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EXPORT OPPORTUNITIES IN THE PRESENCE OF ADJUSTMENT COSTS

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Abstract

This paper studies firm behavior and market outcomes that result from new export opportunities in a context of capital adjustment costs and imperfect labor mobility. We develop a dynamic model of firms and workers and estimate its structural parameters using Argentine data. Results uncover quantitatively important complementarities between export opportunities and the ability of firms to react to positive price shocks. These complementarities are comparatively more important in the short run, for small shocks, and related to investment decisions.

Este trabajo estudia el comportamiento de las firmas y equilibrios de mercado que se generan a partir de nuevas oportunidades de exportación en un contexto con costos de ajuste al capital y movilidad imperfecta de los trabajadores. Desarrollamos un modelo dinámico de firmas y trabajadores y estimamos los parámetros estructurales de este modelo usando datos de Argentina. Los resultados indican que existen importantes complementariedades entre las oportunidades de exportación y la capacidad de las firmas de reaccionar ante shocks positivos de precios. Estas complementariedades son comparativamente más importantes en el corto plazo, para shocks pequeños, y se manifiestan más marcadamente en las decisiones de inversión.

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Key Words: **Trade Liberalization, Firm Heterogeneity, Adjustment Costs, Capital Mobility, Labor Market Dynamics**

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1 Introduction

When export opportunities arise, the gains from trade can only be materialized if the economy adjusts. In particular, in order to expand and meet new markets, firms must tune their capital stock by investing in product lines, machines and equipment. This process is costly and imperfect, and, in fact, investment adjustment may be fully hindered. With labor market frictions, labor adjustment is also costly, and employment may only adjust sluggishly. The dynamic path of wages, employment, capital and investment depends on the level of factor adjustment costs and on the size of the export shock. This complementarity can be important. A profound trade reform or a large export shock (e.g., a significant export preference) can trigger a proportionally different response than a smaller shock. Large shocks can, in fact, make factor adjustment profitable, even if it is very costly. Alternatively, a given trade shock can have a much larger effect if domestic conditions are adequate. In this paper, we set out to explore this interaction between the size of the shock, firm characteristics, and capital and labor adjustment costs on the dynamic responses of the economy to trade shocks.

We formulate a dynamic structural model of trade with worker's intersectoral search and firm's capital accumulation decisions. Our framework combines the labor supply model with workers' mobility costs of Artuç, Chaudhuri and McLaren (2010) with the labor demand model with capital adjustment costs of Cooper and Haltiwanger (2006). The labor supply side is characterized by a rational expectations optimization problem of workers facing mobility costs and time-varying idiosyncratic shocks. The labor demand side is characterized by the rational expectations intertemporal profit maximization problem of firms facing costs for adjusting their capital stock and time-varying technology shocks. To deal with trade shock, our model features multiple sectors. To deal with general equilibrium effects and labor market responses, we endogeneize equilibrium wages across sectors.[1]

Firms face different types of costs of capital adjustments. There are convex costs that induce firms to smooth investment over time. There are also non-convex, fixed, costs that create occasional investment bursts instead. And there are irreversibilities of investment when installed capital can be sold at a fraction of the purchasing prices. Overall, these costs generate regions of investment (and disinvestment) inaction. When a trade shock occurs, some firms will be moved out of this inaction region and invest. The economy thus adjusts. But many other firms will remain in the inaction region, especially if the costs of adjustment are high. As a consequence, the economy reacts partially and gradually. If the trade shock is large, or if a

[1] This feature is shared by the trade model of Artuç, Chaudhuri and McLaren (2010) but it is a major difference with the capital adjustment costs models of Cooper and Haltiwanger (2006) and Bloom (2009).

given trade shock arrives in a setting with lower costs, then the adjustment will be fuller and quicker.[2]

We fit our model to plant-level panel data and household survey data from Argentina. We use the firm-level data to identify the technology and capital adjustment costs parameters that define labor demand. We use the panel component of the household survey data to identify the labor mobility costs parameters. We recover the structural parameters that characterize the frictions faced by both workers and firms. We then combine all these estimates to characterize the stationary steady-state of the economy. Finally, we use the estimated parameters and the solution of the equilibrium to simulate counterfactual adjustments of investment, capital, labor allocations and wage distributions across sectors after a trade shock. We also study the impacts on output, exports, and on aggregate real GDP.

Our findings are as follow. A positive trade shock to the Food & Beverages sector, whose domestic price increases, triggers a gradual increase of the capital stock. Covering 75-95 percent of the transition to the new steady state takes between five and nine years. There is also a relatively sluggish response of the labor market. Real wages increase at first in Food and Beverages but decline elsewhere. Workers gradually reallocate towards the expanding sector, and wages start to decline (while real wages in all other sectors slightly recover). If the trade shock becomes larger, the economy responds more. More importantly, the aggregate capital stock becomes proportionately more responsive. This is because higher price changes make a larger proportion of firms move out of the inaction region. It is noteworthy that the proportional adjustment of real wages is instead independent of the size of the shock. In the estimated production function, capital has a small effect on the marginal productivity of labor and thus the magnification effect on capital is attenuated by technological factors. In addition, the general equilibrium effects that we incorporate in the model cause the price of non-tradables to increase, causing the real wage to decline during the transition. There are, instead, magnification effects on profits. This result has important distributional consequences. First, a positive trade shock benefits firms (entrepreneurs who own managerial ability) more than workers. Second, a larger shock tends to benefits firms' profits proportionately more than workers' wages.

As expected, the economy adjusts much more abruptly and quickly in the absence of capital

[2]It is noteworthy that the treatment of capital adjustment costs is succinct in the related trade literature. Artuç, Chaudhuri and McLaren (2010) assume fixed capital and Dix-Carneiro (2010) works out an example with arbitrary costs. In contrast, imperfect labor mobility has been extensively studied. A branch of the literature focuses on workers' moving sectoral costs (Artuç, Chaudhuri and McLaren, 2010; Artuç, 2009; and Dix-Carneiro, 2010) and workers' sector-specific experience (Coşar, 2010; Dix-Carneiro, 2010; Davidson and Matusz, 2004; Davidson and Matusz, 2006; and Davidson and Matusz, 2010). Another set of explanations focuses on firm behavior and includes firing and hiring costs (Kambourov, 2009; Dix-Carneiro, 2010) and market search frictions (Coşar, 2010; and Coşar, Guner and Tybout, 2010). All these studies conclude that large adjustment costs may lead to large unrealized gains from trade.

adjustment costs. There is also a complementarity between adjustment costs and trade shocks. In the simulations, capital becomes proportionately more responsive to price shocks when the costs of adjusting capital are lower. This complementarity is much stronger in the short-run than in the long-run because investment reacts faster with reduced costs. As the economy adjusts, the complementarity losses strength. The implications of a trade reform or a trade shock can be very different for economies with varying levels of domestic distortions.

The paper is organized as follows. In section 2, we discuss the theoretical model of firm and worker behavior in the presence of capital adjustment costs and labor mobility costs. In section 3, we discuss the data, the estimation strategy and the main results. In section 4, we compute the stationary rational expectations equilibrium of the model and we estimate the effects of trade liberalization on labor market by performing counterfactual simulations. Finally, section 5 concludes.

2 The Model

In this section, we develop the general equilibrium structural model that we use to explore how the economy adjusts to a trade shock in the presence of factor adjustment costs. Firms face capital adjustment costs, as in Cooper and Haltiwanger (2006), and workers face labor mobility costs, as in Artuç, Chaudhuri, and McLaren (2010). The dynamic optimization problem of the firms delivers a set of supply functions for output and a set of demand functions for labor in each of the sectors, given product prices and the costs of adjusting capital. The behavior of firms is described in section 2.1. Workers maximize utility. They choose a consumption bundle, given their income and product prices, and they choose a sector of employment, given wages and the costs of mobility. Their behavior is described in section 2.2. The equilibrium of the economy is discussed in section 2.3. Section 2.4 discusses some new features of our model vis-à-vis the related literature.

2.1 Firms: Labor Demand, Investment, and Output Supply

Our model of firm behavior is based on Cooper and Haltiwanger (2006). The purpose of the model is to derive investment, labor demand, and output supply functions of different sectors in the presence of costly capital adjustment. There are J sectors in the economy; $J-1$ of these sectors are exportable or importable manufactures, and the remaining sector is a large non-manufacturing/non-tradable sector.[3] Each sector is composed of a continuum of firms.

[3]In the empirical implementation of the model in section 3 we work with 5 manufacturing sectors and 1 non-tradable sector for a total of J=6 sectors.

In a given sector j, production technology is Cobb-Douglas:

$$(1)\quad Q^j(A_{ijt}, K_{ijt}, L_{ijt}) = A_{ijt} K_{ijt}^{\alpha_K^j} L_{ijt}^{\alpha_L^j},$$

where A_{ijt} is a Hicks-neutral productivity shock faced by firm i at time t, K_{ijt} is the capital stock and L_{ijt} is the labor input. Productivity shocks A_{ijt} follow a first-order Markov Process. Firms differ in A_{ijt}, so that the productivity shocks are a source of firm heterogeneity that trigger different investment and employment decisions. The coefficients α_K^j and α_L^j are estimable parameters, as is the transition function for A_{ijt}, which we specify in Section 3.

Labor is a variable input that adjusts freely, whereas capital is subject to adjustment costs. Investment becomes productive with a one period lag so that capital accumulation is given by:

$$(2)\quad K_{ij,t+1} = (1 - \delta^j) K_{ijt} + I_{ijt},$$

where I_{ijt} denotes gross investment and δ^j is the capital depreciation rate.

To model capital adjustment costs, we adopt the specification in Cooper and Haltiwanger (2006), which includes three types of costs: fixed adjustment costs, quadratic adjustment costs, and partial investment irreversibilities. The cost function is

$$(3)\quad \begin{aligned} G^j(K_{ijt}, I_{ijt}) \;=\; & \gamma_1^j K_{ijt}\, 1[I_{ijt} \neq 0] + \gamma_2^j (I_{ijt}/K_{ijt})^2 K_{ijt} + \\ & + p_b^j I_{ijt}\, 1[I_{ijt} > 0] + p_s^j I_{ijt}\, 1[I_{ijt} < 0], \end{aligned}$$

where $1[I_{ijt} \neq 0]$, $1[I_{ijt} > 0]$ and $1[I_{ijt} < 0]$ are indicator variables that are equal to one when investment is non-zero, strictly positive, and strictly negative, respectively. The first term captures fixed adjustment costs, which are paid whenever investment or disinvestment take place. Fixed costs are independent of the investment level in order to capture non-convexities and increasing returns to the installation of new capital. We assume that these costs are proportional to the pre-existing stock of capital K_{ijt} at the firm level. Proportionality with respect to K captures the fact that as a firm grows larger fixed costs of investment do not become irrelevant, and, on the contrary, the importance of indivisibilities, plant restructuring, worker retraining and interruption of production, increase with firm size.[4]

The second term in (3) captures the quadratic adjustment costs. These are variable costs that increase with the level of the investment rate. Variable costs are higher when the invest-

[4] Fixed costs can be modeled as proportional to the level of sales or profits at the plant-level; see for example Bloom (2009), Cooper and Haltiwanger (2006), Caballero and Engel (1999). Alternatively fixed costs can also be modeled as independent of firm size, as in Rho and Rodrigue (2012). We argue that fixed costs and irreversibilities generate investment inaction even under the more conservative specification of fixed costs that depend of firm size.

ment rate changes rapidly. We assume these costs are proportional to the predetermined level of capital as well. These costs are motivated by the observation in Dixit and Pindyck (1994) who argue for the existence of increasing costs in the incorporation new capital, in the reorganization of production lines and in worker's training.

Finally, the last two terms in (3) capture partial irreversibilities related to transactions costs, reselling costs, capital specificity and asymmetric information (as in the market for lemons). These costs are incorporated into the model by assuming a gap between the buying price p_b^j and selling price p_s^j of capital so that $p_b^j > p_s^j$.

The presence of fixed costs and irreversibilities generates a region of inaction for the firm, as well as regions of investment and disinvestment bursts. Following a negative shock firms may hold on to capital in order to avoid fixed costs and reselling losses; conversely, in periods of high profitability, firms may choose not to increase the capital stock as much, in anticipation of eventual future costs of selling that capital, or not at all, to avoid fixed costs. Quadratic adjustment costs, on the other hand, create incentives to smooth out investment over time. In the empirical section, we estimate the fixed cost parameter γ_1^j, the quadratic cost parameter γ_2^j, and the ratio of buying to selling price $\gamma_3^j = p_b^j / p_s^j$.

Regarding product markets, we assume that products are homogeneous, that firms are small, and that all manufactures are tradable. The country is small and faces exogenously given international prices p_{jt}^*. The government sets trade taxes at the rate $\tau_{jt} \geq 0$, in the case of imports, or $\tau_{jt} \leq 0$, in the case of exports. Domestic prices faced by producers are $p_{jt} = p_{jt}^*(1 + \tau_{jt})$. In the non-manufacturing sector, prices are endogenously determined in a competitive market. In each industry, we assume weakly decreasing returns to scale ($\alpha_L^j + \alpha_K^j \leq 1$), due to fixed factors such as managerial capacity, an assumption that is supported by the estimation results. Since firms are heterogeneous in productivity and prices are exogenous, this is a sufficient condition to prevent the most productive firms from completely sweeping the market.[5] We make two further simplifying assumptions regarding participation. First, we do not model the decision to enter or exit the domestic market. That is, the number of firms is fixed and there are no fixed costs of production so that even the least productive firms find it profitable to produce. Second, we do not model the decision to export. Since firms face a perfectly elastic demand, the decision to export does not play any role in this model.[6]

[5] Without capital adjustment costs, strictly decreasing returns to scale would be a necessary and sufficient condition.

[6] It is theoretically straightforward to work with a monopolistic competition model as in Melitz (2003) that incorporates market power, constant marginal costs, and firm participation decisions. However, the assumption of fixed international prices seems more realistic for a small Argentine manufacturing sector. In addition, the monopolistic competition model would require the estimation of a larger number of parameters, such as elasticities of substitution, and number of varieties, that can complicate the already complex estimation method. See Coşar (2012) and Coşar, Guner, and Tybout (2011) for monopolistic competition models.

Given the predetermined level of capital and the productivity shock, firms choose labor to maximize instantaneous profits. From the profit maximization problem we obtain firm-level labor demand and output supply. Let μ_t^j denote the cross-section joint distribution of capital and productivity (K, A) in sector j, and let the mass of firms be normalized to one. Integrating firm-level labor demand and output supply over the distribution of firms, and given the Cobb-Douglas assumption on technology, we obtain aggregate labor demand N^{dj} and aggregate output supply Y^j

$$(4) \quad N^{dj}(s_t) = \int_{(K,A)} \left[\left(\frac{\alpha_L^j p_{jt}}{w_{jt}} \right) A K^{\alpha_K^j} \right]^{1/(1-\alpha_L^j)} \mu_t^j (dK \times dA)$$

$$(5) \quad Y^j(s_t) = \int_{(K,A)} \left[\left(\frac{\alpha_L^j p_{jt}}{w_{jt}} \right)^{\alpha_L^j} A K^{\alpha_K^j} \right]^{1/(1-\alpha_L^j)} \mu_t^j (dK \times dA).$$

The state variables are the firm-level productivity shock A_{ijt} and capital stock K_{ijt} as well as a vector s_t of aggregate variables. The aggregate state variables are the prices of all tradable sectors p_t ($j = 1 \ldots J-1$), the cross-section distributions of firms for all sectors μ_t, and the labor allocations in all sectors N_t. Wages and prices of non-tradables are determined endogenously in equilibrium and thus are not included among the state variables.

The investment decision is based on the maximization of intertemporal discounted operating profits net of capital adjustment costs. The Bellman equation is:

$$(6) \quad V^j(A_{ijt}, K_{ijt}; s_t) = \max_{I_{ijt}} \left(\pi^j(A_{ijt}, K_{ijt}; s_t) - G^j(K_{ijt}, I_{ijt}) + \beta_0 E_t V^j(A_{ij,t+1}, K_{ij,t+1}; s_{t+1}) \right)$$

where $\beta_0 \in (0, 1)$ is a discount factor and π^j are maximized instantaneous profits.[7] E_t is the expectation operator conditional on information available at time t and taken over the productivity shocks and output prices.[8] We will make more specific assumptions about the stochastic processes of productivity and prices when we describe the estimation method and simulation exercises. The solution to the Bellman equation leads to the following policy function:

$$(7) \quad I_{ijt} = g^j(A_{ijt}, K_{ijt}, s_t).$$

To sum up, at time t, the capital stock is predetermined. Given K, the realization of the profitability shock A, and the aggregate state variables, profit maximization delivers optimal levels of labor demand and output supply, as well as, given the costs of adjustment, the optimal level

[7] Firm-level instantaneous profits are given by $\pi^j(A_{ijt}, K_{ijt}; s_t) = (1 - \alpha_L^j) \left[\left(\frac{\alpha_L^j}{w_{jt}} \right)^{\alpha_L^j} p_{jt} A_{ijt} K_{ijt}^{\alpha_K^j} \right]^{1/(1-\alpha_L^j)}$.

[8] The evolution of capital, labor allocations, and firm distributions, on the other hand, is endogeous.

of investment. Due to the presence of fixed costs and irreversibilities, some firms may not react to shocks that are not large enough. Investment determines firm-level capital for next period and, together with the stochastic process of productivity, next period firm distribution. For manufacturing, since goods are tradable and prices are exogenously determined, firms sell all their output at those prices. Instead, prices for non-manufactures must clear the market. Wages must adjust to equate demand and supply. Equilibrium wages, labor allocations, and prices for non-tradables are further described in the next two sections.

2.2 Workers: Labor Supply and Output Demand

To characterize the behavior of workers, we follow the labor mobility cost model of Artuç, Chaudhuri, and McLaren (2010) and Artuç (2012). This is a dynamic discrete choice model in which workers choose their sector of employment based on wages, job quality, mobility costs, and idiosyncratic utility shocks. The model predicts equilibrium worker mobility, equilibrium wage differentials, and dynamic responses.[9]

The economy is populated by a continuum of homogeneous workers with measure $\bar{N}$. Workers are assumed to have Cobb-Douglas preferences defined over consumption of goods, so that they spend a constant fraction ϕ_j of their labor income in good j. All individuals are risk neutral, have rational expectations, and are employed in one of the J sectors. A worker $l \in [0, \bar{N}]$ employed in sector j at time t perceives an indirect instantaneous mean utility (optimized over consumption of goods) defined as

$$u_{jt} = \frac{w_{jt}}{P_t} + \eta^j \tag{8}$$

where w_{jt} is the sector nominal wage, P_t is a price index, and η^j is a time-invariant utility shifter, which could be interpreted as the quality of employment in sector j.[10] These terms are common to all workers. At the end of the period, workers have the option to move to another sector at a cost. Workers can move within manufacturing sectors and also between manufacturing and the non-tradable sector. The cost of moving from sector j to sector k is C^{jk}, with $C^{jj} = 0$ for all j.

In addition to the common mean utility and moving costs, workers have heterogeneous

[9] Note that the model allows for wage differentials across sectors but not for wage heterogeneity across firms (in a given sector). All firms pay the same market wage. We can thus study inter-sectoral labor mobility but we do not deal with intra-sectoral mobility.

[10] The instantaneous mean utility function of a worker employed in sector j defined over goods and job quality is $\widetilde{u}^j = \frac{\Pi_{h=1}^J x_h^{\phi_h}}{\Pi_{h=1}^J \phi_h^{\phi_h}} + \eta^j$, where x_h denotes consumption of good h and $\sum_{h=1}^J \phi_j = 1$. Optimizing with respect to x we obtain the indirect utility function (8) with a price index given by $\log P = \sum_{h=1}^J \phi_h \log p_h$.

preferences over sectors captured by a vector ε_{lt} that is realized at the end of period t. A worker l that chooses sector j at the end of t receives the idiosyncratic benefit ε_{ljt}. Workers learn the values ε_{ljt} for all sectors j before deciding to stay in their current sector or to move. For simplicity, these shocks are independently and identically distributed across individuals, sectors and time.

The worker's problem is to maximize the expected discounted value of being in a sector, net of mobility costs, by choosing in each period the sector of employment. The state variables in the decision are the current sector of employment and vector of idiosyncratic shocks ε_{lt} and the aggregate state variables $s_t = (p_t, N_t, \mu_t)$. Output prices, labor allocations and firm distributions together determine equilibrium wages. The Bellman equation of a worker l in sector j who chooses sector k at the end of t is

$$(9)\quad U^j(\varepsilon_{lt}, s_t) = \frac{w_{jt}}{P_t} + \eta_j + \max_k \left\{ \varepsilon_{lkt} - C^{jk} + \beta_1 E_t U^k(\varepsilon_{l,t+1}, s_{t+1}) \right\},$$

where β_1 is a discount factor and E_t is the expectation operator conditional on information at t and taken over idiosyncratic utility shocks and output prices.

As it is standard in discrete choice models, we assume that ε_{ljt} follows a type 1 extreme value distribution with location parameter $-\nu\gamma$ and scale parameter ν.[11] This assumption is convenient because the idiosyncratic shock ε can be integrated out analytically. The costs C^{jk}, the variance of the idiosyncratic utility shocks ν, and job quality η^j are estimable parameters.

Denote by $W^j(s_t)$ the expectation of $U^j(\varepsilon_{lt}, s_t)$ with respect to the vector ε. Thus, $W^j(s_t)$ can be interpreted as the expected value of being in sector j, conditional on s_t but before the worker learns his realization of ε_{lt}. The Bellman equation can be rearranged as

$$(10)\quad \begin{aligned} U^j(\varepsilon_{lt}, s_t) &= \frac{w_{jt}}{P_t} + \eta_j + \beta_1 E_t W^j(s_{t+1}) + \\ &+ \max_k \left\{ \beta_1 E_t W^k(s_{t+1}) - \beta_1 E_t W^j(s_{t+1}) - C^{jk} + \varepsilon_{lkt} \right\}. \end{aligned}$$

The convenience of this format will become clear when we describe the estimation method. Let m_t^{jk} be the fraction of agents who switch from sector j to sector k. This is the probability of choosing k conditional on being in j. Under the extreme value distributional assumption, the conditional probability of moving from j to k takes the usual multinomial logit form

$$(11)\quad m^{jk}(s_t) = \frac{\exp\left(\left(\beta_1 E_t W^k(s_{t+1}) - \beta_1 E_t W^j(s_{t+1}) - C^{jk}\right)\frac{1}{\nu}\right)}{\sum_{h=1}^{J} \exp\left(\left(\beta_1 E_t W^h(s_{t+1}) - \beta_1 E_t W^j(s_{t+1}) - C^{jh}\right)\frac{1}{\nu}\right)},$$

[11]The cdf is $F(\varepsilon_{ljt}) = \exp(-\exp(-\varepsilon_{ljt}/\nu - \gamma))$, with $E(\varepsilon_{ljt}) = 0$, and $Var(\varepsilon_{ljt}) = \pi^2\nu^2/6$. The parameter γ is the Euler's constant.

with

$$(12)\quad W^j(s_t) = \frac{w_{jt}}{P_t} + \eta_j + \beta_1 E_t W^j(s_{t+1}) + \\ +\nu \log \sum_{h=1}^{J} \exp\left(\left(\beta_1 E_t W^h(s_{t+1}) - \beta_1 E_t W^j(s_{t+1}) - C^{jh}\right)\frac{1}{\nu}\right).$$

The total number of agents moving from j to k, or gross flow, is equal to $m^{jk}(s_t)N_{jt}$, where N_{jt} is the number of workers employed in sector j at time t. The transition equation governing the allocation of labor between sectors is thus given by

$$(13)\quad N_{j,t+1} = \sum_{k \neq j} m^{kj}(s_t)N_{kt} + m^{jj}(s_t)N_{jt}.$$

This shows that, on aggregate, the individual decisions at time t determine the labor supply to each sector j at time $t+1$. At time t, the current labor allocation is predetermined and upon shocks to labor demand the labor market adjusts only through changes in wages.

Aggregate demand for good j at prices $p_{jt} = p^*_{jt}(1+\tau_{jt})$ is

$$(14)\quad D_{j,t+1} = \frac{\phi^j}{p_{jt}} \sum_{h=1}^{J} \left(w_{ht}N_{ht} + \int_{K,A} \left[\pi^h(K,A;s_t) - G^h(K, I(K,A;s_t))\right] \mu_t^h(dK \times dA) \right).$$

2.3 Equilibrium

All markets are competitive. All tradable sectors face exogenous prices, with domestic prices equal to international prices plus trade taxes. Sectors in which supply is larger than demand are net exporters, whereas sectors in which supply is smaller than demand are net importers. Gross trade flows are not determined. Equilibrium prices for non-tradable goods must equate domestic supply to domestic demand given by equations (5) and (14).

Aggregate labor demand in each sector, given by equation (4), together with current labor allocation (13), determines wages both within manufactures and in the non-tradable sector. Then, given each firm's current profitability shock, the capital stock, and the equilibrium wage paid in the sector, firms choose investment in period t. These decisions determine the current period investment and influence the following period's $(t+1)$ firm distribution and labor demand for each sector. On the other hand, each worker observes sector wages and his idiosyncratic shock ε and decides whether to remain in his current sector or move. In the aggregate, these decisions determine the following period's labor allocation. Supply of capital is assumed to be perfectly elastic with time-invariant prices (as in a small economy open to international capital flows).

The previous equilibrium conditions hold for all time periods and all vectors of aggregate state variables. We are also interested in defining a stationary equilibrium, which we will use in simulation exercises to study trade shocks. In a stationary equilibrium, there are firm-specific productivity shocks and worker-specific utility shocks, but there are no aggregate shocks to prices of tradables and average productivity. As a consequence, while we observe fluctuations in firm-level labor demand, investment and output, and in worker-level mobility, there are no fluctuations at the aggregate level. To define a stationary equilibrium we add the condition that labor allocations, aggregate capital, output, wages, prices of non-tradables, and the distribution of firms are time-invariant.

2.4 Discussion

We end with a brief discussion of some of the distinguishing features of our model vis-à-vis the related trade and macro literature. In this paper, we are interested in trade shocks and, for this purpose, we need to develop a multi-sector model. Some sectors compete with imports, others are net exporters, and yet others are non-traded. These sectors in principle respond differently to trade shocks. In addition to the multi-sector feature, we endogeneize equilibrium wages across sectors. This is done, as explained, by modeling labor demand on the firm side and labor supply of the workers side. This implies that sectoral wages respond to the trade shock, which allows us to study labor market adjustment and distributional issues. This is a major difference with the seminal papers on capital adjustment costs such as Cooper and Haltiwanger (2006) and Bloom (2009).

There is another important difference with the literature. Bloom (2009) models a one-sector economy where firms face both capital and labor adjustment costs but workers move freely (and wages are not determined endogenously). We develop a model where workers face mobility costs and firms face capital adjustment costs, but not labor adjustment costs (such as firing and hiring costs). Our setting does not lend itself to adding labor adjustment costs on the firm side. The estimated labor mobility costs, as in Artuç, Chaudhuri, and McLaren (2010), are a reduced form measure of mobility costs imposed by labor market frictions, including the costs faced by both firms and workers. Thus, including labor adjustment costs to the firm optimization problem implies a double counting of some of the labor mobility costs. We prefer this setting because it allows for differences in wages across sectors and for general equilibrium effects, in particular on wages.

3 Estimation

In this section, we discuss how we estimate the different components of the theoretical model, which comprise parameters related to the firms' and workers' decision problems, for the case of Argentina. We estimate the parameters associated with each of these problems separately, relying on different methodologies, and using two main data sources: a panel of firms and a panel of workers. We work with 6 sectors: "Food and Beverages", "Apparel, Leather and Textiles", "Nonmetallic Minerals", "Primary Metals and Fabricated Metal Products", "Other Manufactures", and "Services." The Services sector corresponds to non-tradable goods. We begin with firm choices in section 3.1, and we move to worker choices in section 3.2.

3.1 Firms

The estimation of the firms' problem requires panel data with detailed information on the investment decision of the firms. In particular, to fit the capital adjustment cost model, we need data on purchases of new capital as well as on sales of installed capital. We estimate the model using an Argentine manufacturing survey, the Encuesta Industrial Anual (EIA, or Annual Industrial Survey), which meets these requirements. Note that the EIA covers only the manufacturing sector.[12]

We use a balanced panel from the EIA consisting of 568 Argentine manufacturing plants for the period 1994-2001. The EIA dataset provides information on gross revenue, costs, intermediate inputs, employment, consumption of energy and fuels, inventory stock, and both gross expenditures and gross sales of capital. Information on gross capital sales is important in order to estimate the role of partial irreversibility in the capital adjustment costs structure.

The firms' model is defined by parameters in the production function, stochastic evolution of variables, adjustment cost function, depreciation rate, and discount factor. Since the firms' problem does not have a closed form solution, we recover the main parameters of interest with a simulated method of moments estimator, as in Cooper and Haltiwanger (2006) and Bloom (2009).[13] In principle, all the parameters of the model could be estimated simultaneously by simulated method of moments, but this strategy requieres numerically searching over a large number of parameters with a computationally-intensive objective function. To reduce the computational burden and improve the reliability of the numerical search, we follow Cooper and Haltiwanger (2006) and combine different strategies to recover different parameters. In

[12] See below for the non-manufacturing sector strategy.

[13] See Ruge-Murcia (2007, 2012) for a comparative analysis of different methods to estimate dynamic stochastic general equilibrium models.

Table 1
Structural Parameters
Production Function and Capital Adjustment Costs

A) Production Function				
Parameters	labor (α_L)	capital (α_K)		
Manufacturing	0.5892^{***} (0.0131)	0.1420^{***} (0.0423)		
Non-Manufacturing	0.3402	0.1153		
B) Stochastic Process and Depreciation				
Parameters	ρ_e	σ_e	δ	
	0.8853^{***} (–)	0.6652^{***} (–)	0.0991 –	
C) Capital Adjustment Costs				
Parameters	γ_1	γ_2	γ_3	
	0.1451^{***} (0.0403)	0.1132^{***} (0.0105)	0.9143^{***} (0.0727)	
Moments	$corr(i, i_{-1})$	$corr(i, a)$	$spike^+$	$spike^-$
Observed	0.188	0.121	0.139	0.011
Simulated	0.149	0.306	0.135	0.013

Source: EIA, Encuesta Industrial Anual (Annual Industrial Survey). Panel A: Estimates of the production function parameters. Panel B: Estimates of the profitability markov process parameters. Panel C: Estimates of the adjustment costs parameters, and comparison of observed and simulated moments.

particular, we limit the simulated method of moments to the estimation of the capital adjustment cost parameters.

To begin with, we set the depreciation rate δ at 9.91 and the discount factor β_0 at 0.95, both common to all firms and all sectors.

To estimate the production function parameters α_L and α_K, we use the method of Olley and Pakes (1996). Since many firms report zero investment, we use materials as a proxy (Levinsohn and Petrin, 2003). Also, since there are relatively few firms in each sector, we estimate a common set of technology parameters for all firms. Results are reported in Panel A of Table 1. The labor coefficient is 0.5892 and the capital coefficient is 0.1420, and both are statistically significant.[14] The estimated production function exhibits decreasing returns to scale.

The EIA surveys firms in the manufacturing sector only, and we do not have comparable data to estimate the parameters of technology for the non-tradable sector. However, it is

[14]These results are comparable to those obtained by Pavcnik (2002) for Chile, for example.

important to include this sector in the analysis because it accounts for almost 80 percent of employment in Argentina. To do this, we calibrate, rather than estimate, the parameters of the production function. We set the values α_L, α_K, and the mean of the profitability shock (A) to minimize a quadratic loss function. In particular, for any set of parameter values for the non-traded sector, we compute the aggregate steady state level of capital as well as the predicted employment level (given the observed sectoral wages). Then, the loss function matches the predicted sectoral employment, the predicted ratio of non-manufacturing to manufacturing capital, and the predicted shares of labor and capital in revenue with their observed counterparts. Information on aggregate capital by sector and the capital share of revenue come from the National Institute of Statistics and Census of Argentina (INDEC) input-output matrix for the year 1997, while information on employment and wages come from our dataset. The calibrated parameters for the non-manufacturing sector are displayed in Panel A of Table 1. The labor coefficient is 0.3402 and the capital coefficient is 0.1153. There are also strong decreasing returns to L and K in the non-manufacturing sector.

What follows is closely based on Cooper and Haltiwanger (2006). To estimate the adjustment cost parameters we first need to specify the stochastic processes of the productivity shocks A_{ijt} and prices of tradable products p_t, since firms form rational expectations about future values of these variables prior to their investment decisions, as per Bellman equation (6). Here we make two important assumptions. The first one is a departure from the model: even though wages are determined in equilibrium, we assume for estimation purposes that firms form expectations about future wages based on an exogenous stochastic process. This assumption is necessary in order to estimate the firms and workers structural parameters separately. The second assumption is that we summarize the stochastic process of productivity, prices and wages by the stochastic process of a new variable which we refer to as "profitability," and which we denote by $\widetilde{A}_{ijt}$. Based on the Cobb-Douglas definition of indirect instantaneous profits $\pi_{ijt} = (1-\alpha_L^j)[(\alpha_L^j/w_{jt})^{\alpha_L^j} p_{jt} A_{ijt} K_{ijt}^{\alpha_K^j}]^{1/(1-\alpha_L^j)}$, we define profitability as a combination of productivity, wages and product prices given by $\widetilde{A}_{ijt} = \left[(\alpha_L^j/w_{jt})^{\alpha_L^j} p_{jt} A_{ijt}\right]^{1/(1-\alpha_L^j)}$. Any variation in trade taxes is also assumed to be part of the stochastic process for profitability. We measure profitability from data on profits, capital, and the estimates of the production function parameters, again following the definition of indirect instantaneous profits, so that measured profitability is given by $\widetilde{A}_{ijt} = \pi_{ijt}/[(1-\widehat{\alpha}_L) K_{ijt}^{\widehat{\alpha}_K/(1-\widehat{\alpha}_L)}]$.

Since the objective is to generate model-based moments and compare them with data-based moments, we need profitability shocks to recreate a non-stationary economy.[15] We thus

[15] In contrast, we shut down aggregate shocks in the simulation exercises in order to focus on permanent changes in the prices of tradable goods and the transition from one stationary equilibrium to another one.

model profitability as the interaction of an economy-wide technology shock (b_t) and a firm-level component (e_{ijt}).

(15) $\ln \widetilde{A}_{ijt} = b_t + e_{ijt}.$

Aggregate profitability b_t follows a first order, two-state (high and low), Markov process with symmetric transition matrix. To create sufficient serial correlation, we set the diagonal elements of the transition matrix to 0.8, which is estimated by Cooper and Haltiwanger (2006) by comparing the standard deviation of the process to observed US data.

Idiosyncratic profitability follows a first order autoregressive Markov process given by:

(16) $e_{ijt} = \rho_e e_{ij,t-1} + \zeta_{ijt},$

where $\zeta_{it} \sim N(0, \sigma_e)$ and ρ_e is the first order autocorrelation coefficient. The coefficients ρ_e and σ_e are critical for understanding key moments associated with the investment rate, such as investment bursts or investment inaction. To simplify, these parameters are also common to all sectors.

We estimate ρ_e and σ_e with an OLS regressions of deviations of profitability from its year mean.[16] Panel B of Table 1 reports an estimate of the moments for the idiosyncratic component of the profitability shock. Idiosyncratic shocks to the firm are highly autocorrelated. From the plant-level data, ρ_e is estimated at 0.8853 for the full sample. We also estimate large variance for the innovations of the idiosyncratic shock process, with a standard deviation (σ_e) of 0.6652. We adopt these parameters for firms in the non-manufacturing sector as well.

We estimate the vector of capital adjustment cost parameters $\Gamma = (\gamma_1, \gamma_2, \gamma_3)$ by simulated method of moments (SMM). The SMM is based on minimizing the distance between empirical moments generated from observed firms, and simulated moments generated from artificial firms that behave as described in the model (McFadden, 1989; Pakes and Pollard, 1989).

For a given vector of adjustment cost parameters Γ, and given the estimates of the production function and stochastic process of profitability, we solve the Bellman equation iteratively and obtain the policy function $I^j(A_{ijt}, K_{ijt}; s_t; \Gamma)$.[17] We simulate a panel of artificial firms by taking random draws of initial capital and a series of profitability shocks.[18] From the simulated

[16]The regression takes the form $\left(\widetilde{A}_{ijt} - \frac{1}{N}\sum_{i\in j}\widetilde{A}_{ijt}\right) = \rho_e\left(\widetilde{A}_{ij,t-1} - \frac{1}{N}\sum_{i\in j}\widetilde{A}_{ij,t-1}\right) + \widetilde{\zeta}_{ijt}$, where N_j is the number of firms.

[17]We discretize the state space of variables K, K', and $\widetilde{A}$ with a grid of 400 $\times$ 400 $\times$ 22. The 22 states for profitability correspond to the 2 aggregate states and 11 idiosyncratic states which are discretized from the continuous AR(1) process in equation (16) following Tauchen and Hussey (1991). See Rust (1996) for a detailed discussion of the conditions that ensure convergence of a Value Function.

[18]We draw a Markov Chain with 1100 time periods for each of 568 firms. We drop the first 100 periods from the

data we compute a vector of simulated moments, denoted by $\Psi^s(\Gamma)$. The simulated moments depend on the adjustment cost parameters through the policy function $I^j(.)$. Let Ψ denote the vector of empirical moments. These are analogous to the simulated moments but computed from the actual firm data. The estimator for the adjustment costs minimizes the weighted distance between the empirical and simulated moments. Formally,

$$(17) \quad \widehat{\Gamma} = \arg\min_{\Gamma} \; [\Psi - \Psi^s(\Gamma)]' W [\Psi - \Psi^s(\Gamma)]$$

where W is a weighting matrix. We use the optimal weighting matrix given by the inverse of the variance covariance matrix of $[\Psi - \Psi^s(\Gamma)]$.[19] Standard errors for the estimates are computed analytically.

Since the function $\Psi^s(\Gamma)$ is not analytically tractable, the minimization is performed using numerical techniques. We use a simulated annealing algorithm to minimize the criterion function. This algorithm works well in a case like ours, with a discretized state space and the potential presence of local minima and discontinuities in the criterion function across the parameter space.[20]

To implement the SMM estimator, we choose moments that describe both the cross-section and time series behavior of the investment rate. Concretely, following Cooper and Haltiwanger (2006), Bloom (2009), Caballero and Engel (2003) and Cooper, Haltiwanger and Power (1999), we match four fairly standard moments. The first two are the serial correlation of investment rates ($corr(i, i_{-1})$) and the correlation between the investment rate and the profitability shock ($corr(i, a)$) because these moments are very sensitive to the structure of the capital adjustment costs. The other two moments are the positive and negative spikes rates, ($spike^+$) and ($spike^-$), defined as the percentage of firms with investment above 20 percent and disinvestment above 5 percent.[21] These moments capture the fact that the investment rate distribution at the plant-level is asymmetric with a fat right tail, as shown in Figure 1.

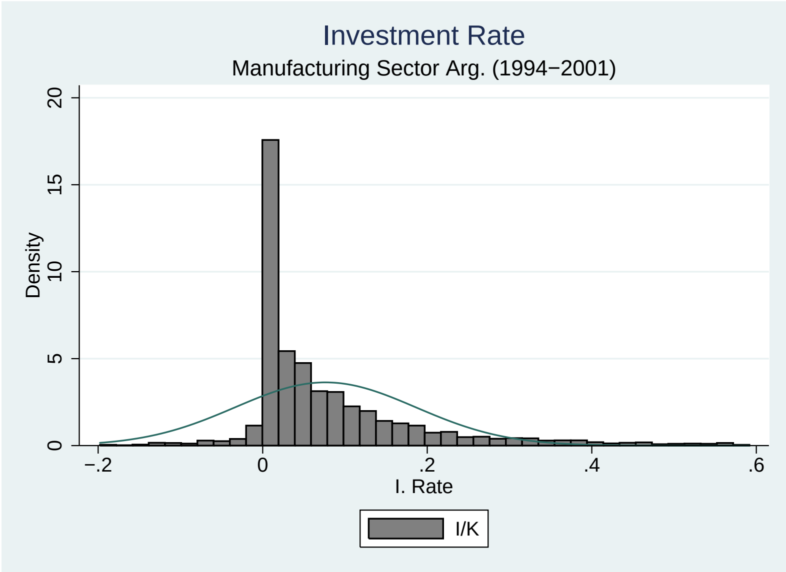
simulated data so that the simulation is independent of the initial conditions.

[19] Lee and Ingram (1991) show that the inverse of the variance-covariance matrix of the actual moments is a consistent estimator for the optimal weighting matrix. We use 1,000 bootstrap replications on actual data to generate the variance-covariance matrix of the actual moments.

[20] For the first 1500 iterations, the updated set of parameters is based on a randomization from the best prior guess. From iteration 1500 onwards, we add a directional component to the parameter search. We also program the algorithm so that the variance of the randomization declines with the number of iterations, allowing the SMM to refine the parameter estimates around the global best fit. We set up the estimation with different initial parameters and seeds to ensure convergence to the global minimum.

[21] The investment rate exceeds 20 percent for 14 percent of firms.

Figure 1
Distribution of the Investment Rate



Source: EIA, Encuesta Industrial Anual (Annual Industrial Survey), Argentina 1994-2001.

Table 1, Panel C, presents our estimates for all three forms of capital adjustment costs along with the standard errors of these estimates. We also report both the observed moments and simulated moments that we match. Due to small sample sizes, we estimate a common set of adjustment cost parameters for all sectors.

The estimated adjustment costs imply large fixed cost, large reselling costs, and large quadratic costs. All the parameters estimated are found to be significantly different from zero. We estimate a fixed cost $\widehat{\gamma}_1 = 0.145$. This is a substantial cost since it implies that the fixed cost of adjustment is about 14.5 percent of the average plant-level capital value. The estimated coefficient for the quadratic adjustment cost parameter ($\widehat{\gamma}_2$) equals 0.113. Using the quadratic adjustment cost function and a steady state investment rate equal to the depreciation rate ($I/K = \delta = 0.0991$), the estimated parameter implies an adjustment cost relative to the average plant-level capital of 0.056 percent. Finally, our estimate of the transaction costs ($\widehat{\gamma}_3 = 0.914$) implies that resale of capital goods would incur a loss of about 8.6 percent of its original purchase price.

Our estimates of capital adjustment cost parameters for Argentina can be directly compared with those in Cooper and Haltiwanger (2006) for the U.S. as we use the same specifications. As expected, Cooper and Haltiwanger (2006) estimate smaller fixed costs ($\gamma_1^{US} = 0.039$), smaller quadratic adjustment costs (γ_2^{US}=0.049), and smaller partial irreversibilities ($\gamma_3^{US} = 0.975$). This implies that capital is more flexible in the U.S. than in Argentina. These differences, as well as the magnitudes of the estimates, are, however, sensible and plausible.[22]

3.2 Workers

The estimation of the workers' problem parameters requires panel data on sectoral wages and gross flows of workers across sectors in order to estimate the labor mobility costs, as well as consumption weights for each sector in order to calibrate aggregate demand. The first line of Table 2 shows the average CPI weights of each product, obtained from National Accounts data. Because demand is assumed to be Cobb-Douglas, a constant fraction given by the CPI weights is spent on each product regardless of prices and income.

We estimate the labor mobility model using the panel sample of the Encuesta Permanente de Hogares (EPH, Permanent Household Survey). The database contains information on individual wages, employment sector, demographic characteristics and other standard variables in labor force surveys. Part of the EPH is a panel and we can use it to track labor employment flows across sector pairs and average sector wages. The top panel of Table 2 shows average wage and employment allocations across our six sectors in the sample period, 1996-2007. The numbers are normalized with respect to the corresponding national average. We see important wage differences across sectors. The average wage in Other Manufactures (e.g., chemicals, plastics) is 1.09, while the wage in Minerals is 0.78. In Food & Beverages, the target sector in the simulations below, the average wage is 0.82 (meaning it is equivalent to 82 percent of the average national wage). The Services (non-traded) sector is the largest sector, absorbing 84 percent of the labor force. Food & Beverages employs around 3.3 percent of total employment.

The set of labor mobility cost parameters are given by the direct mobility costs C^{jk}, a vector of sector employment quality η^j, and ν, a parameter that determines the variance of the idiosyncratic utility shocks. We impose some restrictions on C^{jk} due to data constraints. In particular, we will assume a common cost C^m within the manufacturing sectors and a cost C^{nm} for movements between manufacturing and non-manufacturing sectors. The set of estimable parameters is thus $\{C^m, C^{nm}, \nu, \eta^j\}$.

We follow a two-step procedure similar to Artuç (2012) and Artuc and McLaren (2012). In the first step, we estimate the normalized moving costs C^m/ν and C^{nm}/ν and sector fixed effects that capture expected continuation values from gross flows of workers. In the second

[22]Bloom (2009) and Bond, Soderbom and Wu (2008) report larger values for the partial irreversibility cost, with capital reselling losses of 47 and 16.9 percent respectively. Both papers also find larger values for the quadratic adjustment cost parameter (2.056 in Bloom, 2009; 1.985 in Bond, Soderbom and Wu, 2008). In turn, the fixed costs parameter γ_1, which is estimated in terms of annual sales (instead of average capital) ranges from 0.3 percent (Bond, Soderbom and Wu, 2008) to 1.3 percent of annual sales (Bloom, 2009). Note that these results are not directly comparable to ours because of these and other differences in specification—e.g., both papers estimate additional parameters to the capital adjustment costs parameters.

Table 2
Estimation of Labor Mobility Costs
Parameters and Data

	Food & Beverages	Textiles	Minerals	Metals	Other Manufactures	Services
CPI weight	0.313	0.052	0.025	0.025	0.211	0.384
Average Wages	0.82	0.84	0.78	0.86	1.09	0.96
Labor Allocation	391	222	92	229	868	10,069

Estimates of Labor Mobility Costs

Parameters	C^m	C^{nm}	ν
	2.07^{***}	1.41^{***}	0.78^{***}
	(0.22)	(0.27)	(0.12)

Source: Panel component of EPH, Encuesta Permanente de Hogares (Permanent Household Survey). First panel shows participation of each sector in expenditure, average wage, and sample size. Second panel shows estimates of labor mobility cost parameters.

step, these estimated expected values together with data on sector wages are plugged into a Bellman equation to construct a linear regression and estimate the parameters η^j and ν.

To see how this works, recall that the total number of workers who move from sector j to k is equal to $N_t^j m_t^{jk}$. Using the probability choice equation (11) multiplied by labor allocations, we get the following expression for gross flows of workers

$$(18)\quad \log\left(N_t^j m_t^{jk}\right) = -\frac{C^{jk}}{\nu} + \frac{\beta_1}{\nu} E_t W_{t+1}^k - \frac{\beta_1}{\nu} E_t W_{t+1}^j + \log\left(N_t^j\right) - -\frac{1}{\nu}\log\left\{\sum_{h=1}^{J} \exp\left(\beta_1 E_t W_{t+1}^h - \beta_1 E_t W_{t+1}^j - C^{jh}\right)\right\}.$$

Flows of workers $(N_t^j m_t^{jk})$ are observed in the data, whereas the expected values $E_t W_{t+1}^j$ are unknown for all j. We capture the expected values with time-varying sector effects. Using sector of destination (k) and sector of origin (j) effects, we can re-write (18) as

$$(19)\quad \log\left(N_t^j m_t^{jk}\right) = -\frac{C^{jk}}{\nu} + \lambda_t^k + \alpha_t^j.$$

where $\lambda_t^k = \frac{\beta_1}{\nu} E_t W_{t+1}^k - \Lambda_t$ is the expected value of sector of destination k, identified up to a year effect Λ_t, and α_t^j captures all terms in (18) that depend on country of origin j.[23] Mobility costs C^{jk}/ν, also unobserved, are assumed to be constant over time and can thus be captured with sector-pair dummies.

[23] In multinomial logit models the probability choice of an alternative k depends on the mean utility of k normalized with respect to a reference value, usually interpreted as the utility of an outside choice. The year effects play the role of the expected value of a reference sector, so that $\Lambda_t = \frac{\beta_1}{\nu} E_t W_{t+1}^o$. The sector of origin effect is similarly given by $\alpha_t^j = -\frac{\beta_1}{\nu} E_t W_{t+1}^j - \frac{1}{\nu}\log[\sum_h \exp\left(\beta_1 E_t W_{t+1}^h - \beta_1 E_t W_{t+1}^j - C^{jh}\right)] + \log(N_t^j) + \Lambda_t$.

A challenge presented by equation (19) is that the logarithmic specification is problematic when the choice probabilities m_t^{jk} are small. Let m_t^{jk} be the theoretical choice probabilities, which are strictly positive, and $\widehat{m}_t^{jk}$ the estimated choice probabilities, given by the observed fraction of workers who switch from j to k. Because the estimated probabilities are computed as frequencies from a panel survey of workers, some values $\widehat{m}_t^{jk}$ can be very small or even zero, especially when the sample size of the survey is not very large and when the theoretical probabilities m_t^{jk} are small. To deal with the zeros and low-value flows, we write the model in levels as

$$\text{(20)} \quad \widehat{y}_t^{jk} = \exp\left(-\frac{C^m}{\nu}\mathsf{D}_{jk}^m - \frac{C^{nm}}{\nu}\mathsf{D}_{jk}^{nm} + \lambda_t^k + \alpha_t^j\right) + v_t^1.$$

where $\widehat{y}_t^{jk} = N_t^j \widehat{m}_t^{jk}$ are worker flows, D_{jk}^m is a dummy that indicates whether j and k are both manufacturing sectors, D_{jk}^{nm} is a dummy that indicates whether either j or k are the non-manufacturing sector, and v_t^1 in an error term. Both indicator variables are zero when $j = k$. The error term has a non-standard distribution (which could in principle be derived from the model). Because of this, and because the flows m^{jk} are created by a (dynamic) discrete choice model, we can estimate this equation with a Poisson pseudo maximum likelihood estimator (Gourieroux, Monfort and Trognon, 1984; Cameron and Trivedi, 1998). For our purposes, the Poisson pseudo ML regression provides estimates of moving costs within manufacturing C^m/ν, and in-and-out of manufacturing C^{nm}/ν, expected values λ_t^k, and the terms α_t^j.

In the second step we separately identify ν and η^j using the Bellman equation for the workers' problem. Multiplying (10) by β_1/ν and taking expectations, we get:

(21)

$$E_t\left[\frac{\beta_1}{\nu}W_{t+1}^j - \frac{\beta_1}{\nu}\left(\frac{w_{t+1}^j}{P_{t+1}} + \eta^j\right) - \frac{\beta_1}{\nu}E_{t+1}W_{t+2}^j - \frac{1}{\nu}\log\sum_k \exp\left(\beta_1 E_t W_{t+2}^k - \beta_1 E_t W_{t+2}^j - C^{jk}\right)\right] = 0.$$

Using the definition of λ_t^j and α_{t+1}^j, we get:

$$\text{(22)} \quad E_t\left[\lambda_t^j - \frac{\beta_1}{\nu}W_{t+1}^1 - \frac{\beta_1}{\nu}\left(\frac{w_{t+1}^j}{P_{t+1}} + \eta^j\right) + \beta_1\alpha_{t+1}^j + \frac{\beta_1^2}{\nu}W_{t+2}^1 - \log\left(N_{t+1}^j\right)\right] = 0.$$

Define:

$$\phi_t^j = \lambda_t^j + \beta_1\alpha_{t+1}^j - \log\left(N_{t+1}^j\right),$$

and

$$\zeta_t = \frac{\beta_1}{\nu} W^1_{t+1} - \frac{\beta_1^2}{\nu} W^1_{t+2},$$

We can now write (22) as a linear regression equation

(23) $$\phi^j_t = \zeta_t + \frac{\beta_1}{\nu}\eta^j + \frac{\beta_1}{\nu}\frac{w^j_{t+1}}{P_{t+1}} + v^2_t,$$

where v^2_t is an error term. In the regression equation (23), the variable ζ_t is a time fixed effect, variable $\frac{\beta_1}{\nu}\eta^j$ is a sector fixed effect, and the real wage $\frac{w^j_{t+1}}{P_{t+1}}$ is taken from the data. The estimated coefficient of real wage, $\frac{w^j_{t+1}}{P_{t+1}}$, is equal to $\frac{\beta_1}{\nu}$. The structural parameters can be estimated using IV with lag wage differences as instruments (as in Artuç, Chaudhuri, and McLaren, 2010).

The estimates of the labor mobility costs are in the bottom panel of Table 2. Our estimate of C^m is 2.07 and of C^{nm} is 1.41. This means that, on average, a worker wishing to switch sectors within the manufacturing sector would pay a mobility cost equivalent to 2.07 times his annual wage earnings. The costs needed to switch from manufactures to non-manufactures (or vice-versa) is lower, around 1.41 times the value of the annual wage income. We also estimate a fairly high variance of the idiosyncratic costs, $\nu = 0.78$.

Our estimates are much lower than those reported in Artuç (2012), using the same specification and U.S. data. He estimates 26 values of C, ranging from 4.5 to 4.8. Artuç and McLaren (2012) also use U.S. data on sectoral and occupational mobility, and report values closer to ours, with estimates of C as low as 0.99 and as high as 1.54 (with ν=0.257). Using different regression specifications, Artuç, Chaudhuri, and McLaren (2010) estimate an average moving cost of 6.565, and a value of ν of 1.884.[24]

4 Responses to Trade Shocks

We now use the model and the estimated parameters to simulate the dynamic implications of a trade shock in the Food and Beverages sector (Sector 1). We model the trade shock as a permanent price increase in Sector 1. The price increase could originate either from an expansion in export opportunities due to an increase in world demand or a decrease in world supply (a change in p^*_{jt}), or from a decrease in trade taxes (a change in τ_{jt}). Either way, for a small country and homogeneous goods, the shock takes the form of an upward shift in a perfectly elastic demand. Since we work with a multi-sector model with tradables and non-

[24] In these three papers, the authors impose, as we do, a value for the discount factor of 0.97.

tradables, the price shock to one sector that we study is not equivalent to an economy-wide macro shock.[25]

We study the transitional dynamics of sectoral capital, employment, wages, profits, output, and exports. We evaluate differences in short-run vis-à-vis long-run responses and also asses how these responses depend on the size of the shock (i.e., a small or a large trade shock). We are particularly interested in the complementarities between price shocks and the level of the cost of adjustment of capital, as well as on the role of firm-level investment decisions.

In order to assess the impact of an unexpected increase in export opportunities we create a stationary economy and shut down all other aggregate shocks. We assume that prices of all tradable products (p_t) are constant, with the exception of the permanent price increase in Sector 1, that occurs at time $t = 1$. Consequently, we assume that productivity A_{ijt} follows the same Markov process as profitability $\widetilde{A}_{ijt}$, given by (15) and (16). We further assume that there are no aggregate productivity shocks, that is, we set $b_t = 0 \; \forall t$ in (15). In the initial stationary equilibrium, at time $t = 0$, firms are subject to Markov productivity shocks that create individual fluctuations in investment, employment and output, while workers are subject to utility shocks that create labor mobility. At the aggregate level, however, labor allocations, capital, output, and firm distributions are constant in the initial stationary equilibrium. At time $t = 1$ there is a permanent price increase in Sector 1 that triggers dynamic responses. After a transition period, the economy converges to a new stationary equilibrium, at time T. Shutting down other price shocks and aggregate productivity shocks allows us to isolate the effect of a trade shock to one sector.

We use the model parameters to simulate the initial stationary equilibrium, the transition period, and the new stationary equilibrium, for firms and workers. For each time period and sector, we jointly solve the optimal decisions of firms and workers from their Bellman equations. Given that we shut down aggregate shocks, firms and workers have perfect foresight of firm distributions, labor allocations, and equilibrium wages during the transition period. The trade shock is a one-time unexpected shock, but there are no other sources of aggregate uncertainty. The only remaining source of uncertainty are firm-level productivity shocks A and worker-level utility shocks ε. From optimal individual decisions we compute aggregate equilibrium variables.

To solve for the equilibrium we discretize the firm-level state variables A and K and use the following algorithm. First, we start with a guessed path for labor allocations $\{N_{jt}\}_{t=0}^{T}$, firm distributions $\{\mu_{jt}(K, A)\}_{t=0}^{T}$, and prices of non-tradables, where 0 and T are the original and new stationary equilibria and periods in between correspond to the transition. Sec-

[25]This is a key difference with the macro literature featuring factor adjustment costs such as Cooper and Haltiwanger (2006), Bloom (2009). See the discussion in Section 2.4.

ond, we solve the firms' Bellman equation and compute equilibrium-path solutions for the value and policy functions with respect to the guessed aggregate variables. That is, for each sector j we obtain sequences of matrices $\{V_0^j(A,K), V_1^j(A,K), \ldots, V_T^j(A,K)\}$ and $\{I_0^j(A,K), I_1^j(A,K), \ldots, I_T^j(A,K)\}$.[26] Third, from the firm-level solutions and using the firm distributions μ_t^j, we obtain aggregate labor demands, equilibrium wages (given the labor allocations), aggregate investment demands, aggregate supply of the non-tradable good, and firm distributions for the following period. We also obtain responses by arbitrary firm-types, for example, firm-level investment status (positive investment, negative investment, and investment inaction). Fourth, wages and prices of non-tradables are plugged in together with the guesses of N and μ into the workers' Bellman equation, which has a closed form solution for equilibrium-path values and can be solved analytically. Finally, labor allocations, firm distributions and prices of non-tradables are updated and the process is repeated until convergence to a fixed point in aggregate variables is achieved. Each iteration involves solving the firms and workers problem jointly, so that all agents form rational expectations about future equilibria and state variables.

4.1 Increase in Export Opportunities

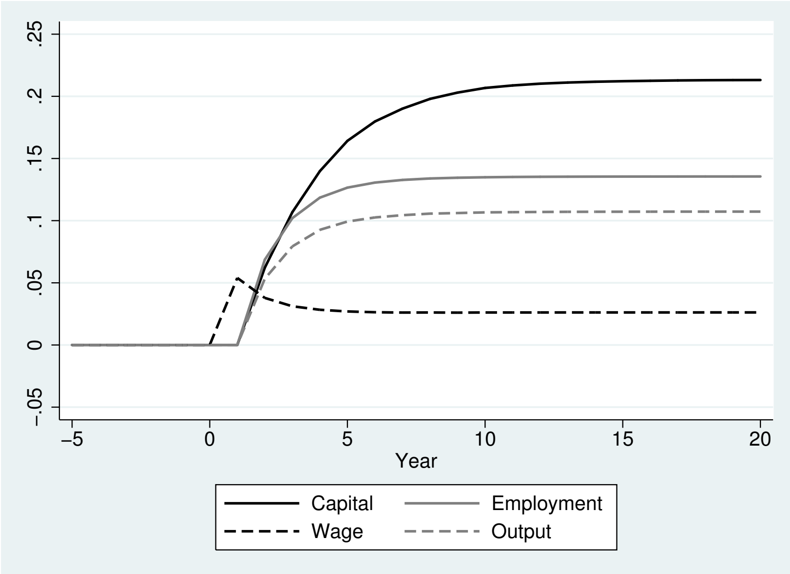
To document the generic dynamic responses, we begin with the impacts of an increase in the price of Food and Beverages (Sector 1) of 10 percent. Figure 2 illustrates the mechanics of the effects in the shocked sector. The immediate implication of a higher price is an increase in profitability for firms in the sector. Firms want to expand, however, capital and employment sectoral allocations are predetermined and do not respond initially.[27] The nominal wage goes up in Sector 1 due to the increase in labor demand. There is an increase in the price index that brings down real wages in all sectors. The net effect in the real wage in Sector 1, however, is positive, as depicted in Figure 2. In the following periods firms invest to adjust their stock of capital and workers flow to Sector 1 attracted by the higher real wages. Because of the idiosyncratic productivity and utility shocks not all firms and workers react at once or equally. Capital and employment gradually increase until they converge to a new steady state level. Output accordingly increases and its response is smaller than the response in capital and employment due to decreasing returns to scale. Real wages decrease with respect to their initial overshot level as labor supply increases in Sector 1.

Figures 3 and 4 display the general equilibrium responses in other tradable sectors and

[26] We discretize A and K into 20 and 154 grid points. T is equal to 30.

[27] Note that investment at t becomes productive capital in $t+1$. In consequence, while there is an investment response in the first year of the shock, the capital stock remains at the steady state level for one period before adjusting.

Figure 2
Price Increase of 10 Percent
Capital, Real Wage, Employment and Output

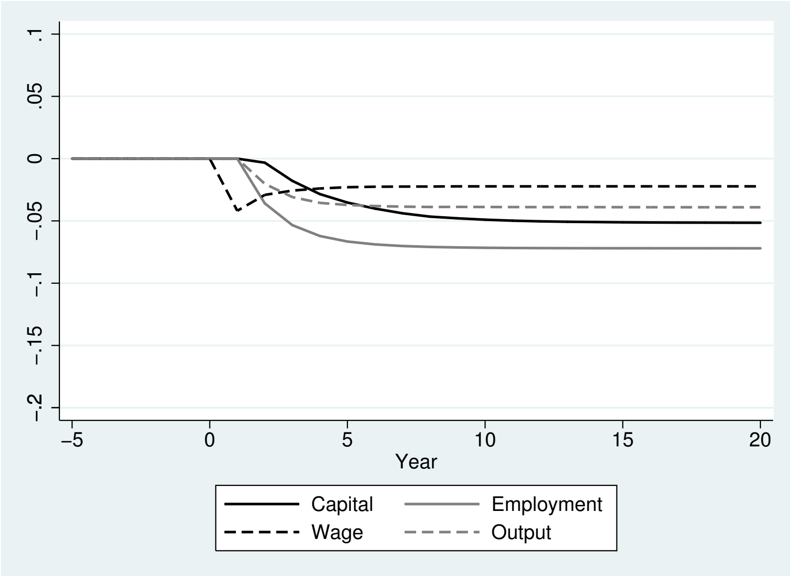


Simulation of a 10 percent increase in the price of Food & Beverages. Dynamic responses of capital, real wage, employment and output in the shocked sector.

in the non-tradable sector. The four other tradable sectors are added up together, and the average wage is computed using sectoral employment as weight. At the time of the shock real wages go down due to the increase in the price index, and then partially recover due to the reduction in sectoral labor supply. Because total labor supply is fixed, employment in other sectors decreases as workers flow to Sector 1. Capital and output decrease in other tradables, whereas they increase in non-tradables due to income demand effects. The price of non-tradables adjusts so that supply is equal to demand.

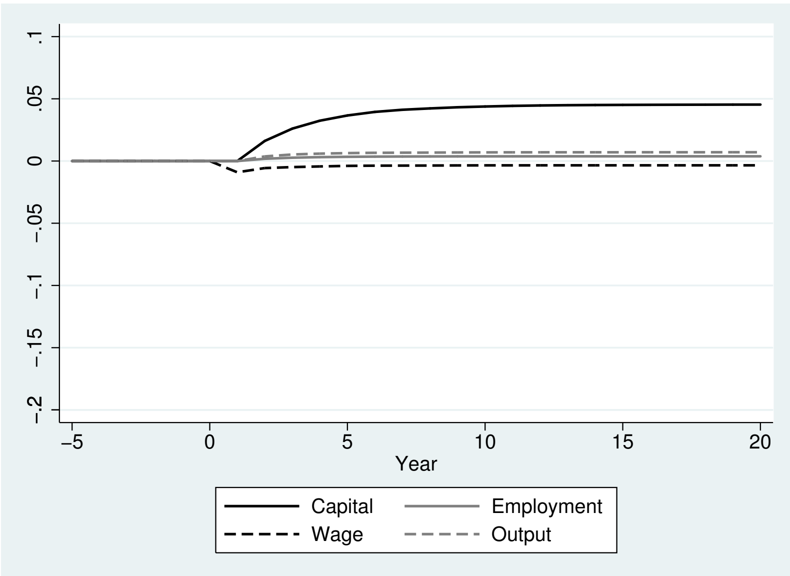
More details about the magnitudes of the responses in Food and Beverages are given in Table 3. For a 10 percent price shock (in the second panel of the table), column 1 shows that the capital stock increases by 6.22 percent initially (Year 2), by 10.68 percent in Year 3, and by 21.33 percent in the new steady state; 95 percent of the transition is covered in 9 years. Employment increases by 6.86 percent in Year 2, 10.20 percent in Year 3, and 13.56 percent in the new steady state; the convergence of employment is faster than for capital, covering 95 percent of the transition in 6 years (column 3). The real wage increases by 5.40 percent at the time of the shock and starts declining gradually after that (column 5). In the new steady state, real wages are only 2.62 percent higher than in the initial equilibrium. This happens even though firms keep expanding capital for a few years because of the continuous inflow of workers. Instead, aggregate profits increase steadily (column 7). The trade shock benefits both

Figure 3
Price Increase of 10 Percent. Other Tradable Products



Simulation of a 10 percent increase in the price of Food & Beverages. Dynamic responses in the other four non-tradable sectors. Average response in wage is computed by weighting sectors according to participation in employment.

Figure 4
Price Increase of 10 Percent. Non-tradables



Simulation of a 10 percent increase in the price of Food & Beverages. Dynamic responses in the non-tradable sector.

firms (i.e., the entrepreneurs who own the fixed managerial ability) and workers in Food and Beverages, but entrepreneurs benefit significantly much more.

Table 3
Responses to Price Shocks in the Food & Beverages Sector
Capital, Employment, Real Wages and Profits

	Capital		Employment		Wage		Profits	
	Percentage Change (1)	Elast. (2)	Percentage Change (3)	Elast. (4)	Percentage Change (5)	Elast. (6)	Percentage Change (7)	Elast. (8)
5% Shock								
Year 1	0	0	0	0	2.74	0.55	9.51	1.90
Year 2	2.78	0.56	3.42	0.68	1.83	0.37	9.64	1.93
Year 3	5.09	1.02	5.07	1.01	1.51	0.30	10.01	2.00
Long Run	10.36	2.07	6.80	1.36	1.31	0.26	10.82	2.16
Transition	10		6		4		4	
10% Shock								
Year 1	0	0	0	0	5.40	0.54	19.26	1.93
Year 2	6.22	0.62	6.86	0.69	3.79	0.38	19.53	1.95
Year 3	10.68	1.07	10.20	1.02	3.11	0.31	20.37	2.04
Long Run	21.33	2.13	13.56	1.36	2.62	0.26	22.05	2.21
Transition	9		6		5		5	
30% Shock								
Year 1	0	0	0	0	15.34	0.51	60.65	2.02
Year 2	19.90	0.66	19.48	0.65	10.85	0.36	61.50	2.05
Year 3	34.82	1.16	28.91	0.96	9.05	0.30	64.28	2.14
Long Run	68.97	2.30	38.40	1.28	7.61	0.25	69.82	2.33
Transition	10		6		5			

Notes: Simulation of 5%, 10% and 30% shocks to the price of the Food & Beverages Sector. Columns (1), (3), (5), and (7): Percentage response of aggregate variables in the shocked sector. Columns (2), (4), (6), and (8): Elasticity of responses (i.e. percentage response divided by percentage price shock). Year 1: Year of shock. Long Run: Year 30. Transition: number of years to converge to 95% of the long run value.

The magnitude of the responses depends on the size of the shock. To see this, we report in Table 3 the impacts of price increases of 5 and 30 percent. As expected, the economy adjusts more when the trade shock is larger. For example, while, as we just showed, a price increase of 10 percent induces a steady state increase in capital, employment and wage of 21.33, 13.56 and 2.62 percent, the responses to a price increase of 30 percent are 68.97, 38.40 and 7.61 percent.

The comparison of responses in Table 3 uncovers a magnification effect of the trade shocks. Column 2 shows that the price elasticity of capital is increasing in the price shock, implying that as the positive price shock becomes larger, the aggregate capital stock of the economy becomes proportionately more responsive. This magnification effect is sizeable. For instance, the long-run elasticity of capital increases from 2.07 to 2.30 for price shocks of 5 and 30 percent respectively. This result is due to the fixed costs and irreversibilities in investment. Fixed costs and irreversibilities create zones of inaction where firms with given combinations of idiosyncratic productivity and predetermined capital stock do not react to a price shock. However, a larger shock makes it profitable for more firms to move out of these inaction regions. There is also a stronger response of active firms (an intensive margin effect). This is a novel mechanism of our paper, which we further explore below.

The enhanced responsiveness of capital to the price shock is not reflected in the responsiveness of the labor market. In fact, the elasticity of employment and real wages in Food and Beverages is roughly independent of the size of the shock. This is because of three forces. First, ceteris paribus, the expansion in the capital stock can only have a relatively small effect on the marginal product of labor because the coefficient $\alpha = 0.142$ is low. This dampens quite significantly any magnification effect of capital on wages. Second, the intersectoral wage differences generated by the shock induce a reallocation of labor towards the expanding sector and this dampens the initial increase in wages. Finally, the general equilibrium repercussions imply an increase in the price of non-tradables that raises the consumer price index and further dampens the response of the real wages in Food & Beverages. Some of these forces can be seen, in part, in the evolution of the nominal wage (not reported) for which the price elasticity does increase with the size of the shock. It follows that because of the nature of our general equilibrium model the magnification effects of capital are observed in nominal wages but not in real wages.

The enhanced responsiveness of capital is, instead, mirrored in profits. In columns 7 and 8 of Table 3, we see a more than proportional response of profits as the price shock becomes larger. For example, a price shock of 10 percent increases profits by 19.26 percent in Year

1 and by 22.05 percent in the new steady state. Instead, following a 30 percent price shock, profits increase by 60.65 and 69.82 percent in Year 1 and in the steady state, respectively. These results have implications for the distribution of the gains from trade. In particular, firms benefit more than workers and, on top of that, as the shock becomes larger, capital expands more than proportionately, and this favors firms relatively even more.

Table 4 displays the proportional responses and elasticities of output and exports in Sector 1 sector, and GDP. Output and exports of Food & Beverages are measured in physical units (quantities), while GDP is measured in real monetary units (with prices normalized to 1 in the initial steady state). As shown above, Food Output increases steadily. After a 10 percent price shock, output increases by 5.33 percent in Year 2, by 7.93 percent in Year 3, and by 10.73 percent in the new steady state. Convergence takes between 6 and 7 years. The proportional response of output (the elasticity with respect to the price shock) decreases slightly with the price shock, especially in the longer-run. For instance, the long-run elasticity for a 5 percent price shock is 1.08, but it drops to 1.01 for a 30 percent price shock. The absence of the magnification effect in output that we observe in capital is due to the decreasing returns to capital and labor and to the absence of a magnified elasticity of labor itself.

Column 3 displays the response of net exports. Prior to the shock, net exports of Food and Beverages are positive and account for 17 percent of output. Net exports increase twofold, because of the increase in output and because of the decline in domestic consumption. The increase in Food prices implies a decrease in domestic demand from Year 1 onwards, which, since international demand is perfectly elastic, implies a shift of units previously sold domestically to the export market. This effect is large: for a 10 percent price shock, the initial response of exports due to a decrease in domestic consumption is of 70.29 percent in Year 1. From Year 2 onwards exports further increase due to the response of output, reaching a long run response of 128.40 percent in the new steady state. The overall reaction of exports is very large (the implied long-run elasticity is 12.84), because exports are initially low relative to domestic consumption and output.[28] Columns (5) and (6) report the percentage of the increase in exports that is explained by an increase in output and a decrease in domestic consumption, respectively. While exports are initially only explained by a fall in consumption, the increase in output becomes relevant during the transition and both forces approximately even out in the long run.

[28]Let x be exports, q be output and c be consumption. It follows that $dx/x = (q/x)dq/q - (c/x)dc/c$, so that the proportional change in exports is a weighted average of the proportional change in output and consumption. Since the export share in output is 0.17, the weights are $(q/x) = 5.89$ and $(c/x) = 4.89$.

Table 4
Responses to Price Shocks in the Food & Beverages Sector
Output, Exports, and real GDP

	Output		Exports				GDP	
	Percentage Change	Elast.	Percentage Change	Elast.	Explained by Output	Explained by Consumption	Percentage Change	Elast.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5% Shock								
Year 1	0	0	37.47	7.49	0	1	0	0
Year 2	2.56	0.51	51.34	10.27	0.29	0.71	0.13	0.03
Year 3	3.90	0.78	58.52	11.70	0.39	0.61	0.21	0.04
Long Run	5.41	1.08	66.77	13.35	0.47	0.53	0.32	0.06
Transition	7		5				8	
10% Shock								
Year 1	0	0	70.29	7.03	0	1	0	0
Year 2	5.33	0.53	98.85	9.88	0.31	0.69	0.42	0.04
Year 3	7.93	0.79	113.31	11.33	0.41	0.59	0.58	0.06
Long Run	10.73	1.07	128.40	12.84	0.49	0.51	0.79	0.08
Transition	6		5				7	
30% Shock								
Year 1	0	0	168.15	5.61	0	1	0	0
Year 2	15.40	0.51	250.58	8.35	0.36	0.64	1.33	0.04
Year 3	22.77	0.76	290.28	9.68	0.46	0.54	1.88	0.06
Long Run	30.31	1.01	330.92	11.03	0.53	0.47	2.54	0.08
Transition	6		5				7	

Notes: Simulation of 5%, 10% and 30% shocks to the price of the Food & Beverages Sector. Columns (1), (3), and (7): Percentage response of aggregate variables in the shocked sector. Columns (2), (4), and (8): Elasticity of responses (i.e. percentage response divided by percentage price shock). Columns (5) and (6): Percentage contribution of changes in output and consumption to the change in exports. Year 1: Year of shock. Long Run: Year 30. Transition: number of years to converge to 95% of the long run value.

Column 7 reports the reaction of real GDP. GDP is computed aggregating output from all sectors, subtracting adjustment costs, and deflating to account for changes in prices. A 10 percent shock to the price of Food and Beverages generates a short run GDP growth of 0.42 percent in Year 2 and a long run accumulated growth of 0.79 percent. Simulations for GDP assume that trade taxes are zero, since only changes in output are considered.

4.2 Complementarities

It is often argued that trade policy should be complemented with domestic reforms to be fully successful. For instance, a trade reform can be fail to have the desired impacts if the domestic conditions are inadequate. In this section, we investigate this complementarity by looking at the role of capital adjustment costs and firm-inaction in the response of the economy. To better illustrate this complementarity, we focus on fixed costs and irreversibilities in capital adjustment. When there is a positive trade shock, firms have incentives to invest, but capital adjustment costs dampen or prevent this expansion. Those firms that are unable to overcome the fixed costs remain in a region of inaction. Other firms react to the shock, but their reaction is smaller relative to their reaction in the absence of adjustment costs. This happens because firms face uncertainty about future productivity levels and consider the probability of having to pay the fixed cost and to face a lower resale value in order to disinvest in the future. In this setting, there is a potential complementarity between the fixed and irreversibilities costs and the price shocks. We want to explore whether this complementary is present and to assess how important it is in the data.

To do this, we simulate a counterfactual scenario in which a trade shock to Food and Beverages takes place in the absence of both fixed costs and irreversibility costs. As in the previous section, the price shock occurs at time $t = 1$, it is unexpected, and there are no sources of aggregate uncertainty past the shock. We can formalize the complementarity. Let Γ denote the estimated adjustment cost parameters, which are the ones used in the simulations of the previous section, and let $\widetilde{\Gamma}$ denote a counterfactual cost structure without fixed costs and irreversibilities in investment, that is, $\widetilde{\gamma}_1 = 0$ and $\widetilde{\gamma}_3 = 0$. Let the $(J-1) \times 1$ vector p denote prices of tradables prior to the shock, and the vector $\widetilde{p}$ denote the price vector after the shock. The vectors p and $\widetilde{p}$ are time invariant and differ only in the price of Food and Beverages. Because there is no aggregate uncertainty, we can write the firm-level and aggregate-level solutions as a function of the exogenous prices p. We can also explicitly write the solutions as a function of the cost parameters, Γ. We use the case of capital as an example. Aggregating over the distribution of firms, aggregate capital κ in sector j can be written as

$$(24)\quad \kappa_{jt+1}(p,\Gamma) = \int_{(K,A)} K_{ijt+1}(A,K,p,\Gamma)\mu_t^j(dK \times dA|p,\Gamma).$$

We are interested in comparing an initial steady state under the estimated adjustment cost parameters and original price vector (p,Γ) with a counterfactual scenario in which a price shock occurs under the alternative cost structure $(\widetilde{p},\widetilde{\Gamma})$. That is, in the case of capital, we are interested in quantifying the response $\kappa_{jt+1}(\widetilde{p},\widetilde{\Gamma}) - \kappa_{jt+1}(p,\Gamma)$. Algebraically, the capital response to a change in prices and cost structure can be written as

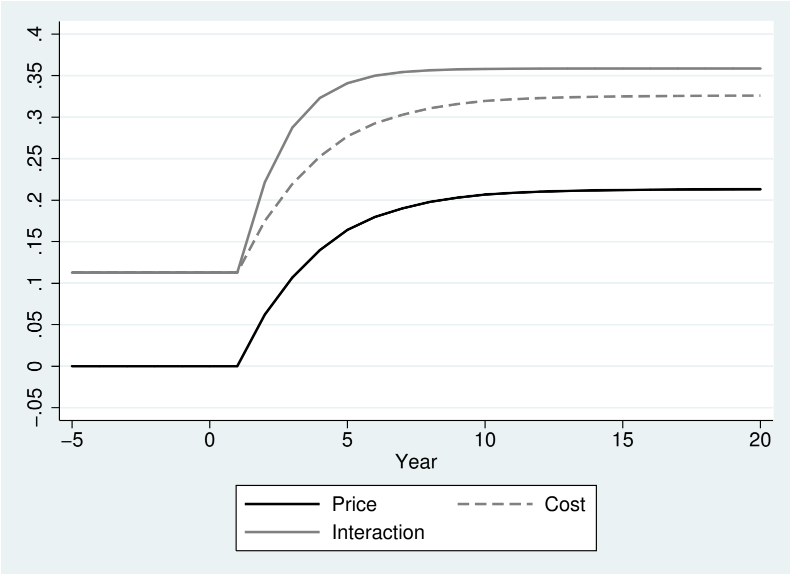
$$\begin{aligned}(25)\quad \kappa(\widetilde{p},\widetilde{\Gamma}) - \kappa(p,\Gamma) &= \left[\kappa(p,\widetilde{\Gamma}) - \kappa(p,\Gamma)\right] + \left[\kappa(\widetilde{p},\Gamma) - \kappa(p,\Gamma)\right] \\ &\quad + \left(\left[\kappa(\widetilde{p},\widetilde{\Gamma}) - \kappa(p,\widetilde{\Gamma})\right] - \left[\kappa(\widetilde{p},\Gamma) - \kappa(p,\Gamma)\right]\right).\end{aligned}$$

The three terms in the decomposition are: i) the effect of a change in the cost structure Γ, at the initial prices; ii) the effect of a change in prices p, at the initial cost structure; iii) the complementarity between p and Γ, defined as the incremental effect of a change in prices at the new cost structure. In order to isolate the contribution of each counterfactual change, the experiment is based on the simulations of four situations: (p,Γ), $(p,\widetilde{\Gamma})$, $(\widetilde{p},\Gamma)$ and $(\widetilde{p},\widetilde{\Gamma})$. The previous section dealt with the comparison of situations (p,Γ) and $(\widetilde{p},\Gamma)$.

Results for aggregate capital are displayed in Figure 5 and Table 5. In Figure 5, from $t = 1$ onwards, the solid black line denotes the price effect—this is the same response as in Figure 2. The vertical distance between the solid black line and the dashed grey line denotes the effect of the change in cost structure. The complementarity is the vertical distance between the dashed and solid grey lines; this is the incremental price effect in the absence of fixed costs and irreversibilities in investment. The figure shows a sizeable complementarity effect that is especially important in the short run. It is important to note that while the complementarity plays a more meaningful role in the early years after the shock, it matters during the whole transition even when the capital adjustment costs that prevent investment inaction are eliminated. This in fact implies, as shown above, a quick and strong reaction of investment in Year 1 and of capital in Year 2. But the complementarity persists. This is because the other factor adjustment costs, and in particular the labor mobility costs C, are still in place. Thus, capital keeps adjusting as labor flows to the Food sector and this adjustment is still boosted by the price-capital-adjustment-cost complementarity.

The complementarity is quantified in Table 5. As expected, the increase in capital is much larger when we shock prices and the cost structure simultaneously (see columns 1 and 2).

Figure 5
Complementarity Between Price Shock and Adjustment Costs



Black solid line: simulation of a price shock of 10 percent. Grey solid line: simulation of a price shock of 10 percent under a counterfactual initial situation of no fixed costs and no irreversibility. Grey dashed line: vertical shift of the black solid line accounting for differences in initial steady states. The black solid line depicts a price effect under the original cost structure. The vertical difference between the grey dashed line and the black solid line depicts the effect of the change in cost structure. The vertical difference between the solid and dashed grey lines depicts the incremental price effect under the counterfactual cost structure (the complementarity).

For a 10 percent price shock, for instance, the long-run increase in capital is 35.85 percent instead of 21.33 percent (Table 3 column 1). The transition period is also shorter. This is not surprising. More informative are instead the differences observed in the three components of the decomposition. We find that the role of the cost structure is more significant in the short-run than in the long-run (column 3). For a 10 percent price shock, the combined shock causes capital to increase by 22.15 percent in Year 2, by 28.74 percent in Year 3, and by 35.85 percent in the long-run. In the short-run, the change in the cost structure explains half of the increase in K. In the long-run, it explains only 31.45 percent. Instead, the joint role of the price change and the complementarity effect becomes more relevant (columns 4 and 5) in the long-run. This is because most of the response to lower capital adjustment costs occurs immediately, while the adjustment to the price shock is more gradual and takes time (as labor reallocates and capital further expands).

The relative importance of the pure price and complementarity components, however, varies along the transition (column 6). In the long-run, the pure price effect becomes relatively more relevant than the complementarity effect. This implies a stronger short-run complementarity between trade shocks and domestic conditions. We claim this is because of the role of firm-

Table 5
Complementarity of Price Shocks and Capital Adjustment Costs. Response of Capital

	Percentage Response	Elasticity	Decomposition			Complementarity (Price + Comp.)
			Cost	Price	Complementarity	
	(1)	(2)	(3)	(4)	(5)	(6)
5% Shock						
Year 2	16.67	3.33	67.64	16.69	15.68	48.44
Year 3	19.91	3.98	56.63	25.56	17.81	41.07
Long Run	23.27	4.65	48.47	44.53	7.00	13.59
Transition	5					
10% Shock						
Year 2	22.15	2.22	50.91	28.06	21.03	42.84
Year 3	28.74	2.87	39.23	37.16	23.60	38.84
Long Run	35.85	3.59	31.45	59.50	9.05	13.21
Transition	6					
30% Shock						
Year 2	42.91	1.43	26.28	46.38	27.34	37.08
Year 3	64.67	2.16	17.44	53.84	28.73	34.79
Long Run	89.61	2.99	12.58	76.96	10.45	11.96
Transition	6					

Notes: Simulation of 5%, 10% and 30% shocks to the price of the Food & Beverages Sectors under a counterfactual scenario of no fixed costs of capital adjustment and no investment irreversibility ($\gamma_1 = 0$ and $\gamma_3 = 1$). Columns (1) and (2): response in percentage and elasticity to a change in prices and change in cost structure. Columns (3), (4), and (5): Percentage contribution of three factors to the total change in column 1, i.e., (3): contribution of the change in the cost structure; (4): contribution of the changes in price at the non-counterfactual cost structure; and (5): incremental contribution of the changes in price at the counterfactual cost structure (complementarity). Column (6): importance of the complementarity term relative to the total contribution of the changes in price; (6) = (5)/((4)+(5)). All results refer to changes in aggregate capital in the shocked sector.

level investment decisions, both in the form of total inaction or of mitigated investment choices. In fact, when we eliminate the fixed costs γ_1 and the irreversibility costs γ_3, investment inaction ceases to be an optimal response. It follows that firms invest quickly, and more strongly, in the wake of a positive price shock. This effect is a short-run effect, and it loses force as the economy adjusts.

The relative size of the complementarity effect depends on the size of the shock (Table 5). For larger prices changes, as expected, the contribution of the change in cost structure becomes less relevant than the joint price effect (pure price effect plus interaction effect). However, the complementarity effect losses relative power as the shock becomes larger. In Year 2, for example, the complementarity accounts for 48.44 percent of the joint effect of a 5 percent price shock. For a 30 percent shock, the complementarity effect accounts for 37.08 percent of the total price effect. In the long-run, these contributions are much more similar, 13.59 percent in the case of a 5 percent price shock and 11.96 percent in the case of a 30 percent price shock. This result is driven by the incentives to investment inaction generated by the inaction costs. Given the value of γ_1 and γ_3 in the baseline, a larger price shock induces a larger proportion of firms to respond in the short-run. To put it differently, if the price shock is small when adjustment costs are high, fewer firms will find it optimal to adjust investment immediately after the shock. In the absence of those costs, thus, the same small price change will induce a much larger response of many of those firms that choose inaction in the baseline. As the price shock grows larger, these differential responses become smaller. In the long-run (in steady state, but also after about 5 years in our simulations) most firms have already adjusted and thus the differential responses narrow. Eventually, when capital adjustment is full (to its steady state), a larger price shock elicits similar proportional responses.

Arguably, the complementarity effect is especially relevant for initially inactive firms. This is because their investment decisions are more significantly affected by the combined forces of the changes in the cost structure and in prices. In the model, firms are characterized by pairs (K, A) and, to illustrate our point, we group them into three types depending on whether these firms find it optimal to i) invest; ii) disinvest; iii) stay inactive in the initial steady state (pre-shock). From equation (24) the total capital response can be written as the aggregation of the responses by firm type (K, A), plus a term that represents the change in firm distribution. Let ι index firm types, with $\iota = 1$ for firms with positive investment, $\iota = 2$, for firm with negative investment, and $\iota = 3$ for inactive firms. Then,

$$\begin{aligned} \kappa_{jt+1}(\widetilde{p}, \widetilde{\Gamma}) - \kappa_{jt+1}(p, \Gamma) &= \sum_{\iota=1}^{3} \int_{(K,A)|\iota} \left[K_{ijt+1}(A, K, \widetilde{p}, \widetilde{\Gamma}) - K_{ijt+1}(A, K, p, \Gamma)\right] \mu_t^j(dK \times dA | p, \Gamma) + \\ &+ \int_{(K,A)} K_{ijt+1}(A, K, \widetilde{p}, \widetilde{\Gamma}) \left[\mu_t^j(dK \times dA | \widetilde{p}, \widetilde{\Gamma}) - \mu_t^j(dK \times dA | p, \Gamma)\right] \end{aligned} \tag{26}$$

For each group, we calculate their contribution to the overall change in the capital stock and we quantify the relative importance of the complementarity effect for initially inactive firms. Results are in Table 6. For initially inactive firms, we find that the interaction of changes in cost and change in structure (column 6) explains a large part of their increase in capital. The relative importance of the interaction term with respect to the total price change (columns 5 + 6) is decreasing in the magnitude of the price shock and in the long run, as expected. This means that the combination of a price shock in the presence of lower "inaction" costs induces inactive firms to respond, and they do so significantly. Column 7 reflects the change in firm distribution; these compositional changes become noticeably less important with larger price shocks.

Table 6
Capital Adjustment by Firm Type

	Positive Investment Firms	Negative Investment Firms	Inactive Firms					Compositional Term
			Total	=	Cost +	Price +	Complementarity	
	(1)	(2)	(3)		(4)	(5)	(6)	(7)
5% Shock								
Year 2	13.03	12.14	10.68		5.06	1.48	4.14	64.15
Year 3	12.64	11.85	9.75		4.23	1.68	3.83	65.77
Long Run	11.58	10.54	8.70		3.62	1.44	3.64	69.18
10% Shock								
Year 2	19.48	17.69	12.59		3.81	2.73	6.05	50.24
Year 3	16.90	15.28	10.81		2.93	2.93	4.94	57.01
Long Run	14.49	13.00	9.23		2.35	2.66	4.21	63.28
30% Shock								
Year 2	28.70	25.29	15.56		1.97	5.21	8.38	30.45
Year 3	21.54	19.30	11.65		1.30	5.20	5.15	47.51
Long Run	16.62	14.82	8.87		0.94	4.59	3.34	59.69

Notes: Table is based on the same simulations as Table 5. It depicts the contribution to the response of aggregate capital (Column 1 of Table 5) of three firm types grouped according to their investment behavior in the steady state of the non-counterfactual scenario: positive investment firms, negative investment firms, and inactive (zero investment) firms; and the change in composition of firms (firm distribution). The contributions are expressed in percentages, so that (1) + (2) + (3) + (7) = 100. The contribution of inactive firms is further decomposed into the cost, price and interaction factors, so that (3) = (4) + (5) + (6).

We now discuss the implications of these results for the adjustment of other variables in the economy. Results following a 10 percent price shock are in Table 7. We begin by looking at the distribution of the gains from trade between real wages and real profits in the Food & Beverages sector. Unlike the case of capital, the effect of changes in the cost structure on the real wage becomes more important in the longer-run. For example, the changes in costs account for 47.68 percent of the total change in wages in the short-run and for 65.70 percent in the long-run. This is because, as before, the adjustment of capital after the elimination of the inaction costs is quick and, moreover, because of the overshooting of the real wage after the price shock. This implies that the joint price effect, and in particular the pure price effect, losses strength during the transition. In the case of profits, the opposite happens. The cost effect is more important in the short-run, and the joint price effect, in the longer-run. The magnitudes of the short- and long-run differences are, however, small, especially compared to those reported for capital.

The impact of the complementarities on the distributional conflict is typically small. The complementarity accounts for only 2.61 percent of the overall change in wages in Year 1; in the steady state, for 1.03 percent.[29] In the case of profits, the complementarity accounts for 1.23 percent in Year 1 and for 3.59 percent in the steady state. The differences in the complementarity effect on wages and profits are important, though. For wages, the relative role of the complementarity vis-à-vis the pure price effect is much larger in the short-run than in the long-run. For profits, it is the other way around. The quicker investment adjustment in the early years of the transition due to the complementarity implies a higher real wage in Food and Beverages and a distribution of the gains from the price shock towards workers in the sector. As this effect vanishes, the gains from the interaction of adjustment costs and prices shift towards firms.

Table 7 also shows results for Food & Beverages employment, output, exports and real GDP. The complementary effect arises in all these responses. As before, the effects are generally small. We illustrate with the case of exports. Most of the change in exports (between 91 and 92 percent) is accounted for by the pure price effect. The complementarity effect accounts for 4.59 percent in Year 1, 5.07 percent in Year 2, and 5.58 percent in the new steady state. The complementarity thus becomes more important in the long-run than in the short-run, and it also becomes relatively more important relative to the pure price effect during the transition.

[29]This is, again, due to the low coefficient of the capital stock and due to the general equilibrium nature of the model, as explained above.

Table 7
Complementarity of Price Shocks and Capital Adjustment Costs
Response of Wages, Profits, Employment, Output, Exports, and GDP

	Percentage Response	Elasticity	Decomposition			Complementarity/ (Price + Comp.)
			Cost	Price	Complementarity	
	(1)	(2)	(3)	(4)	(5)	(6)
Real Wages						
Year 1	10.85	1.09	47.68	49.71	2.61	4.99
Year 2	9.03	0.90	57.30	41.93	0.76	1.79
Long Run	7.88	0.79	65.70	33.27	1.03	3.01
Transition	3					
Real Profits						
Year 1	23.53	2.35	16.94	81.84	1.23	1.48
Year 2	23.81	2.38	16.74	82.04	1.21	1.46
Long Run	27.00	2.70	14.76	81.65	3.59	4.21
Transition	4					
Employment						
Year 2	6.14	0.61	-14.24	111.78	2.46	2.15
Year 3	9.53	0.95	-9.17	107.08	2.10	1.92
Long Run	12.90	1.29	-6.78	105.11	1.67	1.56
Transition	6					
Output						
Year 2	10.32	1.03	45.25	51.66	3.09	5.64
Year 3	13.24	1.32	35.27	59.92	4.82	7.44
Long Run	16.23	1.62	28.77	66.12	5.12	7.19
Transition	5					
Exports						
Year 1	77.04	7.70	4.18	91.24	4.59	4.79
Year 2	107.52	10.75	2.99	91.93	5.07	5.23
Long Run	139.39	13.94	2.31	92.12	5.58	5.71
Transition	5					
Real GDP						
Year 2	5.40	0.54	92.05	7.78	0.17	2.15
Year 3	5.60	0.56	88.77	10.35	0.87	7.78
Long Run	5.79	0.58	85.77	13.56	0.67	4.71
Transition	3					

Notes: Analogous to Table 5. Only 10 percent price shocks are reported. All results refer to changes in aggregate variables in the shocked sector.

5 Conclusions

We have developed a structural dynamic general equilibrium model of trade and the labor market with factor adjustment costs. Firms make intertemporal investment decisions facing capital adjustment costs that include fixed costs, convex costs and investment irreversibility costs. Workers choose employment sector based on equilibrium intersectoral wage differences and labor mobility costs. These costs include various labor market frictions such as imperfections in firing and hiring workers as well as specific utility shocks. The model features general equilibrium effects, articulating both the product and the labor market, in a multisector economy. This allows us to analyze the interplay between trade shocks and factor adjustment costs. We have fitted our model to household survey panel data and plant-level panel data from Argentina and recovered measures of the adjustment frictions faced both by workers and firms. Using the structural parameters, we have simulated the response of the model, both of firms and workers, following a positive trade shock to the Food and Beverages sector. Shocks to other sectors or multiple shocks can also be considered.

With factor adjustment costs, the economy adjusts sluggishly both in terms of firm-level investment and of the labor market. Covering 95 percent of the transition to the new steady state can take ten years for capital and six years for employment. Real wages in the Food & Beverages sector increase on impact, but then partially decline as firms gradually hire more workers. Real wages in all other sectors decline on impact, but then partially increase as worker flow to the shocked sector. Profits increase gradually. As expected, the shock creates a distributional conflict favoring workers and firms in the Food & Beverages sector at the expense of workers and firms elsewhere. A larger trade shock triggers a larger response. In the case of capital, this response is proportionally larger as the shock grows larger because more firms are moved out of the investment inaction region. This magnified response also shows up in profits. However, because of the technology, which is not very capital intensive, and because of general equilibrium effects, that imply increases in non-tradable prices, there are no magnification effects on real wages. Larger shocks can thus exacerbate the unequal distribution of the gains from trade, especially between firms and workers in the affected sector.

Our model features a complementarity between domestic reforms and trade shocks. We have explored this theme by simulating counterfactual scenarios with trade shocks and reductions in capital adjustment costs. The economy reacts more to the combined shock. More importantly, capital becomes proportionately more responsive when the trade shock occurs in an environment with lower factor adjustment costs. This complementarity is much stronger in the short-run than in the long-run. This is because, without capital adjustment costs that affect investment inaction, adjustment occurs quickly and strongly. As the economy adjust, the complementarity losses strength.

Our analysis emphasizes this interplay between trade reforms and complementary domestic policies related to frictions in factor markets. In an economy with distortions, firm investment inaction can be prevalent. Workers may also find it too costly to reallocate. A trade shock can thus have little or no impact on the economy. A larger shock may overcome those limitations and a stronger response may take place. For instance, a United States limited preference granted on a specific product may be of little consequence for a least developed country facing high frictions, but can have sizeable impacts on economies with better functioning factor markets. In turn, a broad regional trade agreement may have sizeable effects, even in very distorted economies, though those effects could be much stronger in less distorted economies. It is crucial to understand these complementarities.

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