of a neoclassical model of firm dynamics.

[4]Relatedly, Baley and Blanco (2021) emphasize the importance of downsizing frictions for Chilean manufacturing firms and propose a sufficient-statistic approach that relates empirical steady-state moments of the investment distribution to aggregate dynamics in response to aggregate shocks. Eisfeldt and Shi (2018) provide a survey of the literature on capital reallocation over the business cycle.

capital adjustment costs—akin to the one proposed by Cooper and Haltiwanger (2006)—is broadly consistent with the observed degree of dispersion in MRPK in several industries and countries. Midrigan and Xu (2014), and more recently David and Venkateswaran (2019), show that MRPKs are not only highly dispersed, but also highly persistent.[5]

We contribute to this literature in two main ways. First, we show empirically that in the context of Peruvian manufacturing, *low* MRPKs are more persistent than *high* MRPKs because of partial investment irreversibility.[6] Second, we show that trade shocks may lead to a temporary increase in dispersion of MRPK.[7]

3 Model of Firm Dynamics and Trade with Capital-Reallocation Frictions

In this section, we present our general-equilibrium model of firm dynamics and trade with capital-reallocation frictions. We begin by describing the model in the absence of trade in output goods, and then introduce import competition.

3.1 Households

Time is discrete and infinite, $t = 0, 1, ...$ An infinitely lived representative household ranks streams of consumption and labor effort according to the following utility function:

$$U_0 \equiv \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \chi N_t \right), \tag{1}$$

where C_t is aggregate consumption and N_t is labor effort, $\beta \in (0, 1)$ is the discount factor and $\chi > 0$ a labor disutility parameter. Aggregate consumption is a constant elasticity of substitution (CES) aggregator of a continuum of measure M_t of different varieties of goods

[5] This literature builds on the seminal model of firm dynamics of Hopenhayn (1992) by introducing capital and adjustment frictions. Hopenhayn (2014) provides a survey of the literature on firm heterogeneity and misallocation.

[6] We obtain this finding by applying statistical methods previously used in the literature on wealth mobility (e.g., Charles and Hurst, 2003). The application of this tool may provide a useful diagnostic for future researchers interested in understanding whether investment frictions mainly affect expanding firms (e.g., financial frictions), or downsizing firms (e.g., irreversibility). Tan (2021) obtains similar results in the context of US entrepreneurial firms.

[7] Relatedly, Gopinath, Ş. Kalemli-Özcan, Karabarbounis, and Villegas-Sanchez (2017) develop a model with financial frictions that delivers an increase in misallocation along the transitional dynamics after an interest-rate shock, consistent with the European experience in the early 2000s.

$$C_t = \left(\int_0^{M_t} c_{jt}^{\theta} dj \right)^{\frac{1}{\theta}} \tag{2}$$

where j is a generic variety, $\theta \equiv \frac{\epsilon-1}{\epsilon}$, and $\epsilon > 0$ is the elasticity of substitution across varieties.

The budget constraint of the household is

$$\int_0^{M_t} p_{jt} c_{jt} dj = N_t + D_t, \tag{3}$$

where we are normalizing the wage to one, i.e. labor is the numeraire of our economy, and D_t are aggregate dividends from ownership of all the firms in the economy.[8]

We can define the CES price index associated with the consumption bundle C_t as $P_t \equiv \left(\int_0^{M_t} p_j^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}$. Using this definition, we obtain the cost-minimizing demand schedule for each variety as

$$p_{jt} = c_{jt}^{-\frac{1}{\epsilon}} P_t C_t^{\frac{1}{\epsilon}} \tag{4}$$

and aggregate expenditure on consumption goods is $\int_0^{M_t} p_{jt} c_{jt} dj = P_t C_t$.

The optimality condition for the consumption-leisure margin is $\chi C_t = \frac{1}{P_t}$, where the left-hand side reports the marginal rate of substitution between consumption and leisure and the right-hand side is the real wage.

3.2 Manufacturing Firms

Consumption good varieties are produced by monopolistically competitive manufacturing firms. Each variety j is produced by a single firm, with production function $y_{jt} = s_{jt} k_{jt}^{\alpha} n_{jt}^{1-\alpha}$, where s_{jt} is idiosyncratic productivity, with stochastic transition $F(s_{jt}, s_{j,t+1})$, k_{jt} is the level of capital, and n_{jt} is labor employed by firm j at time t. The capital share is $\alpha \in (0, 1)$.

Firms internalize the demand function (4) in their input demand decisions. Under the assumption that all manufacturing output is consumed domestically (i.e., $y_{jt} = c_{jt}$ for all j), we get that for a given level of productivity and inputs, revenues are given by

$$p_{jt} y_{jt} = P_t C_t^{\frac{1}{\epsilon}} s_{jt}^{\theta} k_{jt}^{\theta\alpha} n_{jt}^{\theta(1-\alpha)}. \tag{5}$$

We now introduce our assumptions on capital adjustment. To increase the size of their

[8] We could also explicitly assume that the household can trade shares in domestic firms. This would not affect the solution, because in equilibrium the household would own the aggregate value of these stocks in every period, and thus the equilibrium would feature no trade in stocks.

capital stock, firms import capital goods from the foreign economy at constant price Q (relative to labor).[9] We assume that the domestic economy is small, in the sense that it takes the price of capital goods as given. Investment takes one period to become productive.

Firms face two types of frictions in capital adjustment. First, investment is partially irreversible. Second, there are convex costs of capital adjustment. To downsize, firms sell used capital on the secondary market at constant price $q \leq Q$, where strict inequality implies partial irreversibility, whereas equality implies free adjustment, i.e., no irreversibility. The difference $Q - q$ is the cost involved in reallocating a unit of capital previously installed by a firm.

Capital stock at the firm level evolves according to the following accumulation equation:

$$k_{j,t+1} = (1-\delta)\, k_{jt} + i_{jt}, \tag{6}$$

where $\delta \in (0,1)$ is the constant depreciation parameter and i_{jt} is investment. When investment is positive, the firm pays a unit price Q for its new capital goods. When investment is negative, the firm receives a unit price q for each unit of capital sold. We summarize the unit cost of investment goods as follows:

$$Q(i_{jt}) = \begin{cases} Q, & \text{if } i_{jt} \geq 0 \\ q, & \text{if } i_{jt} < 0. \end{cases} \tag{7}$$

Moreover, firms incur convex costs whenever they adjust their capital stock. We specify these costs as quadratic costs:

$$\gamma\left(k_{j,t+1}, k_{jt}\right) \equiv \gamma_0 \left(\frac{k_{j,t+1} - (1-\delta)\, k_{jt}}{k_{jt}} \right)^2 k_{jt}, \tag{8}$$

with $\gamma_0 \geq 0$.

We assume that the labor input is freely adjustable in every period. Hence, the labor choice is static and firms optimally set the marginal revenue product of labor equal to the wage:

$$\theta(1-\alpha) P_t C_t^{\frac{1}{\epsilon}} s_{jt}^{\theta} k_{jt}^{\theta\alpha} n_{jt}^{\theta(1-\alpha)-1} = 1. \tag{9}$$

Each firm incurs an idiosyncratic fixed cost of operations f_{jt}, denominated in units of labor, i.i.d. across time and firms, with distribution $G(f; s)$.[10] After observing this cost and

[9] This assumption is motivated by the observation that Peru imports a substantial share of the investment goods employed in domestic production.

[10] We allow the distribution of the fixed continuation cost to vary depending on productivity; this flexibility improves the model fit to the data. In Section 8.3 we consider a version of the model in which

producing, firms choose whether to pay the cost and continue operations into the following period or to exit at the end of the current period.

Let Z be the aggregate state of the economy, to be fully specified below. Sales net of labor cost, after choosing the optimal level of labor input, are given by $\pi(k, s, Z) \equiv \max_n P(Z)C(Z)^{\frac{1}{\epsilon}} s^\theta k^{\theta\alpha} n^{\theta(1-\alpha)} - n$. The value of a firm equals the present discounted value of its profits, which we express in units of the aggregate consumption goods. Thus, the value of a firm with state (k, s, f, Z) that chooses to continue operations in the following period is defined recursively as follows:

$$V^c(k, s, f, Z) = \max_{i,k'} P(Z)^{-1} \left[\pi(k, s, Z) - f - Q(i)i - \gamma(k', k)\right] + \beta \mathbb{E}\left[\frac{C(Z)}{C(Z')} V(k', s', f', Z') \,|s, Z\right], \tag{10}$$

subject to the capital accumulation equation $k' = (1-\delta)k + i$, and the transition law for the aggregate state $Z' = \Gamma(Z)$. Notice that the continuation value in equation (10) discounts the future value using the household's discount factor, because households own all manufacturing firms. In other words, we explicitly allow general-equilibrium forces to shape micro investment dynamics out of the stationary equilibrium, following the contributions of Khan and Thomas (2008) and Alessandria and Choi (2007).

The value of a firm that chooses to cease operations at the end of the period is

$$V^x(k, s, Z) = P(Z)^{-1} \left[\pi(k, s, Z) + q(1-\zeta)(1-\delta)k - \gamma(0, k)\right], \tag{11}$$

where $\zeta \in [0, 1]$ is an additional irreversibility parameter that applies only when firms exit and sell their whole capital stock, so that the overall resale price of capital in this case is $q(1-\zeta)$. Firms optimally choose whether to continue or exit, that is,

$$V(k, s, f, Z) = \max\left\{V^c(k, s, f, Z), V^x(k, s, Z)\right\}. \tag{12}$$

The investment decision of continuing firms can be characterized by three possible types of actions. If firms are sufficiently productive, given the aggregate state and their current capital level, they expand their capital stock. If they are sufficiently unproductive, they downsize. If their productivity is in an intermediate region, they choose to be in the inaction region and let their capital depreciate. The presence of this inaction region arises because of the assumption of partial irreversibility of investment.

We now introduce entry of new firms. In every period, there is an exogenous constant mass of potential entrants M^p. Each potential entrant receives a signal s^e about

this distribution is independent of s.

its future productivity conditional on entry, drawn from the unconditional distribution of idiosyncratic productivity. Entry entails the payment of an i.i.d. cost f^e, drawn from the distribution $G(f; s^e)$, and denominated in units of labor. Upon entry, idiosyncratic productivity is drawn according to the transition $F(s^e, s')$. Hence, a potential entrant chooses to enter the market if

$$P(Z)^{-1} f^e \leq \max_{k'} -P(Z)^{-1} Q k' - \gamma(k', 0) + \beta \mathbb{E}\left[\frac{C(Z)}{C(Z')} V\left(k', s', f', Z'\right) | s^e, Z\right]. \tag{13}$$

3.3 Commodity Firms

We assume that the economy also produces another good, with amount X_t, which is traded with the foreign economy and, for simplicity, is not consumed domestically. We refer to this good as a commodity, consistent with the fact that a substantial share of Peru's exports are commodities.

Commodities are produced by homogeneous perfectly competitive firms using a linear technology that takes labor as only input: $X_t = A^X N_t^X$, where A^X is a constant productivity parameter and N_t^X is labor employed in the commodity sector.[11] These firms are also owned by the representative household. In equilibrium, the price p^X is constant and satisfies $p^X = \frac{1}{A^X}$. Hence, commodity firms are indifferent between any level of production and make zero profits. Notice that while this assumption implies that the domestic wage expressed in terms of commodity exports is constant, the real wage in terms of domestic consumption, which guides households' and manufacturing firms' decisions, is endogenous because it depends on the manufacturing price level.

3.4 Foreign Economy

We now describe the international-trade patterns in the model. We abstract from fully modeling the production structure in the foreign economy, which is not central for the main insights of the paper. In our initial stationary equilibrium, the foreign economy supplies investment goods at constant price Q and imports commodities from the domestic economy. The trade shock, fully specified below, is a change in the structure of domestic imports: Trade liberalization allows the foreign economy to sell a positive measure of manufacturing varieties at an exogenous price in the domestic market.

[11] It is possible to extend the model and allow for productive capital in this sector. However, many capital goods, especially equipment, are specific at the industry level. Moreover, production of commodities is geographically constrained, thus limiting reallocation of structures as well. Overall, reallocation of capital away from manufacturing industries and toward commodities production is unlikely to be a quantitatively important phenomenon, and for simplicity we abstract from it.

3.5 Recursive Stationary Equilibrium

Our definition of recursive stationary equilibrium is standard. An equilibrium consists of household choices, firm value functions, aggregate price level, and a joint distribution of firm capital and productivity, such that households maximize utility, firms' decisions are consistent with the dynamic program introduced above, and the distribution of firms over individual state variables perpetuates itself. In the interest of space, we relegate a more detailed definition to Appendix D.1.

3.6 Trade Shock and Aggregate Dynamics

In the stationary equilibrium before the trade shock, the total number of varieties M coincides with the number of domestic varieties, which we denote M^D. After the trade shock, the foreign economy sells M_t^F in the domestic market at exogenous price p_t^F. The total number of varieties is thus $M_t = M_t^D + M_t^F$ We model this shock as an unexpected change that hits the economy in its stationary equilibrium. In response to this shock, all endogenous variables evolve over time along a transition path that brings the economy to a new stationary equilibrium with manufacturing imports.

Along this transition path, the key aggregate state variable Z_t in firms' problem is the distribution of individual states, $\lambda_t(k_{it}, s_{it})$. Hence, the value functions in Bellman equations (10), (11), (12), (13) depend on the aggregate state $Z_t \equiv \lambda_t(k_{it}, s_{it})$.

The market-clearing condition for goods is modified, to account for the fact that consumers purchase both domestic and foreign varieties of the consumption good:

$$C_t = \left(\int_0^{M_t^D} y_{jt}^{\theta} dj + \int_{M_t^D}^{M_t} c_{jt}^{\theta} dj \right)^{\frac{1}{\theta}}, \tag{14}$$

where the second term inside the parenthesis represents manufacturing imports. Furthermore, domestic production of commodities for export ensures balanced trade in every period:

$$\int_0^{M_t^D} Q(i_{jt}) i_{jt} dj + p_t^F \int_{M_t^D}^{M_t} c_{jt} dj = p^X X_t. \tag{15}$$

4 Data on Capital Reallocation and Import Competition

In this section, we describe our main data sources on firm dynamics and trade in the context of Peruvian manufacturing firms and introduce our measurement strategy.

4.1 Data Sources

Our analysis combines three main data sources. The first source is the *Encuesta Económica Anual* (EEA) for the period 2000-2014 (Instituto Nacional de Estadística e Informática, 2018). This is an annual firm-level survey administered nationally by the Peruvian Statistical Agency (INEI). The data contain firm balance-sheet information, including variables related to inputs and profitability. Moreover, the EEA provides detailed information on fixed assets, i.e., capital. In particular, the survey disaggregates capital in different categories: land, fixed installations, buildings, machinery and equipment, furniture, computers, and transportation. For our analysis, we consider the six largest manufacturing industries in Peru according to 2-digit CIIU Rev.3: Food and Beverages, Apparel, Textiles, Chemicals, Printing, and Machinery and Equipment n.e.c. (not elsewhere classified). Together, these industries account for the majority of manufacturing employment and sales.[12]

As is often the case with non-census administrative data, while the EEA is effectively a census for large and medium-sized firms, it only surveys a sample of smaller firms.[13] Thus, to compute entry and exit rates, we complement the EEA with the Peruvian firms' registry *(Padrón RUC)*, which is available for the period 2007-2017 (Superintendencia Nacional Tributaria, 2018; Instituto Nacional de Estadística e Informática, 2017). This dataset lists all firms registered with the Peruvian Tax Authority in each of these years, as well as the date of the beginning of legal operations. With this additional information, we can, for instance, identify whether firms that left the survey are still active, and thus distinguish between sample attrition in the EEA and actual exit.

Finally, we complement these firm-level data with the UN Comtrade dataset for information on trade flows at the product level between China and other countries (United Nations, 2018). This information spans the period from 2000 to 2013 and is available at the annual level.[14]

[12] In Appendix A.1, we report details on the number of firms and the size of each industry.

[13] Throughout our sample period, all firms with annual sales above 2 million Soles, i.e., approximately 600 thousand US dollars, are included.

[14] We use the correspondences of the World Integrated Trade Solution (WITS) from the World Bank to convert six-digit Harmonized System (HS) product level codes to CIIU Rev.3. (World Bank, 2018)

4.2 Measurement

We now discuss how we measure the main variables of interest for our empirical analysis.

Capital and Productivity. We use data on value added and inputs to recover productivity measures following the procedure proposed by Asker, Collard-Wexler, and De Loecker (2014), to account for the fact that we do not separately observe output prices and quantities. We assume a standard value for the elasticity of substitution, namely $\epsilon = 4$ (e.g., Bloom, 2009; Asker, Collard-Wexler, and De Loecker, 2014), and recover an industry-specific value for α by computing, for each industry, the median expenditure share on labor in firm's value-added, i.e., $\theta(1-\alpha)$. We then measure (revenue total factor) productivity ω_{jt} as follows:

$$\omega_{jt} \equiv \frac{p_{jt}y_{jt}}{k_{jt}^{\theta\alpha} n_{jt}^{\theta(1-\alpha)}} \tag{16}$$

where $p_{jt}y_{jt}$ is value added, k_{jt} is the capital stock measured as book value, and n_{jt} is the number of employees.[15] Notice that this measure is not equivalent to the definition of TFPR (Total Factor Productivity - Revenue) used, for instance, by Hsieh and Klenow (2009), which is instead $\tilde{\omega}_{jt} \equiv p_{jt}s_{jt} = \frac{p_{jt}y_{jt}}{k_{jt}^{\alpha} n_{jt}^{1-\alpha}}$. Under our assumptions on production and demand, which are consistent with the theoretical model of Section 3, $\omega_{jt} = B_t^{\frac{1}{\epsilon}} s_{jt}^{\theta}$ depends only on aggregate conditions through a demand shifter B_t common across all firms and firm-level physical productivity s_{jt} (often referred to as TFPQ, Total Factor Productivity - Quantity). Conversely, $\tilde{\omega}_{jt}$ is directly tied to marginal revenue products, and thus to distortions or frictions in factor demand.[16]

We measure the marginal revenue product of capital (MRPK) as follows:

$$MRPK_{jt} = \frac{\partial p_{jt}y_{jt}}{\partial k_{jt}} = \theta\alpha \frac{p_{jt}y_{jt}}{k_{jt}}. \tag{17}$$

We also exploit information about the composition of the capital stock at the firm level. In particular, we construct firm-specific depreciation rates by combining information on the share of capital stock invested in different types of assets with the asset-specific depreciation

[15] We deflate all nominal variables with Peru's GDP deflator (Banco Central de Reserva del Perú, 2018).

[16] We provide further details on this distinction in Appendix A.2. To the extent that there is model misspecification, or mismeasurement in ϵ and α in the data, our measure of productivity ω_{jt} may also be contaminated by factors other than physical productivity, such as distortions or adjustment costs. Our analysis implicitly assumes that these forces are not systematically correlated with firm productivity. Following Asker, Collard-Wexler, and De Loecker (2014), we adopt this definition because it makes revenue productivity independent of capital-reallocation frictions (and exogenous to capital and labor choices) under the assumptions of our model, thus providing a more direct empirical counterpart to the exogenous idiosyncratic productivity process we calibrate.

rates in U.S. Fixed Asset Tables (US Bureau of Economic Analysis, 2017). We then measure investment consistent with the capital accumulation equation (6) and these depreciation rates. We provide further details in Appendices A.3 and B.2. In addition, we use the information on the consumption of energy and materials at the firm level to construct measures of capital utilization.

Exit. The EEA provides an accurate measurement of exit for medium and large firms. As far as small firms are concerned, we enhance the measurement of their survival or exit as follows. In the EEA, we define a firm's exit year as the last year the firm is present in the sample (except if it is 2014, which is the last year of our analysis). Next, using the Peruvian firms' registry, we construct the end of operation dates for all firms that are recorded between 2007 and 2017, and we merge this information with the EEA, using firms' tax ID number, whenever we observe it. If a firm "exiting" from the EEA is not observed in the registry at a later date, we keep the measure of exit based on the EEA. If a firm is instead present in the registry at a later date, we replace the exit date based on the EEA with the discharge year from the registry. This procedure leads to a sizable improvement in the measurement of exit for small firms. Overall, the average exit rates decrease from 27.4% to 18.4% for the whole sample period, and from 32.5% to 17.9% during 2007-2013.[17]

Import Competition. We use bilateral trade data to construct two different industry-level measures of exposure to import-competition shocks. First, we use Chinese import intensity, defined as the share of Chinese-originated imports relative to global Peruvian imports, at the 4-digit level of CIIU Rev 3.1 industries, n.[18] We call this measure $ImpInt_{nt} = \frac{Imports_{China,nt}}{Imports_{World,nt}}$. Second, given the steady increase of Chinese imports during the 2000s in most industries, we also create an exposure measure using deviations from import intensity trends by industry. This approach allows us to focus on the responses to (likely) unexpected increases in Chinese import intensity. To measure deviations from trends, we first construct 2-digit industry-specific linear time trends in Chinese import penetration. Then, we obtain the import-competition shock as the difference between 4-digit industry import penetration and its corresponding 2-digit trend. We label this variable $ChComp_{nt}$ and it is our preferred measure for the import-competition shock.

Moreover, to capture increases in Chinese import intensity that derive from productivity enhancement in China rather than from demand trends in Peru, we instrument

[17] We always verify our results related to exit with the post-2007 sample. See Appendix A.1 for the complete exit summary statistics. Unfortunately, our data sources do not allow us to observe transition in and out of informality. Thus, we cannot distinguish the case of a firm that exits and ceases its activity from the case of a firm that exits but continues some operations in the informal sector.

[18] We follow Bloom, Draca, and Van Reenen (2016) and divide Chinese imports by total imports because data on total domestic absorption are not available at the 4-digit industry level.

both $ImpInt_{nt}$ and $ChComp_{nt}$ following the approach of Autor, Dorn, and Hanson (2013). Specifically, we use import intensity and deviations from import intensity trends in several border Latin American countries as instruments for our competition shocks in Peru.

5 Quantifying Reallocation Frictions in Stationary Equilibrium

In this section, we first describe the main empirical features of firm dynamics and investment in the Peruvian manufacturing sector. We then use this evidence to calibrate and validate the properties of the stationary equilibrium of our model.

5.1 Empirical Evidence on Capital-Reallocation Frictions

Consistent with the findings of a large literature on capital misallocation, we find that MRPK displays large dispersion across firms within the same industries, and the relative rankings of MRPKs display persistence over time. Specifically, the standard deviation of (log) MRPK controlling for industry and year fixed effects is 1.47. This dispersion is not driven by a particular industry; rather, it is large in all manufacturing industries. MRPKs are not only highly dispersed in the cross-section of firms, but also highly persistent at the firm level: The within-firm autocorrelation coefficient of (log) MRPK is 0.73.

MRPK dispersion is suggestive evidence of frictions in capital reallocation in response to firm-level profitability shocks. In the presence of frictions, firms respond to profitability shocks by only gradually adjusting their capital stock. Moreover, firm-level persistence in the returns from capital indicates that it takes time for firms to adjust to these shocks.[19]

We now investigate the effects of these frictions on capital adjustment both on the intensive margin—i.e., for continuing firms—and on the extensive margin—i.e., their effects on the exit margin.

[19] Consistent with this view, proposed by Asker, Collard-Wexler, and De Loecker (2014), we find that dispersion in MRPK is positively correlated with dispersion in firm-level productivity within each industry (see Appendix B.1). Nevertheless, we stress there are several possible causes of MRPK dispersion. While we focus on frictions in response to idiosyncratic shocks, as in Asker, Collard-Wexler, and De Loecker (2014), other frictions such as policy distortions may be better captured by permanent "wedges" as in Hsieh and Klenow (2009). We abstract from these sources of inefficiency in our analysis; moreover, in Appendix B.4 we rule out some of these explanations for our main empirical findings.

5.1.1 Asymmetric Capital Adjustment and MRPK Mobility

When we analyze the dynamic evolution of capital at the firm level, we find that firm capital is downwardly rigid, leading to asymmetric adjustment in response to firm-level shocks. First, to illustrate this point, we follow the literature and consider the fraction of negative investment rates. We find that only 11% of adjustments are negative.[20] We will target this moment to calibrate the degree of investment irreversibility.

Next, we uncover more detailed evidence consistent with investment irreversibility on the intensive margin, which we will compare to the corresponding patterns in the stationary equilibrium of our model. In particular, we analyze the dynamics of MRPK, by applying a non-parametric estimation procedure that borrows from the literature on household wealth and income "mobility" (e.g., Charles and Hurst, 2003). We estimate the matrix of transition probabilities across terciles of the distribution of MRPKs. A generic element of this matrix is the probability that a firm in a given tercile of the current distribution of MRPK (within its industry) moves to another given tercile in the following year.

We see the mobility of MRPK as a useful diagnostic for capital-reallocation frictions in the context of models of investment with firm-level profitability shocks. To see why, consider first a firm with high current MRPK, that is, a high level of value-added relative to its level of capital. If the firm responds to its high return from capital by increasing its capital stock, its MRPK will fall accordingly. Hence, a high persistence of high MRPKs would suggest that there are frictions that slow down firms' investment and growth. Conversely, a firm with low MRPK may respond to its relatively low return from capital by downsizing. Therefore, conditional on a given process for the profitability shocks, a high persistence in low MRPKs signals the presence of frictions that render disinvestment costly.

To exploit this insight, we first de-mean MRPKs by regressing them on year and industry fixed effects and then estimate the transition probabilities across terciles of MRPK for all Peruvian manufacturing firms. We report our estimates in the left panel of Table 2. The probability of staying in the bottom tercile is 82%. The probability of staying in the top tercile is lower and equals 77%, which shows that firms adjust more slowly to negative profitability shocks than to positive ones. We also perform the same analysis for the mobility of productivity ω in Appendix B.3.1, and find that, in contrast, high levels of ω are more persistent than low levels. This suggests that the high persistence of low MRPKs is likely due to frictions in capital reallocation rather than asymmetries in the distribution of profitability shocks.[21]

[20] See Appendix B.2 for detailed statistics about the investment distribution.

[21] We obtain similar results in several robustness checks. In particular, we estimate the transition matrix of MRPK allowing for firm exit as an additional state (see Appendix B.3.2). In addition, we construct

Capital composition, depreciation, and MRPK mobility. We now leverage a unique feature of our dataset. For each firm, we observe the portfolio composition of its capital stock among the following categories: land, buildings, fixed installations, machinery, computers, furniture, and transportation equipment. We exploit the fact that the depreciation rate of capital goods is heterogeneous across different types of capital. Because capital composition displays heterogeneity across firms within each industry, the effective average depreciation rate of capital also varies at the firm level.[22] Moreover, some types of capital are more likely to be specific at the firm level (e.g., machinery) and thus effectively more irreversible.

Heterogeneity in the degree of investment depreciation and irreversibility has important consequences for firms' ability to downsize in response to negative profitability shocks. High depreciation implies that a firm can decrease its level of capital relatively fast, even without selling used capital. Conversely, low depreciation implies that the only way a firm can reduce its level of capital is by disinvesting, which is a costly activity in the presence of partial irreversibility. Therefore, if capital irreversibility prevents downsizing, the persistence of MRPK should be more prevalent for firms with low firm-level depreciation rates. Moreover, in the presence of heterogeneity in the degree of investment irreversibility, the persistence of MRPK should largely be accounted for by more specific types of capital.

In Appendix C.1 we formalize these insights in a model with two types of capital with heterogeneous depreciation and heterogeneous degree of irreversibility, and we confirm these predictions in the data. In so doing, we buttress the finding that partial irreversibility plays a crucial role in determining the patterns of capital adjustment in our dataset, particularly the low mobility of MRPK for firms hit by low profitability shocks. In Appendix C.1 we also measure capital utilization at the firm level and find that its distribution is consistent with optimal firm behavior in the presence of downsizing frictions.

A caveat in interpreting this analysis is that the composition of firms' capital stock, even across capital goods with different depreciation rates, is an endogenous choice, and might reflect differences—including unobservable ones—across firms. Developing a theory of endogenous firm-level depreciation rates is beyond the scope of this paper. Our analysis takes heterogeneity in capital composition and depreciation rates as given and is thus meant to produce a further piece of suggestive evidence in favor of the importance of

industry-specific MRPK terciles and perform this analysis separately for the six industries in our sample in Appendix B.3.3. Our results are also robust to the choice of a different number of quantiles. We also estimate the autocorrelation of MRPK including firm fixed effects in Appendix B.3.4, perform a variance decomposition of the dynamics of MRPK in Appendix B.5, and analyze the properties of labor reallocation in Appendix B.8, finding no asymmetric persistence.

[22]See Appendix A.3 for details on the construction of firm-level depreciation rates.

partial irreversibility, by exploiting our uniquely rich information about firm capital.

5.1.2 Capital and Firm Exit

Exploiting the measurement strategy for exit explained in Section 4.2, we now show that conditional on productivity, firms with higher capital are more likely to survive in their industry. We estimate the following probit model, which relates the probability of survival of a firm j in industry n between year t and $t+1$, $Prob(survival_{jnt,t+1})$, with productivity ω_{jnt} and capital stock k_{jnt}. Specifically,

$$\begin{aligned} Survival_{jnt,t+1} &= \begin{cases} 1 & \text{if} \quad z^*_{jnt} > 0 \\ 0 & \text{otherwise} \end{cases} \\ z^*_{jnt} &= \alpha + \beta_1 \log(\omega_{jnt}) + \beta_2 \log(k_{jnt}) + \gamma_n + \gamma_t + \epsilon_{jnt}, \end{aligned} \tag{18}$$

where γ_n are 4-digit industry fixed effects and γ_t are year fixed effects that we include to account for the fact that our measurement of exit is potentially noisier for years in which we cannot match the EEA survey with the firm registry.

The estimated coefficients are $\beta_1 = 0.29$ (0.02) and $\beta_2 = 0.21$ (0.01), with standard errors in parenthesis clustered at the firm level. Conditional on productivity, firms with a lower capital stock have a significantly higher probability of exiting their industry.[23] Conditional on a level of capital, unproductive firms are more likely to exit. Accordingly, the estimated survival isoprobability curves (shown in Appendix B.6) are downward sloping; we will target this slope in our calibration. This result is also robust to only considering the period post-2007, for which we use the firm registry, as Appendix B.6 illustrates.

Investment irreversibility is consistent with these empirical patterns of selection. Firms with a high level of capital face a larger cost of exiting and have a higher option value of staying in business. Thus, they are more likely to survive, conditional on their level of productivity. In contrast, many models of trade imply that productivity is a sufficient statistic for survival.[24]

Capital composition, depreciation, and selection. To further relate the patterns of selection with investment irreversibility, we leverage our measure of firm-level depreciation

[23] Lee and Mukoyama (2015) provide evidence of an unconditional relationship between size (measured by employment) and exit in US manufacturing.

[24] Consistent with this literature, in Section 5.3 we demonstrate that the contours of the survival probability in the absence of capital-reallocation frictions are horizontal in the capital-productivity space; that is, the survival probability does not depend on the level of capital.

rates again. If, conditional on productivity, firm size matters for survival due to investment irreversibility, the effect of capital on survival, relative to productivity, should be more critical for firms operating capital with a low depreciation rate. Firms holding assets with high depreciation, in contrast, could downsize by letting their capital depreciate. Hence, their option value of staying on the market should depend less on their capital stock.

We operationalize this intuition by estimating our prediction model for survival, fully interacted with firm-level depreciation. In Appendix B.7 we show that indeed there is a negative relationship between the relative effect of capital stock on survival and firm-level depreciation rates. For firms holding high-depreciation assets, productivity is relatively more important than the level of capital in understanding selection. Subject again to the caveat that the composition of capital is an endogenous variable, these results provide additional support for the role of investment irreversibility in explaining the patterns of selection.

5.2 Calibration of Stationary Equilibrium

Building on this empirical evidence on capital reallocation, we now describe our choices for parameter values of the model, reported in Table 1. Our strategy is to set the preference parameters to values in a standard range in the investment literature and to leverage our micro evidence on Peruvian manufacturing firms to inform the values of parameters related to technology and firm dynamics, using the stationary equilibrium of our model.

Preferences. A period in our model coincides with a year, reflecting the frequency of our data. We set the discount factor to induce a 4% interest rate and the labor disutility parameter as in Lanteri (2018). Consistent with our measurement assumptions, we also set the value of the elasticity of substitution across varieties following the literature (e.g., Bloom, 2009; Asker, Collard-Wexler, and De Loecker, 2014).

Technology and reallocation frictions. We set the parameter values related to technology to match salient moments of our data on Peruvian manufacturing. Consistent with the procedure described in Section 4.2, given the elasticity of substitution ϵ, we measure the median labor share and use it to inform our calibration of the capital share α. Next, we set δ equal to the median firm-level depreciation rate.[25] We use the exogenous mass of potential entrants M^P to normalize the real wage $1/P$ to equal one third (as in Clementi and Palazzo, 2016); we then set the price of new investment Q goods equal to the price

[25]While in the empirical analysis and in the extended model described in Appendix C.1 we allow for heterogeneous depreciation rates, for our quantitative model analysis we assume a common depreciation rate across firms. This simplifies the computation; moreover, our empirical targets are robust to measuring investment assuming a homogeneous depreciation rate.

level P in the stationary equilibrium, consistent with the standard assumption in the real-business-cycles literature; we normalize productivity in the commodity sector $A^X = 1$.

We parameterize idiosyncratic productivity as an AR(1) process in logs and we discretize it with 31 nodes using the method of Tauchen (1986); we assume that the distribution of the fixed continuation (and entry) cost is uniform over the interval $\left[0, \eta_0(1 - (1+s^\theta)^{\eta_1} + (1+s^\theta)^{\eta_2})\right]$, where s is the current realization of idiosyncratic productivity (and the power $\theta = \frac{\epsilon - 1}{\epsilon}$ maps physical productivity into revenue productivity).[26] Next, we use a method-of-moments procedure to jointly determine the values of $(\rho, \sigma, q, \zeta, \gamma_0, \eta_0, \eta_1, \eta_2)$ to closely match the following key moments: (i) autocorrelation of revenue productivity ω; (ii) standard deviation of ω; (iii) frequency of negative investment; (iv) standard deviation of investment rates; (v) average slope of survival isoprobability lines (equation (18)); (vi) exit rate; (vii) average capital stock of exiting firms (relative to continuing firms); and (viii) average productivity of exiting firms (relative to continuing firms).[27] This procedure ensures that the stationary equilibrium of the model is aligned with the main empirical facts about capital reallocation on both the intensive and extensive margins.[28]

The estimated degree of irreversibility for continuing firms, $1 - \frac{q}{Q}$, implies that firms lose approximately 41% of the value of their used capital when they downsize. This estimate is close to the high end of existing estimates in the literature. For instance, Bloom (2009) estimates a resale loss of 34% using US data. This is consistent with the presence of large frictions in our empirical setting. When firms exit, they lose an additional 18%.

[26] The flexible dependence of the upper bound of the distribution on productivity s helps us to reproduce the average characteristics of exiting firms. In Section 8.3, we discuss a simplified version of the model, in which the distribution of f is independent of s.

[27] As far as the idiosyncratic productivity process is concerned, we target the properties of residualized revenue productivity ω, after controlling for industry and time fixed effects. We account for the effect of endogenous firm selection on the distribution of measured productivity; we thank Yan Bai for this helpful suggestion.

[28] We report all numerical targets in Appendix D.2. Because our calibration slightly underpredicts the high dispersion of firm revenue productivity, we also perform a robustness check of our main results with respect to the dispersion of idiosyncratic shocks in Appendix D.8. Section 5.3 discuss several additional untargeted empirical moments that the model reproduces closely.

Parameter	Value	Target / Source
β	0.96	Literature
χ	2.15	Literature
ϵ	4	Literature
α	0.396	Capital Share
δ	0.105	Depreciation Rate
ρ	0.759	Autocorrelation of ω
σ	0.79	Standard deviation of ω
q/Q	0.591	frequency of negative investment
ζ	0.176	Slope of exit thresholds
γ_0	0.001	Standard deviation of i/k
η_0	0.059	Exit rate
η_1	5.201	Relative size at exit
η_2	5.2025	Relative productivity at exit

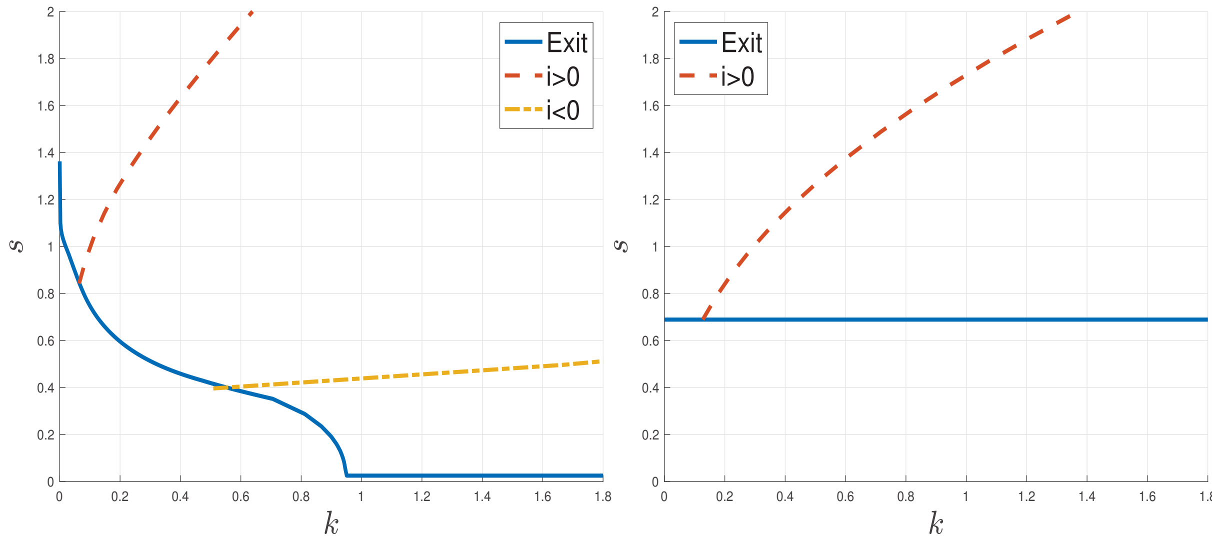
Table 1: Parameter Values.

5.3 Properties of Stationary Equilibrium and Model Validation

We now describe the main properties of the stationary equilibrium and compare several untargeted moments in the model and in the data.

Investment and exit thresholds. In the left panel of Figure 1, we show the thresholds for positive investment (dashed line), negative investment (dashed-dotted line), and exit (for illustration purposes, we show the threshold conditional on drawing the average continuation cost from the distribution $G(f;1)$, solid line), as functions of capital stock on the x-axis and productivity on the y-axis. Firms below the exit threshold choose to exit. Among continuing firms, those with individual states above the positive investment threshold increase their capital stock; firms below the negative investment threshold downsize; the remaining ones are in the inaction region and let their capital depreciate.

The model induces selection based on capital, conditional on productivity, consistent with the empirical evidence. Specifically, the exit threshold is downward sloping, meaning that smaller firms are more likely to exit. This is a direct consequence of partial irreversibility, because in the presence of this friction, firms with larger capital stock find it more costly to downsize and exit. Furthermore, the option value of staying in business,



(a) Baseline model (b) Frictionless model

Figure 1: Thresholds for Investment, Disinvestment, and Exit.

Notes: The left panel (a) displays the thresholds for exit (solid line), positive investment (dashed), and negative investment (dashed-dotted) as functions of capital (x-axis) and productivity (y-axis) in the baseline model. The right panel (b) displays the exit threshold (solid line) and investment/disinvestment threshold (dashed) in the frictionless model.

hoping for a positive idiosyncratic shock, is larger for firms with a high level of capital. For comparison, the right panel of Figure 1 displays the exit threshold (solid line) implied by a "frictionless" model—i.e., with $q = Q$, $\zeta = 0$, and $\gamma_0 = 0$. In this model, the exit decision depends only on productivity. Hence, the exit threshold is horizontal. Moreover, the absence of irreversibility implies that there is no inaction region. Firms above the dashed line increase their capital, and firms below this same line decrease their capital.[29]

Investment responsiveness and lumpiness. We now examine the responsiveness of firm investment to shocks and its degree of "lumpiness". We provide further details on this analysis in Appendix D.2, where we also consider a richer version of the model with three adjustment costs, namely partial irreversibility, convex cost, and fixed cost of adjustment.

First, we measure the responsiveness of firm investment to changes in MRPK; to this end, we estimate a reduced-form relation between investment rate and (log) MRPK at the firm level, also controlling for firm effects, in both the stationary equilibrium of the model and the data (where we also include industry and year fixed effects). The estimated coefficient is close in data and baseline model (approximately 0.48 in the data and 0.50 in

[29]In Appendix D.4, we also compare several aggregate variables in our model with their counterpart in the frictionless model.

the model). In contrast, the frictionless model significantly overpredicts the responsiveness of firm investment to MRPK, namely by a factor of (approximately) four.

Next, we examine the degree of lumpiness of micro investment in our model and in the data. We do this in several ways. We begin this analysis by comparing the unconditional frequency of investment spikes in the model and in the data. Cooper and Haltiwanger (2006) focus on US data and define spikes as adjustments over 20% of the capital stock, in absolute value. According to this metric, the frequency of lumpy adjustments is 0.47 in our data, showing a substantial degree of lumpiness, and 0.28 in our model. However, we should account for the fact that our empirical setting features significantly more dispersed productivity shocks, and, as a result, more dispersed investment rates than in Cooper and Haltiwanger (2006). Accordingly, we adjust the threshold for a spike by a factor equal to the ratio of the standard deviation of micro investment in our data and in their data, obtaining that spikes are adjustments above 49% of the capital stock. With this definition, we find that the model is closely aligned with the data, despite lumpiness not being a calibration target. Specifically, the fraction of lumps is approximately 0.20 in our data and 0.23 in the model.[30]

Furthermore, we consider additional measures related to the distribution of large capital adjustments at the firm level. In particular, we measure the average capital age as well as the average time that elapses between consecutive large adjustments, building on Baley and Blanco (2021). Finally, we consider the typical size of large capital adjustments, as well as the level of investment in years surrounding a large adjustment. Along all these dimensions, the model is broadly in line with the empirical evidence, as we show in detail in Appendix D.2.

MRPK dispersion and mobility. Our model is consistent with substantial dispersion in MRPK across firms. Specifically, the standard deviation of (log) MRPK is 1.47 in the data, 1.25 in the baseline model, and 1.07 in the frictionless model, which, despite the absence of frictions, generates MRPK dispersion because of time-to-build in investment and dispersed innovations to firm productivity.

Furthermore, as we discussed above, in the data we observe higher persistence of MRPK for firms with low MRPK. In Table 2, we report the estimated transition probabilities for MRPK terciles in both data (left panel) and model (right panel). Capital-reallocation frictions are crucial in delivering both persistence in MRPK and, importantly, *asymmetry*

[30] As is typically the case in models with non-convex adjustment costs, our model produces a better empirical fit for the distribution of larger capital adjustments than for smaller adjustments, which are compressed in the inaction region in the model and display a smoother distribution in the data (Cooper and Haltiwanger, 2006). In models with fixed costs, this limitation can be addressed by assuming that fixed costs do not apply to sufficiently small investment (Khan and Thomas, 2008).

in the persistence of MRPK, with higher probabilities of remaining low-returns firms; in contrast, the frictionless model predicts that there is no persistence in MRPK, as we display in Appendix D.2.

		at $t+1$		
		1	2	3
Tercile at t	1	0.82	0.16	0.02
		(0.00)	(0.00)	(0.00)
	2	0.19	0.69	0.12
		(0.00)	(0.01)	(0.00)
	3	0.03	0.20	0.77
		(0.00)	(0.01)	(0.01)

(a) Empirical Mobility of MRPK

		at $t+1$		
		1	2	3
Tercile at t	1	0.62	0.28	0.10
	2	0.39	0.37	0.25
	3	0.16	0.34	0.50

(b) Mobility in the Model

Table 2: Mobility (Transition Probabilities) of MRPK.
Notes: The table reports the estimated transition probabilities for terciles of the MRPK distribution. The left panel refers to empirical estimates (bootstrapped standard errors in parentheses); the right panel refers to the model.

Overall, the stationary equilibrium of the model is consistent with the main facts about capital reallocation that we document in the data. All of these properties are induced by the calibrated capital-reallocation frictions.

5.4 Comparison with Literature on Adjustment Costs

Building on a large literature on micro investment, our model features two types of capital adjustment costs, a convex cost, and a non-convex cost—namely, partial irreversibility. In their seminal contribution, Cooper and Haltiwanger (2006) focus on US firms and consider an array of adjustment costs, including the ones in our model, as well as fixed costs of investment. They estimate a smaller degree of irreversibility—between a 2.5% and 20.5% resale loss depending on specifications—than ours, which is instead closer to the estimate in Bloom (2009)—namely a 34% resale loss. More recent papers in the literature on investment with heterogeneous firms feature a combination of a convex cost and a non-convex cost, as our model. For instance, Asker, Collard-Wexler, and De Loecker (2014) analyze investment dynamics in a large set of countries by estimating a model with a convex and fixed cost.

We explore the reasons behind a larger estimated degree of partial irreversibility relative to Cooper and Haltiwanger (2006) (Asker, Collard-Wexler, and De Loecker, 2014, do not consider partial irreversibility). While it is challenging to make exact comparisons between models that are not quite identical (in ours, adjustment costs also affect moments related to entry and exit), an important reason is that both our data and theirs share a similar degree of asymmetry in the investment distribution, with only approximately 10% of observations displaying negative investment; however, the volatility of productivity shocks is substantially higher in our data than in US data. As a result, to match the frequency of disinvestment, our calibration procedure requires a larger capital-reallocation friction. To verify this argument, we experiment by decreasing the degree of irreversibility by half in our model, leaving all other parameter values—including productivity dispersion—unchanged. Consistent with our conjecture, we find that the frequency of negative investment nearly doubles. Moreover, also consistent with this explanation, Lanteri (2018) matches the frequency of negative investment in US data in a model of US firm investment with only partial irreversibility, calibrating a relatively small degree of irreversibility (a resale loss of approximately 7%).

6 Trade Shocks, Capital Reallocation, and Aggregate Productivity

In this section, we use the calibrated model to study the effects of an import-competition shock, with an emphasis on the role of capital-reallocation frictions for productivity dynamics.

6.1 Aggregate Dynamics

We begin by discussing the effects of the import-competition shock on aggregate variables both in the long-run and along the transition. We set the values of the two parameters governing the magnitude of the trade shock (i.e., the mass of additional varieties M^F and their price p^F) to match two targets, namely the long-term import penetration of Chinese manufacturing goods in Peru (Chinese imports divided by domestic absorption), and the price of Chinese imports (relative to domestic goods). Specifically, at the end of our sample, the import penetration of China in Peru is approximately 10%. Over the period 2001-2013, the price index of Chinese manufacturing goods in Peru averages approximately one half the price of domestically produced manufacturing goods.[31]

[31] We use Peruvian firms' export prices to proxy for the price of domestic goods.

6.1.1 Long-Run Effects of Import Competition

We compute the final stationary equilibrium with trade in consumption goods and compare several aggregates of interest with their initial values. Consumption increases by 0.78%, which—given our assumed preferences—implies an equal decline in the price level. Capital stock, hours in manufacturing, and mass of domestic active firms decrease by approximately 10%. Domestic manufacturing output, defined as $Y_t^D \equiv \left(\int_0^{M_t^D} y_{jt}^{\theta} dj\right)^{\frac{1}{\theta}}$, declines by approximately 12%.[32] This decline is driven by increased competition for domestic manufacturers, which induces substitution of domestic demand toward imported varieties, and reallocation of labor toward the production of commodities for export. We report these results in Table D7 in Appendix D.4.

6.1.2 Transitional Dynamics

Next, we analyze the equilibrium transition path that takes the economy from the initial stationary equilibrium to the final one. Appendix D.3 describes our solution method, which keeps track of the joint distribution of firm capital and productivity. We find that convergence to the final steady state takes approximately 20 years. Although the shock is a sudden and permanent change in the set of varieties available to domestic consumers and the price of imported varieties is constant, import penetration is increasing over time, from around 8% on impact to around 10% when the economy converges to its new steady state.

Figure 2 displays the transitional dynamics of the aggregate price level (top left), aggregate capital stock (top right), domestic manufacturing output (bottom left), and mass of active firms (bottom right). Noticeably, after the trade shock hits, the increase in competition induces a drop in the price level, which *overshoots* its long-run value, and then gradually recovers as the domestic industry adjusts to the new competitive environment. On impact, the competitive pressure induced by import competition is strongest. Over time, domestic manufacturing firms downsize, leading to a recovery in output prices. The labor input employed in manufacturing (which we display in Appendix D.4) also drops in response to the shock.

As the figure shows, these aggregate dynamics are similar in the baseline model (solid lines) and the frictionless model (dashed line), with the difference that aggregate capital and mass of active firms drop faster in the absence of reallocation frictions. Next, we zoom

[32] Notice that this expression for domestic manufacturing output follows from our assumption that domestic and foreign varieties are equally substitutable. Under this assumption, we have $C_t = \left(\int_0^{M_t^D} y_{jt}^{\theta} dj + \int_{M_t^D}^{M_t} c_{jt}^{\theta} dj\right)^{\frac{1}{\theta}} = \left((Y_t^D)^{\theta} + (C_t^F)^{\theta}\right)^{\frac{1}{\theta}}$ with $C_t^F \equiv \left(\int_{M_t^D}^{M_t} c_{jt}^{\theta} dj\right)^{\frac{1}{\theta}}$ denoting manufacturing imports.

in on the different implications of these two models for productivity dynamics.

6.2 Productivity Dynamics: the Role of Capital-Reallocation Frictions

We now show that capital-reallocation frictions induce a short-run loss in domestic aggregate productivity in response to the import-competition shock. Specifically, the distance in aggregate productivity between our baseline model and the frictionless model widens for several years as a result of heightened competition in the short run. We use our calibration to quantify this effect.

Aggregate total factor productivity (TFP) is

$$TFP_t \equiv \frac{Y_t^D}{K_t^\alpha N_t^{1-\alpha}}. \tag{19}$$

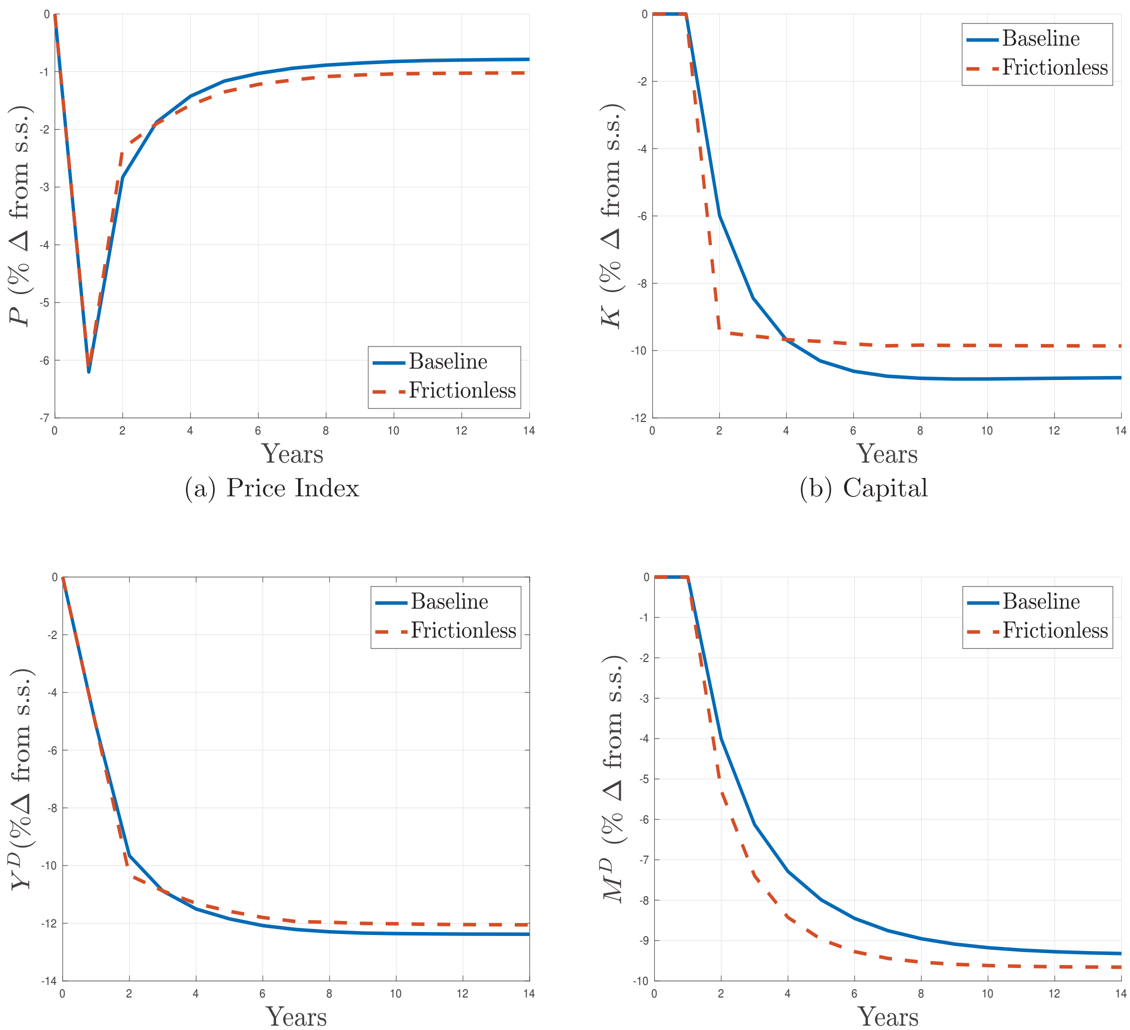
In our model with CES aggregation, TFP_t is affected both by the distribution of capital and productivity of active firms and by the total number of active firms, due to a love-for-variety effect. For this reason, we also introduce the following "adjusted" measure:

$$TFP_t^{Adj} \equiv TFP_t \times (M_t^D)^{-\frac{1-\theta}{\theta}}, \tag{20}$$

where the second term performs a normalization, offsetting the mechanical effect of a time-varying number of firms on aggregate productivity, due to our assumption of love for variety.[33] We perform this normalization to isolate the effects of the allocation of capital on aggregate productivity and we begin our analysis by focusing on the dynamics of TFP_t^{Adj}; then, in Section 6.3.4 we also explore the love-for-variety channel and the dynamics of TFP_t.

In the left panel of Figure 3, we illustrate the dynamics of adjusted TFP in our calibrated model and in the frictionless model. The figure portrays percentage changes relative to the initial stationary equilibrium. Notice that the stationary equilibria (initial and final) of the baseline model differ from the respective stationary equilibria (initial and final) of the frictionless model; in particular, in the initial stationary equilibrium, capital-reallocation frictions imply that TFP^{Adj} is 14.1% higher in the frictionless economy.

[33] To derive this correction term, consider two economies, A and B. In both economies, all firms employ identical levels of inputs k and n and produce identical levels of output $y = k^\alpha n^{1-\alpha}$, which are then aggregated in a CES fashion as in our model. However, there are M_A firms in economy A and M_B firms in economy B. Then, aggregate output is $M_A^{\frac{1}{\theta}} y$ in economy A and $M_B^{\frac{1}{\theta}} y$ in economy B. Hence, TFP is $M_A^{\frac{1-\theta}{\theta}}$ in economy A and $M_B^{\frac{1-\theta}{\theta}}$ in economy B.



(a) Price Index

(b) Capital

(c) Output: Manufacturing

(d) Mass of Active Firms

Figure 2: Aggregate Dynamics After the Trade Shock.

Notes: The figure displays the transitional dynamics of the price index of manufacturing varieties (a), aggregate capital stock (b), domestic manufacturing output (c), and mass of active manufacturing firms (d). The trade shock hits the economy in period 1. The y-axes of all panels report percentage changes relative to the initial stationary equilibrium.

In our baseline economy, TFP_t^{Adj} falls by 0.4% in response to the import-competition shock and then gradually increases, eventually displaying a long-run increase of approximately 0.9%. In contrast, in the frictionless model, this measure of productivity increases by 0.8% on impact and then overshoots its long-run level for a few years. As a result of these different dynamics, the gap in TFP_t^{Adj} between the frictionless model and the baseline model, expressed as a percentage of TFP_0^{Adj} in the baseline model, widens from 14.1% in stationary equilibrium to 15.5% at $t = 2$, implying a short-run efficiency loss of 1.4%. Moreover, the short-run efficiency gap induced by the shock remains sizable for over 5 years after the shock.

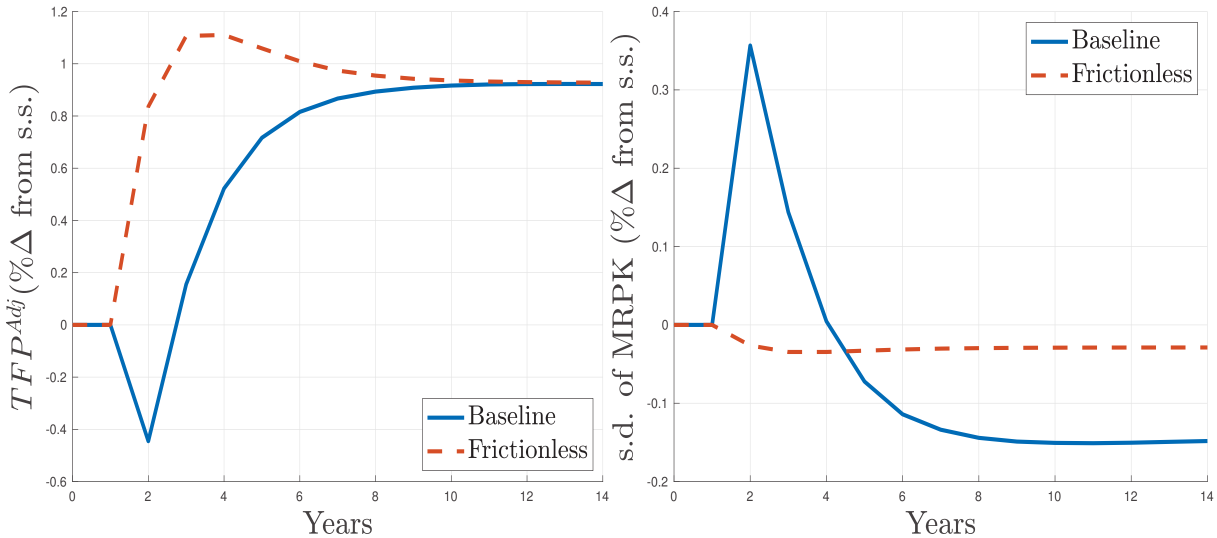
In the right panel of Figure 3, we display the time series of the cross-sectional dispersion of (log) MRPK, again comparing our economy with the frictionless economy. Both series are expressed in terms of percentage changes from the respective initial stationary-equilibrium values. The import-competition shock induces a short-run increase in the dispersion of MRPK. This measure is not a sufficient statistic for aggregate productivity in our model, because entry and exit dynamics change the distribution of idiosyncratic productivity of active firms; nevertheless, a short-run increase in MRPK dispersion suggests that the efficiency of the allocation of capital decreases in response to the shock. In contrast, MRPK dispersion displays a negligible change in the frictionless economy. The figure also shows that the dispersion of MRPK decreases in the long run, especially in the baseline model.

6.3 Inspecting the Mechanism

We now analyze the mechanism that connects an increase in import competition with a short-run loss in aggregate productivity. Specifically, we describe the roles of investment and firm selection for the allocation of capital. We then discuss the love-for-variety effect.

6.3.1 Investment and Inaction

The left panel of Figure 4 displays the thresholds for positive and negative investment before and immediately after the trade shock hits the economy (solid and dashed lines, respectively). The drop in the price level, combined with expectations of its increase as the economy adjusts, implies that even relatively productive firms decide to postpone their investment decisions. An outward shift in the threshold for positive investment and a smaller change in the threshold for negative investment result in a widening of the inaction region; approximately 2% of firms postpone investment. Moreover, firms that invest reduce their investment. For these reasons, the allocation of capital moves further apart from the frictionless allocation, and the distribution of MRPK becomes more dispersed.



(a) Adjusted Aggregate TFP (b) Standard deviation of MRPK

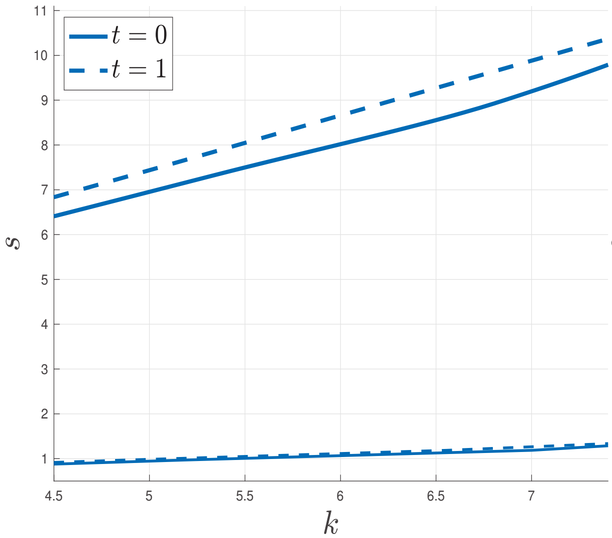
Figure 3: Aggregate TFP and MRPK Dispersion.

Notes: The left panel (a) displays the path of aggregate TFP, corrected for changes in the mass of active firms (TFP_t^{Adj}, equation (20)), in the baseline model (solid line) and in the frictionless model (dashed line). The right panel (b) displays the path of the dispersion of MRPK in the baseline model (solid line) and in the frictionless model (dashed line). The y-axes report all variables expressed as percentage changes relative to the initial stationary equilibrium. Notice that the stationary equilibria (initial and final) of the baseline model differ from the respective stationary equilibria (initial and final) of the frictionless model.

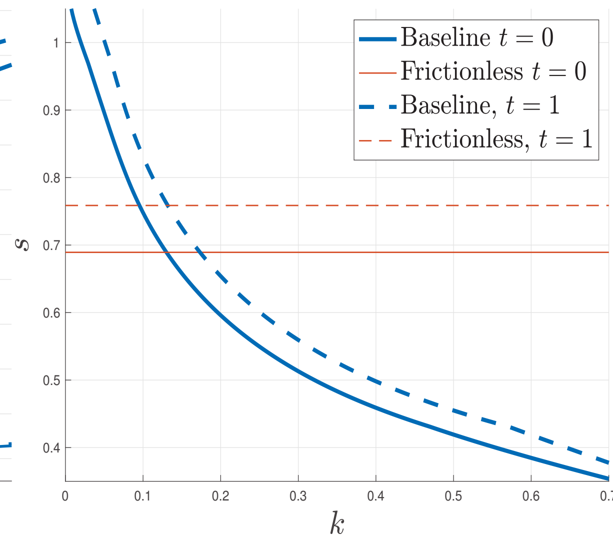
6.3.2 Selection

In the right panel of Figure 4, we show the exit thresholds under both the baseline calibration (thick lines) and in the frictionless model (thin lines). For each model, the solid line denotes the exit threshold in the initial stationary equilibrium, whereas the dashed line denotes the exit threshold after the trade shock hits the economy in the first period.

As the figure shows, the shock shifts the exit thresholds up, indicating a larger exit flow. The exit rate increases by approximately 1.5 percentage points on impact. Moreover, consistent with the patterns of selection in stationary equilibrium, the shock induces selection as a function of both productivity and capital in our baseline model. Specifically, some relatively productive—but small—firms optimally exit. In contrast, in the frictionless model the exit rate increases by approximately 3.3 percentage points and productivity is the only determinant of exit. The entry rate (flow of entrants at t divided by mass of active firms at t) drops by 2.5 percentage points in the baseline model, and by 1.9 percentage points in the frictionless model.



(a) Thresholds for Investment and Disinvestment



(b) Thresholds for Exit

Figure 4: Investment and Exit Thresholds Before the Trade Shock and on Impact.

Notes: The left panel (a) displays the effect of the trade shock on investment and disinvestment thresholds in the baseline model. This right panel (b) displays the effect of the trade shock on exit thresholds in the baseline model (thick lines) and frictionless model (thin lines). The solid lines refer to the initial stationary equilibrium ($t = 0$). The dashed lines refer to the period in which the trade shock hits ($t = 1$). The x-axis reports capital and the y-axis reports productivity.

6.3.3 Decomposition

We now decompose the quantitative effects of the intensive (investment) and extensive (selection) margins of reallocation for aggregate productivity. To isolate the role of the intensive margin, we re-evaluate TFP_2^{Adj} assuming that at $t = 1$ (in response to the shock) firms use the same decision rules for entry and exit as in the stationary equilibrium, but they use the equilibrium investment decision rules of $t = 1$. In this case, we obtain a decline in aggregate productivity of 0.7% relative to the stationary equilibrium in the baseline model and no decline in the frictionless model. Moreover, MRPK dispersion increases by almost 0.5% in the baseline model. Comparing this counterfactual with the overall dynamics displayed in Figure 3, we find that the equilibrium selection patterns at $t = 1$ contribute positively to aggregate productivity by approximately 0.3 percentage points in the baseline model and 0.8 percentage points in the frictionless model. Consistent with these findings, in Appendix D.4, we plot the dynamic response of the average productivity s of active firms, which increases sluggishly in the baseline model and jumps in the frictionless model, overshooting its long-run level.

6.3.4 Capital Allocation vs. Love of Variety

As we explain in Section 6.2, the adjusted measure TFP_t^{Adj} (equation (20)) relies on a normalization because the number of firms has a positive mechanical effect on TFP_t, even without any changes in the cross-sectional allocation of inputs. We now examine this love-for-variety effect in response to the trade shock.

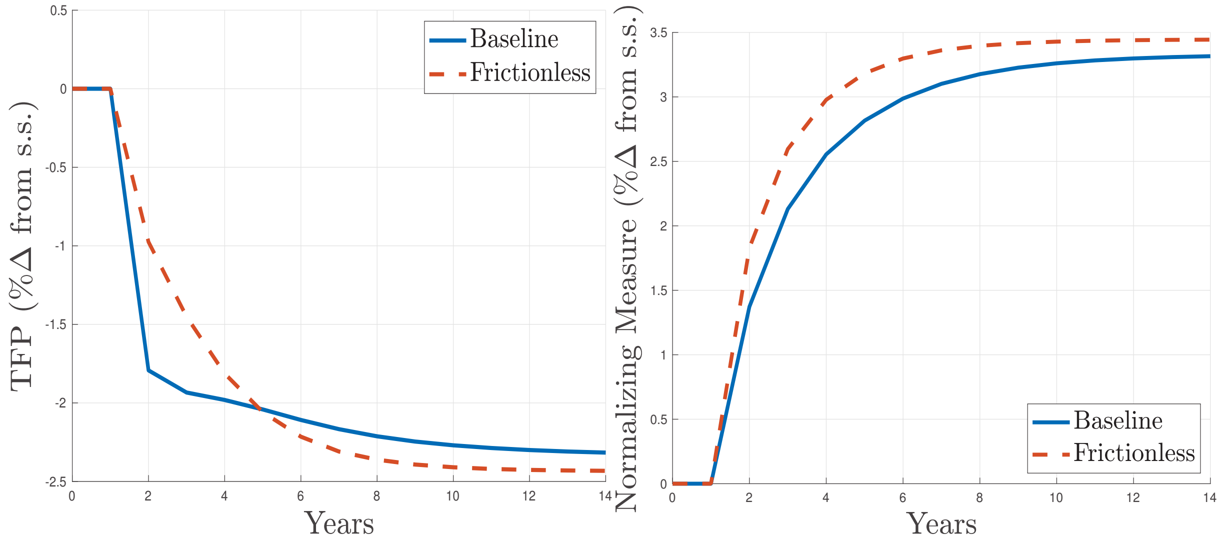
In Figure 5 we display TFP_t (left panel) and the correction term $(M_t^D)^{-\frac{1-\theta}{\theta}}$ in equation 20 (right panel), thus providing a further decomposition of TFP_t^{Adj}. We compare again our calibrated model (solid lines) with the frictionless economy (dashed lines). Because the import-competition shock increases the level of competition in the domestic economy, the number of active domestic firms drops in both models, inducing an increase in the correction term $(M_t^D)^{-\frac{1-\theta}{\theta}}$. However, as we explained above, capital-reallocation frictions dampen the firm exit flow in our model, relative to the frictionless economy. As a result, the number of varieties decreases by less in our model, slightly dampening the short-run TFP loss. Quantitatively, the gap in TFP_t between the frictionless model and the baseline model, expressed as a percentage of TFP_0 in the baseline model, widens from 8% in stationary equilibrium to 9% at $t = 2$.

In the long run, the love-for-variety effect is quantitatively powerful. By comparing Figures 3 and 5, we see that when we normalize productivity by the number of firms, the trade shock induces a long-run improvement in TFP, because of reallocation and selection, whereas when we do not adjust the measure of productivity, the decrease in the number of firms dominates the changes in the allocation of capital and we obtain a 2.3% decrease in TFP_t.[34] However, the number of domestic varieties is not critical for welfare, because households enjoy the presence of cheap imported goods. We further discuss welfare effects in the next subsection.

6.4 Welfare

We conclude this section by discussing the welfare effects of the trade shock in our model. These results are reported in detail in Appendix D.4. We find that accounting for transitional dynamics leads to welfare gains from the trade shock equal to approximately 0.19% of permanent consumption, as consumption gains are partly offset by higher labor input, due to the expansion of the export sector. A simple steady-state comparison, in our dynamic model with capital, would misleadingly suggest welfare losses. To better understand

[34] This effect is consistent with the findings of Fattal Jaef (2018), which shows that removing firm-level distortions may have effects of opposite sign on aggregate productivity through changes in the allocation of inputs and changes in the number of varieties.



(a) Aggregate TFP (b) Love-for-Variety Correction

Figure 5: Aggregate TFP and Love-for-Variety Effect.

Notes: The left panel (a) displays the path of aggregate productivity TFP_t (equation (19)) in the baseline model (solid line) and in the frictionless model (dashed). The right panel (b) displays the path of the term $(M_t^D)^{-\frac{1-\theta}{\theta}}$. Both variables are expressed as percentage changes relative to respective initial stationary-equilibrium values. The y-axes report all variables expressed as percentage changes relative to the initial stationary equilibrium. Notice that the stationary equilibria (initial and final) of the baseline model differ from the respective stationary equilibria (initial and final) of the frictionless model.

the importance of accounting for the transition, recall that after the trade shock consumption initially overshoots its long-term value as consumers benefit from the favorable terms of trade induced by cheap manufacturing and a constant price of exported commodities.[35] Hence, while productivity gains materialize slowly over time, welfare gains materialize early in the transition. However, we also find that the welfare gains are more muted under our baseline calibration relative to a frictionless model, because of the sluggish productivity gains discussed above. Overall, welfare gains from the trade shock would thus be almost twice as large in the absence of capital reallocation frictions.[36]

[35]The overshooting result and its welfare implications appear to be consistent with the recent analysis of Alessandria, Choi, and Ruhl (2021).

[36]We highlight that while the model carefully targets several salient features of firm dynamics to obtain quantitative predictions about productivity, it abstracts from other features of the economy that are relevant for a quantitative welfare analysis, such as household heterogeneity and the related distributional effects of trade.

7 Validating the Mechanism: Empirical Evidence on Trade Shocks and Capital Reallocation

In this section, we analyze empirically the effects of Chinese import competition on capital reallocation in Peruvian manufacturing. We first introduce China's accession to the WTO as a significant import-competition shock for Peruvian manufacturing firms. We then use cross-industry variation in import penetration from China to estimate the impact of import competition on several margins related to our model mechanism. This evidence on trade shocks and capital reallocation corroborates our model results and is an independent contribution of the paper, complementing the empirical literature on the labor-market effects of trade (e.g., Autor, Dorn, and Hanson, 2013; Acemoglu, Autor, Dorn, Hanson, and Price, 2016). Finally, we introduce an extension of our model with multiple industries and use it to estimate these effects using similar variation in the model.

7.1 Evidence on Chinese Import Competition in Peru

In December 2001, China gained accession to the World Trade Organization (WTO). This event resulted in a worldwide reduction in tariffs placed on Chinese products and a fast growth in China's volume of goods exported. Since then, China's exports of manufacturing products have grown more than sixfold. This export expansion affected many destinations around the world, including Peru. From 1998 to 2008, Chinese import value increased by a factor of 19 and went from 3% to 14% of total Peruvian imports, with substantial heterogeneity across industries. By 2010, China became Peru's leading source country.[37]

At the same time, China's accession to the WTO did not immediately represent a significant exporting opportunity for the Peruvian manufacturing sector.

As we show in Appendix E.1, only commodity-producing sectors obtained significant exporting opportunities from China's trade liberalization. Meanwhile, most manufacturing industries—including the six industries we analyze—did not show an increase in exporting activity to China. Moreover, in the short run, Chinese imports were consistently focused on final goods. We discuss the role of imports of intermediate goods in Section 7.5.

We thus view China's impact on Peruvian manufacturing as primarily an import-competition shock, which may induce firm selection and factor reallocation due to increased import competition.[38] Therefore, we use the measure $ChComp_{nt}$ to capture unanticipated

[37] We do not observe such a large inflow of Chinese goods in other Latin American countries that share a border with Peru. While these countries experience a significant increase in Chinese import competition, this is less stark relative to the Peruvian economy.

[38] Clearly, in other empirical settings, other channels, in part explored in the literature, could also be

import-competition shocks to domestic manufacturing firms. This measure, introduced in Section 4, exploits variation in import-competition exposure across different industries and years. Appendix E.2 contains the main summary statistics for this variable. For all our specifications, the main text shows the results that refer to the instrumental variable approach that uses Chinese imports to border Latin American countries, as explained in Section 4.2. We report the corresponding OLS estimates in Appendix E.[39]

7.2 Effects of Trade Shocks on MRPK Dispersion

First, we analyze the effect of import competition on MRPK dispersion. To this end, we estimate the following specification:

$$\sigma_{nt}^{MRPK} = \delta_0 + \delta_1 ChComp_{n,t-1} + \gamma_m + \epsilon_{nt}, \tag{21}$$

where σ_{nt}^{MRPK} refers to the dispersion of MRPK in 4-digit industry n and year t, $ChComp_{n,t-1}$ is the import-penetration shock in the same industry in year $t-1$, and γ_m is a fixed effect at the 2-digit industry level m.

Table 3 presents all the empirical estimates. In the top panel, we show that higher import competition is associated with significantly higher dispersion of MRPK in the following year. The first column refers to the full data sample. Our empirical estimates imply that an increase in one standard deviation of our competition measure (approximately 0.12) leads to an increase in MRPK dispersion of approximately 1.2%. In the second column we restrict attention to medium and large firms, for which the survey is effectively a census, potentially leading to a more consistent measurement of MRPK dispersion, and our estimates predict an effect of 1.6%.

We also perform three additional analyses, for which we illustrate all these results in Appendix E.3. First, we estimate an alternative empirical specification with lags to verify that the increase in MRPK dispersion is transitory, consistent with the model predictions (Figure 3). Then, we verify that these predictions are robust to considering MRPK dispersion at the 2-digit level. Finally, we check that these results hold before 2003, i.e., on impact, right after China's WTO accession, where the identifying variation in the data

operative. In particular, trade shocks may enhance some industries' export intensity, as they did with the soy, steel, and aluminum industries in the United States. Import competition could also lead to an increase in exports to other destinations due to quality upgrading, as Medina (2021) shows. We leave an exploration of the role of capital reallocation frictions for exporter dynamics for future research.

[39] For all specifications, we verify that the instruments are relevant, with F-statistics above the rule of thumb threshold. They also pass the test of overidentifying restrictions. First-stage results are shown in Appendix E.2.

comes only from differences across industries.

7.3 Effects of Trade Shocks on Investment and Inaction

Next, we analyze the effects of import competition on the investment behavior of firms in terms of inaction, investment, and disinvestment. To this end, we estimate the following specification:

$$z_{jnt} = \delta_0 + \delta_1 ChComp_{nt} + \delta_2 \log(\omega_{jnt}) + \delta_3 \log(k_{jnt}) + \gamma_n + \epsilon_{jnt}, \tag{22}$$

where z_{jnt} are dummy variables with a value of one if the firm is in the inaction region (the absolute value of investment rate is less than 10%), the positive investment region (investment rate larger than 10%), or the negative investment region (investment rate lower than -10%). Because this regression leverages firm-level variation, different from equation (21), we include 4-digit industry fixed effects γ_n.

We report our estimates for δ_1 in the bottom panel of Table 3. The first column shows that the import-competition shock increases inaction in the short run. Consistent with our model, this effect comes from a decrease in the positive investment region (second column) rather than from significant effects on the negative investment region (third column). Quantitatively, in the data, a one-standard-deviation trade shock increases the fraction of firms in the inaction region by 5.3 percentage points.

7.4 Effects of Trade Shocks on Selection

Finally, we examine the effects of import competition on firm selection. Specifically, we re-estimate our prediction model for survival in equation (18), now controlling for our measure of import competition:

$$\begin{aligned} Survival_{jnt,t+1} &= \begin{cases} 1 & \text{if} \quad z^*_{jnt} > 0 \\ 0 & \text{otherwise} \end{cases} \\ z^*_{jnt} &= \beta_0 + \beta_1 ChComp_{nt} + \beta_2 \log(\omega_{jnt}) + \beta_3 \log(k_{jnt}) + \gamma_n + \gamma_t + \epsilon_{jnt} \end{aligned} \tag{23}$$

We report our estimates for β_1 in the fourth column of the bottom panel of Table 3. Import competition increases the exit rate in the data. A one-standard-deviation shock increases the exit rate by approximately 1.8 percentage points.[40]

[40] In Appendix E.5, we verify that this effect is robust to the use of the sample of firms post-2007, where the exit measure is corrected using the firm registry.

Consistent with the predictions of our model—and in contrast with the frictionless model—the estimated coefficients on productivity (0.280, s.e. 0.018) and capital (0.203, s.e. 0.009) confirm that the level of capital plays an important role for selection, conditional on productivity. In particular, some unproductive, but large, firms are more likely to survive the trade shock, while some small, but relatively productive, firms exit. We illustrate this outward shift in the survival isoprobability lines in Appendix E.4.

7.5 Intermediate Goods and Other Robustness Checks

We perform several additional analyses of the empirical effects of trade shocks, which we report in more detail in Appendix E.5. First, we verify that the firm-level responses of reallocation to import competition are robust to controlling for the indirect effects of Chinese imports through access to cheaper intermediate goods. To this end, we merge our data with additional information on the input-output matrix for Peru (Instituto Nacional de Estadística e Informática, 2021) and we construct a variable that summarizes industry exposure to cheaper imports through the input-output network. In this analysis, we consider both the margin of selection and the intensive margin of firm investment.

Second, we verify that our results are robust to an alternative measure of the trade shock that does not control for industry-specific linear trends in import penetration ($ImpInt_{nt}$, defined in Section 4.2). Third, we consider alternative instruments for import penetration based on non-Latin American countries.

Finally, building on the analysis of Section 5.1, we also use our firm-level depreciation measure to investigate the role of capital composition. Consistent with the relevance of partial investment irreversibility, we find that our results on inaction are largely accounted for by firms with low depreciation rates. We also verify that firm-level depreciation rates are uncorrelated with our measure of import competition $ChComp_{nt}$, suggesting that the trade shock does not induce large changes in capital composition.

7.6 Model Extension with Multiple Industries

Our empirical strategy leverages cross-industry variation in the data. However, our model results of Section 6 are based on a single manufacturing industry and combine aggregate general-equilibrium effects with industry-level effects. To bring model and data analysis closer, we now extend our model to allow for multiple industries, introducing assumptions under which the aggregate dynamics of our single-industry model coincide with those of the multi-industry extended model. We then estimate the same margins as in the previous subsection in model-simulated data. Appendix D.9 provides more details about this

	σ_{nt}^{MRPK}	
	Full Sample	Large firms' Sample
$ChComp_{nt-1}$	0.107	0.134
	(0.040)	(0.044)

(a) Effects of Trade Shocks on MRPK Dispersion.

	Investment			Probability of Survival
	Inaction	Positive Investment	Negative Investment	
$ChComp_{nt}$	0.456	-0.537	0.081	-0.825
	(0.092)	(0.107)	(0.065)	(0.507)

(b) Effects of Trade Shocks on Investment and Selection.

Table 3: Empirical Effects of Trade Shocks.

Notes: Panel (a) reports our estimates of the effects of import competition on MRPK dispersion at the 4-digit industry-year level. The first column reports the estimates for δ_1 in equation (21) in the full data sample (398 observations). The second column restricts attention to firms with annual net sales above 2 million soles, for which the EEA survey is a census (378 observations). Robust standard errors are in parentheses. Panel (b) reports our estimates of the effects of import competition on investment activity and selection at the firm level. The first column refers to inaction (absolute value of investment rate less than 10%); the second column refers to positive investment (investment rate larger than 10%); the third column refers to negative investment (investment rate less than -10%). They report the empirical estimates for δ_1 in equation (22) (the number of observations is 6,413). The fourth column reports our estimates for β_1 in equation (23) (the number of observations is 11,554). Standard errors clustered at the firm level in parentheses.

extension.

We assume a continuum of industries $n \in [0, 1]$, each populated by a continuum of firms, subject to the capital-reallocation frictions described in our baseline model. Labor is mobile across firms and industries. For each industry, households purchase a CES aggregate C_{nt} of a continuum of varieties, as in our baseline single-industry model. M_{nt}^D varieties are produced domestically, and M_{nt}^F varieties are imported from the foreign economy. Both to simplify the analysis and because we focus on short-run dynamics, we assume that aggregate consumption is a Leontief aggregator of all industry-level goods: $C_t \equiv \min_n \{C_{nt}\}$. Hence, in equilibrium there is a common level of consumption $C_{nt} = C_t$ for all n, even if different industries face different levels of import competition and heterogeneous price levels P_{nt}.

We feed into the model the same aggregate import competition shock as in the baseline analysis of Section 6. We then add to this initial aggregate shock a temporary industry-specific component by assuming that the mass of imported varieties M_{nt}^F is heterogeneous across industries, generating cross-industry variation in the degree of import competition when the trade shock hits. By imposing that the industry-specific shocks have a mean-zero effect on industry price levels, we ensure that all aggregate variables, including the equilibrium interest rate, are as in the baseline simulation of Section 6. Nevertheless, each industry experiences different outcomes in terms of reallocation patterns and selection when the trade shocks hit at $t = 1$.

We believe that estimating the effects of trade shocks on capital reallocation in the model using cross-industry variation, with common general-equilibrium dynamics across industries, as we do in the data, provides further validation for our model predictions. However, we also highlight that we face the following challenge to a quantitative comparison between the estimated effects in the data and in the model. In the empirical analysis, we build on the literature on the China shock to isolate exogenous trade shocks in the data. Hence, as we explain in Section 4.2, the instrumented shock $ChComp_{nt}$ measures exogenous deviations from (2-digit industry) trend of the ratio of Chinese imports to total imports at the 4-digit industry level. We divide Chinese imports by total imports because data on total domestic absorption are not available at the 4-digit level.

Instead, the model features a single foreign economy, and no distinction between 2-digit and 4-digit industries; thus, in the model we measure the import-competition shock as the overall import expenditure share in each industry and estimate the responses in the initial periods ($t = 1, 2$) to measure the effects of unexpected shocks.[41] Because of these

[41] In our simulation, we consider 32 industries in the model. We feed industry-level shocks in import penetration that induce a standard deviation of prices P_n of approximately 1%; we verify that the relationships we estimate are robust to changes in the size of these shocks.

necessary differences between data and model, we do not focus on a quantitative comparison of the values of the estimated coefficients and, even though several estimates have similar magnitudes, this is not a measure of quantitative success of our model; nevertheless, we can perform a quantitative comparison between baseline and frictionless model regression estimates, which share the same shock and estimation strategy.

We estimate the effects of unexpected import competition at $t = 1$ on the dispersion of MRPK (at $t = 2$), as well as on investment activity and selection at $t = 1$. Table 4 reports the estimated coefficients of all outcome variables on industry-level import share, for both the model with calibrated reallocation frictions (baseline) and the frictionless version of the model. Across all these regressions, we find that the responses in the model baseline model with multiple industries are consistent with our empirical evidence, because industry-level trade shocks increase MRPK dispersion, shift firms from positive investment to inaction, and increase exit, preserving the effects of capital on selection. In contrast, the frictionless model does not generate an increase in MRPK dispersion, predicts a counterfactual strong disinvestment response, and a larger exit flow, which is based only on productivity. Quantitatively, these estimates imply large effects of capital-reallocation frictions on firm dynamics in response to trade shocks. Specifically, in the absence of frictions, the effect of the shock on positive (negative) investment is approximately twice (seven times) as large; the exit probability estimates imply that the average marginal effect of the shock on exit is 68% larger than with the calibrated frictions.

8 Additional Counterfactual Analyses

In this section, we describe three additional counterfactual analyses of our quantitative model. We report additional results in Appendix D.

8.1 Role of General-Equilibrium Forces

Our model features an endogenous discount rate for firm profits, consistent with household utility maximization (see equation (10)). Both to relate to the literature on investment and interest rates and to account for the fact that firm discount rates in a small economy like Peru are likely affected by global market conditions, on top of domestic ones, we now explore the role of the endogenous interest rate for our main results on investment dynamics after trade shocks.

To perform this analysis, starting from our calibrated stationary equilibrium, we consider a counterfactual domestic manufacturing industry, hit by the same aggregate shock as

	σ_{nt}^{MRPK}
Import Shock (baseline)	0.272
	(0.004)
Import Shock (frictionless)	0.008
	(0.000)

(a) Effects of Trade Shocks on MRPK Dispersion.

	Investment			Probability of Survival
	Inaction	Positive Investment	Negative Investment	
Import Shock (baseline)	0.456	-0.663	0.208	-1.271
	(0.031)	(0.020)	(0.018)	(0.106)
Import Shock (frictionless)	-0.095	-1.256	1.351	-1.520
	(0.016)	(0.022)	(0.022)	(0.086)

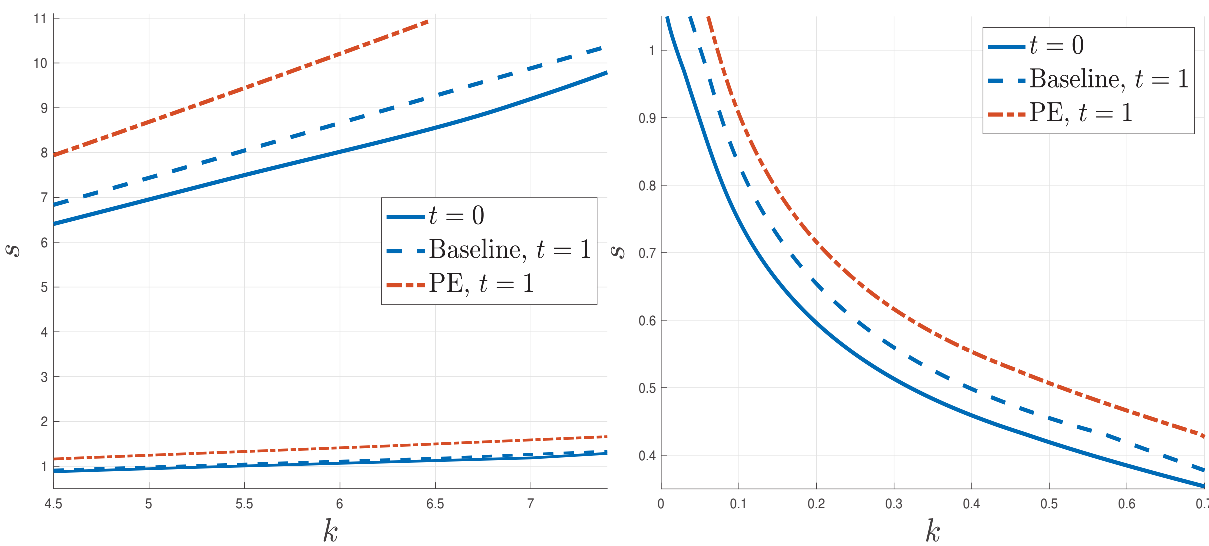
(b) Effects of Trade Shocks on Investment and Selection.

Table 4: Effects of Trade Shocks in the Multi-Industry Model.

Notes: The table reports the effects of import competition on the same outcome variables as Table 3, estimated in simulated data from the multi-industry model, with 32 industries and approximately 8,200 firms in each industry. Panel (a) reports the estimated effect of import competition (import expenditure share) in industry n at $t = 1$ (when trade shocks surprise agents in the model) on MRPK dispersion in industry n at $t = 2$. The first row refers to the multi-industry model with baseline reallocation frictions. The second row refers to the frictionless version of this model. Robust standard errors are in parentheses. Panel (b) reports the estimated effects of import competition (import expenditure share) in industry n at $t = 1$ on investment activity and selection at the firm level at $t = 1$. The first column refers to inaction (absolute value of investment rate less than 10%); the second column refers to positive investment (investment rate larger than 10%); the third column refers to negative investment (investment rate less than -10%). The first row refers to the multi-industry model with baseline reallocation frictions; the second row refers to the frictionless version of this model. Standard errors in parentheses.

in Section 6, but where firms discount profits at a constant rate, equal to the discount factor β. In Figure 6 we display the results of this analysis and compare them with our general-equilibrium results. Specifically, in the left panel we show that response of the thresholds for investment and disinvestment; with a constant interest rate, the threshold for positive investment shifts significantly more than in general equilibrium, which is broadly consistent with the results in the literature on the role of the interest rate with non-convex adjustment costs.

In the right panel we show the response of the exit threshold, again comparing the constant interest rate economy with our baseline general-equilibrium model. Also in this case, we find that a constant interest rate leads to a larger shift in the exit threshold, causing a larger exit flow in response to import competition. When we consider the aggregate effects of these micro dynamics on industry TFP, we find that with a constant interest rate the trade shock induces a short-run decline in TFP_t^{Adj} that is approximately twice as large as in the case with endogenous interest rate.



(a) Thresholds for Investment and Disinvestment (b) Thresholds for Exit

Figure 6: Role of Endogenous Interest Rate.

Notes: The left panel displays the thresholds for investment and disinvestment, before (solid lines) and immediately after the trade shock (dashed lines for baseline general-equilibrium model, dashed-dotted lines for constant interest rate). The right panel displays the threshold for exit, before (solid lines) and immediately after the shock (dashed lines for baseline general-equilibrium model, dashed-dotted lines for constant interest rate).

8.2 Role of Convex Adjustment Cost

Our model features a convex adjustment cost and partial irreversibility. To highlight the important role of partial irreversibility, we also consider a version of the model without convex cost and recalibrate it to match the same moments, except for the standard deviation of investment rates, which is most closely related to the convex cost. Despite a small baseline value for γ_0, removing this cost more than doubles the standard deviation of investment rates.

When we hit this alternative economy with the trade shock, we obtain similar results. Specifically, the trade shock causes an increase in investment inaction, as well as an outward shift in the exit threshold, leading to higher dispersion in marginal products. Quantitatively, this version of the model induces a short-run aggregate-productivity (TFP_t^{Adj}) loss of 1.5% relative to its frictionless counterpart, i.e. a model with the same parameter values, except for partial irreversibility.

8.3 Role of Distribution of Continuation Cost

Our baseline model assumes that the distribution of the fixed continuation cost f depends on the level of firm productivity s. By inducing exit of some large and productive firms, this assumption allows us to match the average characteristics of exiting firms. We now investigate a version of the model in which the distribution of f is independent of s. Specifically, we set $\eta_1 = \eta_2 = 0$ and recalibrate the model to target the same moments. This version of the model induces a worse fit in terms of the characteristics of exiting firms; specifically, exiting firms are on average approximately half as large as in the data.

When we hit this economy with the trade shock, we find that aggregate productivity (TFP_t^{Adj}) displays a small increase on impact (approximately 0.2%) and a larger increase in the frictionless version of the model (approximately 1.6%). When we decompose the role of intensive and extensive margins as in Section 6.3.2, we find that the contribution of the intensive margin is similar to our baseline model (approximately -0.7%, which also induces a similar increase in MRPK dispersion), whereas the extensive margin induces a stronger improvement in the composition of active firms than in the baseline case. Because this difference in the selection margin applies to both the model with frictions and the one without frictions, the overall short-run gap in TFP_t^{Adj} due to reallocation frictions is similar to our baseline result (approximately 1.7%).

9 Conclusions

This paper takes a first step in bridging the quantitative macro literature on investment and firm heterogeneity with the literature on the effects of international trade. We focus on the effects of import-competition shocks and combine micro data and a model to show that capital-reallocation frictions play an important role in shaping productivity dynamics in the short run.

Capital reallocation is costly, particularly in manufacturing, where capital is more likely to be specific at the firm and industry levels. This friction induces dispersion in MRPK and slows the process of downsizing of manufacturing that takes place when cheap manufacturing imports become available in the domestic economy. Moreover, frictions in reallocation affect the patterns of selection, making larger firms more likely to survive, conditional on productivity.

The joint effects of general-equilibrium forces and frictions in capital reallocation on the transitional dynamics following an import competition shock are sizable. The economy takes several years to reach a new stationary equilibrium with higher aggregate productivity. Meanwhile, short-run dynamics feature a spike in inaction, sluggish improvements in the selection of active firms, increased dispersion in returns from capital, and a larger efficiency gap relative to a frictionless economy.

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