Trade Shocks and Factor Adjustment Frictions: Implications for Investment and Labor*

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Abstract

When export opportunities arise, the gains from trade can only be materialized if the economy adjusts. In order to expand and meet new markets, firms must hire new workers and tune their capital stock by investing in product lines, machines and equipment. If this process is costly and imperfect, the economy reacts partially and gradually. We formulate a multi-sector dynamic model featuring capital adjustment costs, firm heterogeneity, and labor mobility costs that we fit to data from Argentina. We estimate the structural capital and labor adjustment cost parameters and using counterfactual simulations we quantify the complementarity between trade shocks and domestic frictions: in the presence of lower costs of factor adjustment there is a sizeable incremental impact of trade shocks on capital, employment, wages, and output. The complementarity is larger for smaller trade shocks, and a large fraction of the capital complementarity is explained by an extensive margin (i.e. firms which do not respond to trade shocks when adjustment costs are high).

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1 Introduction

When export opportunities arise, the gains from trade can only be materialized if the economy adjusts. 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. In this paper, we explore the complementarity of trade shocks and domestic factor market frictions: in the presence of lower costs of factor adjustment, there is an incremental impact of the trade shock that affects the dynamic path of wages, employment, capital and investment. 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 because large shocks can make factor adjustment profitable, even if it is very costly. Alternatively, a given trade shock can have a much larger effect under more adequate domestic conditions.

This complementarity between trade and domestic factors features predominantly in the literature, but its quantification has often been elusive. Early qualitatively evidence is provided by, for example, Welch, McMillan, and Rodrik (2003), who argue that the negative impacts of the liberalization of the cashew sector in Mozambique was mainly due to the imperfect structure of the internal markets. Topalova (2010) shows that trade liberalization had more pronounced impacts on poverty among Indian states where inflexible labor laws impeded factor reallocation across sectors. Similarly, Balat, Brambilla and Porto (2009) show that coffee exports had larger poverty reducing impacts in Ugandan districts with lower marketing costs. These reduced-form papers, among many others, can only suggest the existence of complementarities. A better sense of the magnitudes can be grasped from the structural model of Kambourov (2009), who studies trade liberalization with labor market frictions. He shows that trade reforms can have a larger effect if they are undertaken jointly with labor market reforms.[1] Similarly, Khandelwal, Schott and Wei (2013) study the system of quota allocation among Chinese textiles and clothing exporters. They show that the gains from trade are larger than expected because the removal of the quota also removes inefficiencies in the quota licensing process.[2] Yet, while these papers establish that trade reforms can be boosted by other domestic reforms, they do not provide a direct quantification of the complementary effect. The objective of our investigation is 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. These complementarities are bound to be important, especially for developing countries.

[1] Concretely, he finds that, in Chile (a low-friction country) trade reforms alone bring welfare gains of 7.3 percent, while trade reforms concurrent with labor market reforms create welfare gains of 8.3 percent. In Mexico (a high-friction country), the gains from trade are 4.1 percent and the gains from joint trade and labor reforms are 5 percent.

[2] They find that 71 percent of the total productivity gain is due to the removal of the licensing regime, while 29 percent is due to quota removal. In addition, they estimate that replacing the politically driven allocation system with a quota auction would raise industry productivity by 15 percentage points.

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 Bloom (2009) and 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 shocks, our model features multiple sectors. To deal with general equilibrium effects and labor market responses, we endogenize equilibrium wages across sectors.[3]

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.[4]

The model features a complementarity of trade shocks and factor market frictions. This complementarity materializes as an incremental or additional effect of the trade shock when factor market frictions are reduced or eliminated. If a trade shock is large, or if a given trade shock arrives in a setting with lower costs, then the adjustment is fuller and quicker.

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 cost 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 simulate a stationary steady-state of the economy. Finally, we use the estimated parameters to compute counterfactual adjustments of investment, capital, labor allocations and wage distributions across sectors after a trade shock. We also study the impacts on output and exports.

To empirically explore the complementarity of trade shocks and domestic frictions, we simulate

[3] 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) in which wages are exogenous.

[4] 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 (2013) 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 and McLaren, 2013; and Dix-Carneiro, 2013) and workers' sector-specific experience (Coşar, 2013; Dix-Carneiro, 2013; and Davidson and Matusz, 2006). Another set of explanations focuses on firm behavior and includes firing and hiring costs (Kambourov, 2009; Dix-Carneiro, 2013) and market search frictions (Coşar, 2013; and Coşar, Guner and Tybout, 2013). All these studies conclude that large adjustment costs may lead to large unrealized gains from trade.

counterfactual economies in which trade shocks occur in the absence of fixed cost and irreversibility of investment, and in which workers mobility costs are reduced by half. As expected, the economy adjusts much more abruptly and quickly when frictions to factor adjustment are reduced. To compute the complementarity we decompose the total change in aggregate variables into a trade shock effect, a change in capital adjustment and labor mobility costs effect, and a complementarity effect (how much more the economy reacts to a trade shock when capital adjustment and labor mobility costs are lower).

We find that the short run reaction of aggregate capital to a trade shock is 78 percent higher when fixed costs and irreversibilities are eliminated, and that 90 percent of this complementarity effect is explained by the reaction of firms that choose not to invest in the baseline steady state (extensive margin). Since the complementarity is largely driven by initial investment inaction, it is larger in the short run and for small trade shocks, as both in the long run and upon facing larger shocks firms are more likely to move out of the inaction region and thus the reduction of adjustment costs becomes less significant. Employment complementarities are sizeable when both capital adjustment costs and labor mobility costs are reduced, accounting for a response to a trade shock that is 47 percent higher than under the baseline scenario. As expected, the trade-capital costs complementarity affects capital relatively more than employment, while the trade-labor costs complementarity affects employment relatively more than capital. Complementarities in output, exports, wages and firm value are smaller but also relevant, especially when capital adjustment costs and labor mobility costs are reduced jointly. The elimination of fixed costs and irreversibilities in investment create a positive, but small, complementarity in wages, whereas a reduction in mobility costs implies that wages react less to a trade shock (negative complementarity), as differences in wages across sectors are due to imperfect mobility. Our conclusion is that the implications of a trade shock or a trade reform 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 a stationary rational expectations equilibrium and we estimate the effects of trade liberalization on investment and labor markets 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 Bloom (2009) and Cooper and Haltiwanger (2006), and workers face labor mobility costs, as in Artuç, Chaudhuri, and McLaren (2010). The behavior of firms is described in section 2.1. The dynamic optimization problem of the firms delivers a set of supply functions for output and a set of demand functions for investment and labor in each of the sectors, given product prices and the costs of adjusting capital. The behavior of workers is described in section 2.2. 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. In our model, both capital and labor are homogeneous. This is a simplification that allows us to work with traditional models of trade amended to accommodate capital adjustment costs, differences in wages across sectors, and gradual mobility while keeping the firms and workers models compatible. Coşar (2013), Dix-Carneiro (2013) and Kambourov (2009) are recent examples of empirical trade models with labor heterogeneity. In section 2.3 we present the equilibrium of the economy and, in section 2.4, we discuss some new features of our model vis-à-vis the related literature.

2.1 Firms: Labor Demand, Investment, and Output Supply

The purpose of our model of firm behavior 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.[5] Each sector is composed of a continuum of firms.

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 Bloom (2009) and Cooper and Haltiwanger (2006), which includes three types of costs: fixed adjustment costs, quadratic adjustment costs, and partial investment irreversibilities. The cost function is

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

[5] 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.

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.[6]

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 investment 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 selling to buying price $\gamma_3^j = p_s^j/p_b^j$.

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}^*. To simplify, we assume that the government does not set any trade taxes, but these can be easily incorporated into the model. Domestic prices faced by producers are $p_{jt} = p_{jt}^*$. 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

[6]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).

firms from completely sweeping the market.[7] 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.[8]

Given the predetermined level of capital and the productivity shock, firms choose labor to maximize instantaneous profits. From the static 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 for sector j 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. Labor allocations are endogenous as well, but predetermined at time t, as we will discuss in the workers' model.

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

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

where $\beta \in (0,1)$ is a discount factor and π^j are maximized instantaneous profits.[9] E_t is the expectation operator conditional on information available at time t and taken over the productivity shocks and

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

[8] It is theoretically straightforward to work with a monopolistic competition model 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. Artuç, Chaudhuri and McLaren (2010), Coşar (2013), Dix-Carneiro (2013), Kambourov (2009), among others, adopt similar modeling assumptions. Instead, see Coşar, Guner, and Tybout (2013) and Rho and Rodrigue (2012) for related models with monopolistic competition.

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

output prices.[10] 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:

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

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 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). 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.[11]

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

$$(8) \quad u_{jt} = \frac{w_{jt}}{P_t} + \eta_j$$

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.[12] These terms are common to

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

[11] 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.

[12] The instantaneous mean utility function of a worker employed in sector j defined over goods and job quality is $\widetilde{u}^j = \frac{\prod_{h=1}^J x_h^{\phi_h}}{\prod_{h=1}^J \phi_h^{\phi_h}} + \eta_j$, where x_h denotes consumption of good h and $\sum_{h=1}^J \phi_h = 1$. Optimizing with respect to x we obtain

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 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 tractability, as in Artuç, Chaudhuri and McLaren (2010), these shocks are independently and identically distributed across individuals, sectors and time.[13]

The worker's problem is to maximize the expected discounted value of being in a sector, net of mobility costs, by choosing the sector of employment at each time period. The state variables in the decision are the current sector of employment and vector of idiosyncratic shocks ε_{lt} as well as 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

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

where β 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.[14] 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}, or ex-ante value function. We have that

$$(10) \quad W^j(s_t) = \frac{w_{jt}}{P_t} + \eta_j + E_\epsilon \max_k \left\{ -C^{jk} + \epsilon_{lkt} + \beta E_t W^k(w_{t+1}) \right\}.$$

Let m^{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 choice

the indirect utility function (8) with a price index given by $\log P = \sum_{h=1}^{J} \phi_h \log p_h$.

[13] For consistency with Artuç, Chaudhuri and McLaren (2010), we adopt their timing convention for idiosyncratic shocks.

[14] 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.

probability of moving from j to k takes the usual multinomial logit form

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

and the ex-ante value function of being in sector j (Rust, 1987) is given by,

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

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. Wages and employment continue gradually adjusting to the new steady state from $t+1$ onwards.

With Cobb-Douglas preferences, expenditure in a good is a share of total income, which is given by the sum of wage income and profits (net of adjustment costs). Aggregate demand for good j at prices $p_{jt} = p^*_{jt}$ is

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

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 endogenize 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 Bloom (2009) and Cooper and Haltiwanger (2006).

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 estimate the different components of the theoretical model, which comprise parameters related to the firms' and workers' decision problems, using Argentine data. 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.

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 of the production function, the stochastic evolution of variables, the adjustment cost function, the depreciation rate, and the 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 Bloom (2009) and Cooper and Haltiwanger (2006). Given the large parameter set, which requires numerically searching over a large number of parameters with a computationally-intensive objective function, and given the small number of firms in the panel data, we follow Cooper and Haltiwanger (2006) and combine different strategies to recover different parameters—thus improving the reliability of the numerical search. In particular, since we are especially interested in the capital adjustment cost parameters, we limit the simulated method of moments to the estimation of these parameters.

To begin with, we set the depreciation rate δ at 0.0991 and the discount factor β at 0.95, both common to all firms and all sectors. To compute δ, we use sectoral depreciation rates for the U.S. (reported by the Bureau of Economic Analysis) and calculate an average weighted by sector size (using the number of firms in each sector as weights).

To estimate the production function parameters α_L and α_K, we use the method of 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.[15] The estimated production function exhibits decreasing returns to scale. Since the EIA surveys firms in the manufacturing sector only, we calibrate, rather than estimate, the production function parameters for the non-tradable sector using data on aggregate capital, capital share in revenue, employment and wages. See Appendix A.1. for more details. 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 Bloom (2009) and 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. First, we assume for estimation purposes that firms form expectations about future wages based on an exogenous stochastic process. This assumption allows us to separately estimate the firms and workers structural parameters, a separation we need due to the computation complexity of our full model.[16] 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.[17] We thus model profitability

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

[16] The assumption that wages follow an exogenous stochastic process is analogous to assumptions made by Cooper and Haltiwanger (2006), by Bloom (2009), and in the dynamic IO literature, for example Hendel and Nevo (2006) and Gowrisankaran and Rysman (2012), in which dynamic consumer demand is modeled according to an exogenous evolution of prices. In our model sectoral wages are determined endogenously in equilibrium. Computing the expectation of wages as a result of equilibrium in the labor market, however, would not only require estimating the firm and workers problem jointly, but it would also involve a very large state space including firm level variables and aggregate level variables, among which are the employment allocations to each of the 6 sectors. The combination of the two factors (large state space and solving both problems jointly) renders the estimation computationally intractable since searching over the structural parameters requires solving the model thousands of times. We thus adopt the assumption that firms form expectations about future wages according to an exogenous stochastic process, for estimation purposes.

[17] 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.

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

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

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 as in Cooper and Haltiwanger (2006).

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

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

where ρ_e is the first order autocorrelation coefficient and $\zeta_{it} \sim N(0, \sigma_e)$. To simplify, the parameters ρ_e and σ_e are also common to all sectors. We estimate ρ_e and σ_e with an OLS regression of deviations of profitability from its year mean. 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. 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 $I^j(A_{ijt}, K_{ijt}; s_t; \Gamma)$. We then generate a panel of simulated firms by taking random draws of initial capital and a series of profitability shocks. From the simulated data and applying the policy function I 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.

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. Since the function $\Psi^s(\Gamma)$ is not analytically tractable, the minimization is performed using numerical techniques.[18]

To implement the SMM estimator, we choose moments that describe both the cross-section and time

[18] See Appendix A.2 for more details on the computation of the simulated moments and the minimization of the distance function.

series behavior of the investment rate. Concretely, following Bloom (2009), Cooper and Haltiwanger (2006), and Caballero and Engel (2003), we match four fairly standard moments. The first two are the serial correlation of the investment rate and the correlation between the investment rate and the profitability shock, 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, defined as the percentage of firms with investment and disinvestment above 20 percent.[19] These moments capture the fact that the investment rate distribution at the plant-level is asymmetric with a fat right tail (Figure 1).

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. Robustness of the SMM estimates to different moments are reported in Appendix A.3.

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.[20]

3.2 Workers

The estimation of the workers' problem parameters requires panel data on workers' sector of employment and wages in order to estimate the labor mobility costs, as well as consumption weights for each sector in order to calibrate aggregate demand. The first row of Panel A) in Table 2 shows the average CPI weights of each product, obtained from National Accounts data. Because demand is assumed to

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

[20]Bloom (2009) reports larger values for the partial irreversibility cost, with capital reselling losses of 42.7 percent, and for the quadratic adjustment cost parameter (0.996). The fixed cost parameter γ_1, which is estimated in terms of annual sales (instead of average capital), is 1.1 percent. Note that these results are not directly comparable to ours because of differences in specification.

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 and other standard variables in labor force surveys. Part of the EPH is a panel and we can use it to track employment decisions 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. As in Artuç, Chaudhuri and McLaren (2010), the estimation strategy is based on the conditional choice probabilities (11) and the ex-ante value functions (12). Using (11) and (12), we can write the ex-ante value function as a function of the probability of staying in the initial sector of employment as

$$(18)\quad W_t^j = \frac{w_{jt}}{P_t} + \eta_j + \beta\ E_t W_{t+1}^j - \nu \ln m_t^{jj}.$$

We can also write the difference in expected continuation values as a function of the difference in choice probabilities

$$(19)\quad \beta\left(E_t W_{t+1}^k - E_t W_{t+1}^j\right) = \nu\left(\ln m_t^{jk} - \ln m_t^{jj}\right) + C^{jk}.$$

Using these two results, first exploited by Hotz and Miller (1993) and the ensuing CCP-estimator literature, we get

$$E_t\left[(\ln m_t^{jk} - \ln m_t^{jj}) - \beta(\ln m_{t+1}^{jk} - \ln m_{t+1}^{kk}) - (\beta-1)\frac{C^{jk}}{\nu} - \frac{\beta}{\nu}\left(\frac{w_{kt+1}}{P_{t+1}} - \frac{w_{jt+1}}{P_{t+1}}\right) - \frac{\beta}{\nu}(\eta_k - \eta_j)\right] = 0.$$

This is an Euler equation that can be estimated, as in Artuç, Chaudhuri and McLaren (2010), by allowing for a disturbance term, ω_{t+1}, which captures the innovation in the stochastic process of wages, unforeseen at time t. Note that in this Euler equation the expectation is taken over realizations of the state s_t so that it is consistent with any structure in the economy provided it evolves as a Markov process. In particular, workers expectations are perfectly consistent with our formulation of firm behavior and this allows us to estimate the labor mobility costs independently of the capital adjustment costs estimates.

Before writing the estimating equation, 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. We also set the value of the discount factor to $\beta = 0.95$. In the end, the set of estimable parameters is thus $\{C^m, C^{nm}, \nu, \eta_j\}$. We normalize $\eta_1 = 0$ for the Food and Beverages sector. With these restrictions, the resulting estimating equation links choice probabilities, mobility costs, and future wages, as follows

$$(20) \quad (\ln m_t^{jk} - \ln m_t^{jj}) - \beta(\ln m_{t+1}^{jk} - \ln m_{t+1}^{kk}) = (\beta - 1)\frac{C^m}{\nu} I^1_{jk} - (\beta - 1)\frac{C^{nm}}{\nu} I^2_{jk} + \frac{\beta}{\nu}\left(\frac{w_{kt+1}}{P_{t+1}} - \frac{w_{jt+1}}{P_{t+1}}\right) + \frac{\beta}{\nu}(\eta_k - \eta_j) + \omega_{jkt+1},$$

where I^1 and I^2 are indicators that capture movements within manufacturing and in or out of manufacturing; that is $I^1 = 1_{[j \neq k \wedge j \neq J \wedge k \neq J)]}$ and $I^2 = 1_{[j \neq k \wedge (j = J | k = J)]}$.

Artuç, Chaudhuri and McLaren (2010) (henceforth ACM) estimate this equation after plugging in the observed gross flows m from the data.[21] In our formulation, this strategy has two main problems. First, our model includes the employment quality terms η to account for time-invariant wage compensating differences across sectors. These terms are important so that the wage differences that are relevant in the workers' decision to move are purged of potential sectoral compensating differentials. However, the ηs are not separately identified from C^m and C^{nm} in equation (20). Second, and more importantly, the ACM regression is based on linking conditional choice probabilities and observed wages at the sector level and requires a consistent estimate of the probabilities m_t^{jk}. The sample size is given by the pairwise sector combinations and the time periods. When the choice probabilities are small (recall that these are transition probabilities from sector j to sector k) they are not precisely estimated in small samples, and the observed frequencies might even be zero, which biases results (Amemiya, 1986).

To circumvent these problems, we utilize instead an MLE estimator for the choice probabilities, given by the probabilities predicted by the model $m_t^{jk}\left(C^m/\nu, C^{nm}/\nu\right)$ and evaluated at the estimates of the parameters C^m/ν and C^{nm}/ν. The conditional log likelihood contribution of each worker l can be written as a function of the normalized mobility cost parameters and is given by

$$(21) \quad \ln \ell_l\left(\frac{C^m}{\nu}, \frac{C^{nm}}{\nu}\right) = \sum_t \sum_j \sum_k d_{ljkt} \ln m_t^{jk}\left(\frac{C^m}{\nu}, \frac{C^{nm}}{\nu}\right),$$

where d_{ljkt} is a dummy indicating whether individual l moved from sector j to sector k at time t. The log likelihood function is obtained by summing over individuals and using the conditional choice probabilities (11). Since the only observed heterogeneity across individuals is their initial sector of

[21] In their regression, the level of gross flows across sectors identifies C^{jk} and the responsiveness of the gross flows to future wage differences identifies ν. See Artuç, Chaudhuri and McLaren (2010) for the full derivation.

employment at each time period, we can write the likelihood function as

$$\text{(22)}\quad \ln L\left(\frac{C^m}{\nu},\frac{C^{nm}}{\nu}\right)=\sum_t\sum_j\sum_k N_{jkt}\ln\frac{\exp\left(-\frac{C^m}{\nu}I^1_{jk}-\frac{C^{nm}}{\nu}I^2_{jk}+\widetilde{W}^k_{t+1}\right)}{\sum_{h=1}^J\exp\left(-\frac{C^m}{\nu}I^1_{jh}-\frac{C^{nm}}{\nu}I^2_{jh}+\widetilde{W}^h_{t+1}\right)},$$

where N_{jkt} is the number of workers moving from sector j to sector k at time t. The terms $\widetilde{W}^k_{t+1}$ are the continuation values of choosing sector k normalized with respect to non-tradable sector J and the variance ν, so that $\widetilde{W}^k_{t+1}=\beta E_t\left(W^k(s_{t+1})-W^J(s_{t+1})\right)/\nu$. The normalization does not affect the choice probabilities. Since the continuation values of choosing a given sector k are the same across individuals and for all initial sectors of employment, we control for them using sector of destination-year effects. In the end, we estimate C^m/ν and C^{nm}/ν using only the expression for the choice probabilities. The likelihood function is globally concave and thus achieves a global maximum.[22]

Plugging these estimates as well as the estimated conditional choice probabilities $\widehat{m}^{jk}_t$ into (20), we get

$$\text{(23)}\quad (\ln\widehat{m}^{jk}_t-\ln\widehat{m}^{jj}_t)-\beta(\ln\widehat{m}^{jk}_{t+1}-\ln\widehat{m}^{kk}_{t+1})-(\beta-1)\frac{\widehat{C^m}}{\nu}I^1_{jk}-(\beta-1)\frac{\widehat{C^{nm}}}{\nu}I^2_{jk}=$$
$$=\frac{\beta}{\nu}\left(\frac{w_{kt+1}}{P_{t+1}}-\frac{w_{jt+1}}{P_{t+1}}\right)+\frac{\beta}{\nu}(\eta_k-\eta_j)+\omega_{jkt+1}.$$

This regression is run at the sector of origin-sector of destination-year level. The estimates from the MLE step are regressed on the average sector wage differences, while sector fixed effects account for the time-invariant employment quality effects η. Since realized wages are correlated with the innovation terms ω, the regression is estimated using IV with lag wage differences as instruments. In this step we estimate the structural parameters ν and η and recover C^m and C^{nm}.[23]

The estimates of the labor mobility costs are in the bottom panel of Table 2. In the baseline specification (column 1), our MLE estimates from (22) are C^m/ν=3.740 and C^{nm}/ν=2.596. The estimate of $1/\nu$ from (23) is 1.448 (which implies a variance of the idiosyncratic costs, $\nu=0.69$). All our estimates are statistically significant. Combining these parameters, we estimate $C^m=2.583$ and $C^{nm}=1.793$. This means that, on average, a worker wishing to switch sectors within the manufacturing

[22]Dynamic discrete choice problems are often estimated using the conditional choice probability (CCP) and nested pseudo-likelihood (NPL) methods developed by Hotz and Miller (1993) and the literature thereafter. Because of aggregate shocks to prices and productivity (and hence wages) captured in the vector of state variables s_t, the structure of our model is different from stationary labor or industrial organization applications where state variables vary across individuals. Intuitively, some variants of the method require estimating choice probabilities non-parametrically, for all states, without using model parameters. When state variables vary across individuals, as in CCP applications, it is possible to construct estimates of the choice probabilities for all possible realizations of the state variables, whereas in our setting we can only compute estimated choice probabilities for the realized wages but not for all other possible states of the economy. On the other hand, because in our setting state variables determining the continuation values $E_tW^k_{t+1}(s_{t+1})$ are the same for all individuals, we can use dummy variables to control for these terms and estimate the parameters using the regular static form for model predicted probabilities in our MLE step. The ACM step is possible because there are pairwise combinations of sectors of origin and destination.

[23]An alternative would be to normalized ν as is usually done in the discrete choice literature. In this case C^m and C^{nm} can be estimated in the MLE step and η can be recovered using a minimum distance procedure based on (20).

sector would pay a mobility cost equivalent to 2.583 times his annual wage earnings. The costs needed to switch from manufactures to non-manufactures (or vice-versa) is lower, around 1.793 times the value of the annual wage income. Omitting η makes ν lower and thus the mobility costs lower, too (column 2). If we restrict C to be common to all sectors, we get an average C of 2.393 (with η, in column 3) and of 1.834 (without η, in column 4). Our estimates are lower than those reported in Artuç, Chaudhuri, and McLaren (2010) for the U.S., where the average moving cost is around 6.565, and ν is 1.884. This is not surprising giving the potential biases described above. Allowing for job quality terms η, Artuç and McLaren (2013) estimate more modest C, ranging from as low as 0.99 to as high as 1.54 (with ν=0.257), also for the U.S. Finally, estimating a comprehensive model that allows for worker heterogeneity with Brazilian data, Dix-Carneiro (2013) finds median mobility costs ranging from 1.4 to 2.7. These costs are comparable to ours (though Dix-Carneiro's estimates show large dispersion across the population).

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). Since Food and Beverages is the main export sector in Argentina, this choice allows us to explore shocks to export opportunities. We model the trade shock as a permanent price increase in Sector 1. The price increase can be the result of an increase in world demand or a decrease in world supply, both implying a change in p^*_{jt}. 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-tradables, the price shock to one sector that we study is not equivalent to an economy-wide macro shock.[24]

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 assess 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 trade 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 unforseen 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

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

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. See Appendix A.4 for computional details.

4.1 Increase in Export Opportunities

To document the generic dynamic responses, we begin with the impacts of a trade shock that increases the price of Food and Beverages (Sector 1) by 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. Capital and employment are predetermined and do not respond initially.[25] The nominal wage goes up in Sector 1 due to the increase in the value of the marginal product of labor. Because of the trade shock, there is an increase in the price index that brings down real wages in all sectors. The net effect on the real wage in Sector 1 is, however, 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 wage. 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.

There are three reasons why convergence to the new steady state is not immediate, all related to costs of adjustment and mobility. One reason is convex costs of investment, which provide incentives to smooth investment over time. The second reason is fixed costs of investment. At the firm level, fixed costs operate in the opposite direction to convex costs, providing an incentive to concentrate investment in one period and remain inactive in others. At the aggregate level, however, fixed costs together with firm heterogeneity generate a gradual reaction to a trade shock. When faced with a

[25] 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.

trade shock, firms decide to invest if they are productive enough (relative to their capital stock) for the returns to investment cover the initial fixed cost. Because idiosyncratic productivity fluctuates over time and is heterogeneous across firms, firms react to the trade shock sequentially upon receiving positive idiosyncratic shocks and contributing to a gradual increase in the aggregate capital stock. The third reason is worker mobility costs. This mechanism is analogous to fixed costs of investment. After a trade shock to Food and Beverages the wage in this sector increases relative to other sectors creating an incentive for workers to move. Moving to Food and Beverages implies paying a fixed mobility cost and workers make this decision taking into consideration their time-varying idiosyncratic preferences for each sector. As workers receive positive preference shocks for Food and Beverages, they decide to move and the labor supply in that sector gradually increases. Increases in capital and employment at the firm level in turn affect the marginal productivity of the other factor and therefore its aggregate demand, which also contributes to the aggregate gradual response.

The magnitudes of the responses are given in Table 3. For a 10 percent price shock, the capital stock in Food and Beverages increases by 6.43 percent initially (Year 2), by 11.15 percent in Year 3, and by 24.38 percent in the new steady state; 95 percent of the transition is covered in 10 years. Employment increases by 7.25 percent in Year 2, 11.51 percent in Year 3, and 17.73 percent in the new steady state; convergence of employment is faster than of capital, covering 95 percent of the transition in 7 years. These responses give rise to increases in output (measured in physical units, i.e., quantities), by 5.59 percent in Year 2, by 8.76 percent in Year 3, and by 13.52 percent in the new steady state. Convergence takes 7 years.

Prior to the shock, net exports of Food and Beverages are positive and account for 17 percent of output. In the model, 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 28.93 percent in Year 1. From Year 2 onwards exports further increase due to the response of output, reaching a long run response of 103.57 percent in the new steady state. This implies a doubling of exports. This reaction is so large because exports are initially low relative to domestic consumption and output.[26] Rows (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 in fact accounts for about three fourths of the overall response in the long run.

Capital, employment and output in other traded sectors decline (Table 3). As the real wage

[26] 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 $(c/x) = 4.89$.

increases in the expanding sector, workers move from other tradables to Food and Beverages, which in turn triggers disinvestment during the transition. In steady state, employment is 9.5 percent lower in the non-food manufacturing sector, the capital stock declines by 6.37 percent and output by 6.08 percent. In the non-traded sector, capital, employment and output expand a little due to income demand effects. In the short-run, workers move out, as Food and Beverages wages become relatively higher. However, there is an increase in the price of non-tradables due to the increase in real income created by the enhanced export opportunities and the non-traded sector thus expands in the longer run. The dynamics of the other sectors are depicted graphically in Appendix A.5.

We now turn to factor returns. The real wage in Food and Beverage increases by 5.40 percent at the time of the shock and starts declining gradually after that. In the new steady state, real wages are only 1.51 percent higher than in the initial equilibrium. This happens because of the continuous inflow of workers, even though firms keep expanding capital for a few years. Instead, the average value of a firm increases more strongly and steadily, by 16.48 percent in the immediate run to 19.69 percent in the long run. We conclude that firms (i.e., the entrepreneurs who own the fixed managerial ability), more than workers, are the real beneficiaries of the shock.

Real wages in other sectors of the economy are lower after the trade shock. In other-tradable sectors (non-food manufactures), the decline on impact is of 4.19 percent. As before, there is overshooting: real wages recover after Year 1 and the long-run decline is of 1.30 percent (with respect to the initial steady state). Real wages in the non-traded sector also decline, by 0.90 percent in Year 1 and, noticeably, they further decline by 1.63 in Year 2. Wages recover from Year 3 onwards but never reach the old steady state level, being 0.26 percent lower in the new steady state. The reason behind the decline on impact in real wages is the increase in food prices that affects real expenditure. As workers later flow from these sectors to Food and Beverages, the marginal product of labor increases and wages recover. This recovery is not sufficiently large to overcome the initial decline. The transition is long, though, and it can take 11 to 12 years to cover 95 percent of path to the new steady state.

4.2 Complementarity

Our model features a complementarity of trade shocks and factor market frictions. This is important because, as it is often argued, the success of trade liberalization may depend on complementary domestic reforms. For instance, a trade reform can fail to have the desired impacts if the domestic business conditions are inadequate; alternatively, the gains from trade can be amplified by concurrent additional reforms. This complementarity has long been recognized in the literature and, recently, it has been moved to the front in the international policy forum. In the link between trade and jobs, for instance, the International Collaborative Initiative on Trade and Employment (ICITE) attests to this.[27]

[27] ICITE is a collaborative effort of ten international organizations: the Asian Development Bank, the African Development Bank, the Economic Commission for Latin America and the Caribbean, the Interamerican Development Bank, the International Labor Organization, the Organization of American States, the OECD, UNCTAD, the World Bank and

In our setting, the complementarity of trade shocks and factor market frictions is defined by the incremental effect of a given trade shock in a scenario with reduced domestic market frictions. These frictions stem from the cost of capital adjustment and the cost of labor mobility. When there is a positive trade shock, firms have incentives to invest, but capital and labor adjustment costs dampen or prevent this expansion. Firms that are unable to overcome the fixed costs of investment remain in a region of inaction, at least until they receive a high enough productivity shock. Other firms react to the shock, but their reaction is attenuated because of the uncertainty about future productivity levels and potential reselling losses in the case of disinvestment. This reaction can also be attenuated if labor mobility costs halt the reallocation of labor that is needed to complement capital. With smaller distortions in capital and labor markets, these responses are enhanced. There is an effect on the extensive margin, since firms may be able to escape out of the inaction region. There is also an effect on the intensive margin, since firms may fully adjust to the first best optimum.

The extensive margin can be described by noting that the fixed and irreversibility investment costs and the labor mobility costs create zones of investment inaction, where firms with given combinations of idiosyncratic productivity and predetermined capital stock do not react. This inaction region depends on the parameters of the model. Also, it can be shifted, expanded, or shrunk, by various trade shocks. In Figure 3 we plot the pre-shock steady state inaction region given the estimated capital and labor adjustment costs. The boundaries of the region are given by the solid black curves labeled $\Delta p = 0$ (referring to a scenario without trade shocks). These two curves delimit three clear zones in the productivity A and capital K space: positive investment, inaction, and disinvestment. Starting on the left side of the capital stock grid, firms with low capital and large productivity shocks are active investment firms. As the productivity shock gets smaller or the stock of capital gets larger firms choose to stay inactive or to disinvest.

A positive trade shock moves the inaction region to the right (and a negative shock shifts it to the left). In Figure 3, for a 10 percent price shock, the boundaries are defined by the dashed curves labeled $\Delta p = 10\%$. In addition, a larger shock can make it profitable for more firms to react, and the inaction region moves further to the right, as shown by the dotted-dashed curves labeled $\Delta p = 30\%$. On one margin, firms that were inactive in the baseline start investing after the shock. On the other margin, firms that were disinvesting find it now optimal to become inactive. While the shifts in curves do not appear to be large, the contour curves show that the inaction region is dense in terms of the distribution of firms (there are 82 percent of inactive firms in the $\Delta p = 0$ region), therefore a small shift in curves implies a change in behavior for a significant number of firms. The inaction region depends on the structure of capital adjustment costs and of labor mobility costs. In the limit case of no fixed costs of investment, the inaction region disappears entirely.

Next, we define the complementarity formally and we quantify it in the data. To do this, we simulate

the WTO. See OECD (2012) for the ICITE mandate and its conclusions so far.

a counterfactual scenario in which a trade shock to Food and Beverages takes place in the absence of both fixed costs and irreversibility costs. We keep the convex costs, which induce smoothness, as well as the original labor mobility costs (which we reduce later in the paper). 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.

To 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 $\widetilde{\gamma}_3 = 1$. 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

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

The three terms in the decomposition are: (i) the effect of a change in prices p, at the initial cost structure; (ii) the effect of a change in the cost structure Γ, at the initial prices; (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 $(\widetilde{p}, \Gamma)$.[28]

The complementarity effect on aggregate capital is displayed in Figure 4. From $t = 1$ onwards, the solid black line denotes the 10 percent price effect—this is the same response as in Figure 2. The

[28] Note that in Kambourov (2009) and Khandelwal, Schott and Wei (2013), the comparison is made between situations (p, Γ), $(\widetilde{p}, \Gamma)$ and $(\widetilde{p}, \widetilde{\Gamma})$. Since simulations do not include a situation $(p, \widetilde{\Gamma})$ the complementarity is thus not directly quantified.

vertical distance between the solid black line and the dashed grey line denotes the steady state effect of the change in cost structure. The complementarity is the vertical distance between the dashed and solid grey lines; this is the *incremental* effect of trade in the absence of fixed costs and irreversibilities in investment. The figure shows a sizeable complementarity effect.

The complementarity effect on the capital stock is quantified in Table 4, Panel A. The table displays the four terms in equation (25). As expected, the total response of the aggregate capital stock is much larger with a combined shock to trade and to the cost structure. For a 10 percent price shock, the combined shock causes capital to increase by 29.06 percent in Year 2, by 36.32 percent in Year 3, and by 46.23 percent in the long-run (vis-á-vis 6.43, 11.15, and 24.38 percent following a trade shock under the original cost structure; row (i)). The transition period is also shorter as one of the reasons for a gradual transition—fixed costs of investment—has been eliminated. The second component reflects the steady state effect of a change in the cost structure (row (ii)). In the absence of fixed costs and irreversibilities, the steady state aggregate capital stock is 17.62 percent higher.[29] In the short-run, the complementarity (component (iii)) is of the same order of magnitude as the pure price effect: capital expands by an additional 5.01 percent due to the complementarity. This implies that the short-run response of the aggregate capital stock is 77.9 percent higher in a scenario with no fixed costs and no irreversibilities. In the long-run, the complementary losses power: it creates an additional expansion in K of only 4.23 percent, which is equivalent to 17.33 percent of the trade shock effect.

The complementarity matters during the whole transition but is particularly important in the short-run. This is because in a scenario without fixed costs and irreversibilities there is a quick and strong reaction of investment in Year 1 and of capital in Year 2 by firms that would otherwise be inactive in the short run, whereas in the long run, upon drawing positive idiosyncratic shocks, firms gradually react in both scenarios. This implies a stronger short-run complementarity between trade shocks and domestic conditions driven by an extensive margin. The effect of the change in structure also becomes less relevant in the long run relative to the trade shock, for the same reason.

To quantify the role played by the extensive margin in the complementarity effect, we compute the capital response of initially inactive firms and their contribution to the response in aggregate capital. Firms are characterized by pairs (K, A). From equation (24) the total capital response can be written as the aggregation of the responses by firm type (K, A), plus the aggregation of the changes in firm distribution, that is

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

[29] Notice that this effect is constant over time. This is because it is a steady state effect and not a transition response. When shocking both $\widetilde{p}$ and $\widetilde{\Gamma}$ there is the alternative of shocking them sequentially or simultaneously. We opt to shock them sequentially, so that the exercise represents a trade shock ($\widetilde{p}$-p) to two different economies (Γ and $\widetilde{\Gamma}$.)

Let ι denote the set of (K, A) firm types that are inactive in the baseline steady state (scenario (p, Γ))). The extensive margin of the total increase in capital is thus given by

$$\kappa_{jt+1}^{\iota}(\widetilde{p}, \widetilde{\Gamma}) - \kappa_{jt+1}^{\iota}(p, \Gamma) \quad = \quad \int_{(K,A)\in\iota} \left[K_{ijt+1}(A, K, \widetilde{p}, \widetilde{\Gamma}) - K_{ijt+1}(A, K, p, \Gamma) \right] \mu_t^j(dK \times dA | p, \Gamma). \tag{27}$$

The extensive margins of the three components of equation (25) are defined analogously.[30]

Results for the extensive margins are displayed in Panels B and C of Table 4. There are two results to highlight. First, Panel B shows that with fixed costs and irreversibilities, initially inactive firms respond to a trade shock by increasing their capital by 4.26 percent in Year 1 (component (i)). When fixed costs and irreversibilities are eliminated, there is an incremental response of inactive firms of 6.09 percent, which is 142.94 percent of the trade shock response, vis-á-vis 77.90 percent for all firms (Panel A). Similar patterns are observed during the other years of the transition and the long run. The complementarity effect is thus relatively more important for inactive firms than for all firms taken together. Second, Panel C depicts the percentage contribution of inactive firms to the response of aggregate capital. In Year 1, inactive firms explain 38.81 percent of the total capital response, 51.53 percent of the response to the trade shock, 18.32 percent of the response to the change in cost structure, and 94.55 percent of the complementarity. Large contributions are expected since the initially inactive firms account for 82 percent of firms. What is interesting is that inactive firms are relatively more relevant in explaining the complementarity effect than the trade shock and cost structure effects, and that the extensive margin accounts for the bulk of the complementarity.[31]

The complementarity of trade shock and capital adjustment costs has implications for the adjustment of other variables in the economy. We begin with Food & Beverages employment, output and exports, and we report results following a 10 percent trade shock in Table 5. As expected, the impacts are much larger with a combined shock to costs and trade, and the transition faster. The complementary effect arises in all these responses. As opposed to the case of capital, however, the complementarity effects are generally small. For employment, the expansion in employment is only 6.88 percent larger in the short run and 2.45 percent larger in the long run. The complementarity has a slightly larger role on output, accounting for an additional 8.10 (short run) and 6.66 (long run) percentage response. Comparable effects are reported for Food exports.

The impact of the complementarity on factor rewards is also typically small. The complementarity has a small effect in Year 2, of 2.65 percent. It becomes, however, more important during the transition (Years 3 to 5) and in the long run, when the complementarity is equivalent to more than 10 percent of the trade shock effect. This is because the trade shock effect in the baseline is decreasing during the

[30] The extensive margin is not defined in terms of firm identity but rather in terms of grid points. Firms receive idiosyncratic shocks and in the long run move all over the (K, A) grid.

[31] In the long run the contribution of the extensive margin is above 100 percent. This is because changes in firm distribution (equation 26) contribute negatively to the complementarity effect.

transition, as workers flow to Food and Beverages (see Table 3). The complementarity also creates a higher response in the value of the firm (present value of net profits) by 2.95 percent (short run) and 4.62 percent (long run). 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 trade shock towards workers in the sector. As this effect vanishes, the gains from the interaction of adjustment costs and prices shift towards firms.

The complementarity also affects the real wages in the other sectors of the economy. In the case of other tradable sectors, recall that the trade shock to the Food and Beverages sector creates a fall in real wages, as the CPI increases. The complementarity goes in the other direction, and actually creates an increase in wages. In the long-run, for example, while the pure price effect would cause real wages to decline by 1.3 percent, the complementarity would boost them up by 0.17 percent. This means that real wages would still decline if the trade shock occurred in an environment with lower capital adjustment costs, but they would be slightly higher nevertheless. This force is actually much stronger in the non-tradable sector. Here, the complementarity effect (in the long-run) is positive but actually higher (in absolute value) than the pure price effect. This means that while the trade shock reduces wages in the non-traded sector when capital adjustment costs are high, the trade shock would actually lead to higher real wages if adjustment costs were low.

An important result of our model is that the complementarity effect depends on the size of the shock. We show results in Figure 5, where the solid black and gray lines represent the short-run and long-run complementarities (relative to the price effect) as a function of trade shocks.[32] In general, we find that the complementarity effect losses power as the shock becomes larger. Consider first the case of capital (top left panel). In Year 2 following a 5 percent shock, for example, the complementarity is almost as important as the pure price effect (i.e., a complementarity of 100). For a 30 percent shock, the complementarity is only equivalent to 66.10 percent of the price effect. In the long-run, these effects remain positive, but are much more similar, 18.46 percent in the case of a 5 percent price shock and 14.52 percent in the case of a 30 percent price shock.

These results are driven by the incentives for inaction generated by the investment costs. In the baseline scenario, a larger price shock implies that it is easier to overcome the fixed cost of investment and a larger proportion of firms respond in the short-run (relative to a small shock). This in turn implies that the incremental price response when fixed costs and irreversibilities are eliminated (cost structure $\widetilde{\Gamma}$) is smaller for a large price shock. 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 trade shock grows larger, these differential responses become smaller. In the long-run (in steady state, but also after about 5

[32]The dashed lines depict complementarities that are discussed in the next section.

years in our simulations) most firms have already adjusted and thus the differential responses narrow.

For Food and Beverages employment, a higher price shock creates a lower complementarity both in the short- and in the long-run (Figure 5, top-right panel). Unlike the case of capital, for very large shocks, the long-run complementarity almost vanishes. Similar patterns are found for Food and Beverages Output and Exports. In the case of real wages in the affected sector, there is still a decreasing pattern in that a higher trade shock elicits a lower complementarity. However, unlike previous variables, this complementarity is higher in the long-run than in the short-run because the real wage overshoots in the short-run and thus the price effect, which we use to benchmark the complementarity, becomes much smaller in the long-run.

4.3 Capital Adjustment Costs and Labor Mobility Costs

In our previous simulations we have focused the attention on the role of capital adjustment costs. Our model, however, also features labor mobility costs C. As we have argued above, we work with these costs to create equilibrium wage differences across sectors. This allows for more meaningful factor adjustments following the shock, because labor may respond differently when sectoral wages are different. In this section we explore trade shock complementarities with both capital adjustment and labor mobility costs.

To do this we run simulations analogous to the ones in the previous section adding a reduction in mobility costs to the elimination of the investment fixed costs and irreversibilities. In the simulations in the previous sections we compared a baseline steady state described by the model parameters (p, Γ, C) and a counterfactual scenario in which we shock the price and change the capital adjustment cost structure $(\widetilde{p}, \widetilde{\Gamma}, C)$.[33] In this section we now compare the same baseline steady state (p, Γ, C) to a counterfactual scenario in which we also change the mobility cost structure $(\widetilde{p}, \widetilde{\Gamma}, \widetilde{C})$. In the counterfactual scenario we arbitrarily reduce labor mobility costs by half. The trade shock is again a 10 percent increase to the price of Food and Beverages. We again decompose the total response into a trade shock component, a cost structure component (that includes a change in both Γ and C), and the complementarity effect or incremental trade shock response. A summary of results is in Table 6.

In the economy with lower mobility costs, as expected, the capital stock, employment, output and exports in Food and Beverages react more to a given price shock during the whole transition. In addition, the complementarity is noticeably stronger. For the case of capital, for instance, the short-run relative complementarity is 77.9 for the economy with high C (Table 4) and 89.77 percent in the economy with lower C (Panel A of Table 6). Since the reduction in C favors worker mobility, the increase in the complementarity is even larger for employment. The short-run relative complementarity for employment is 6.88 with high C (Panel A of Table 5) and 46.91 with reduced C (Panel B of Table

[33]To simplify notation we did not write variables or scenarios as explicitly dependent on C in the previous section, since C was kept constant.

6). This means that in an economy with reduced capital adjustment costs the trade shock effect on employment is 6.88 percent larger than in the baseline economy, whereas in an economy in which labor mobility costs are reduced by half (in addition to the reduction in capital adjustment costs), the trade shock effect on employment is in turn 46.91 percent larger than in the baseline economy. These results highlight that the economy reacts even more strongly to the same trade shock when capital and labor adjustment costs are both smaller. In other words, the trade shock creates incentives for investment and these incentives are boosted by better joint business conditions in both capital and labor markets. Similar stronger complementary effects are found in output (Panel C), and exports (Panel D).

Workers in Food and Beverages earn higher real wages after the joint shock (Panel E). The joint complementarity, however, is negative. This means that real wages would increase less after a given price shock when both capital and labor adjustment costs are lower. This is because the lower C facilitates the inflow of workers following the shock and this erodes the gains. Smaller labor mobility costs make in fact labor less specific and act as a wage-equalizing force across sectors. In contrast, the value of the firm instead increases much more under the joint shock and the complementarity is positive and strong. The fact that the sectoral specificity of labor is lower when C is low benefits entrepreneurs who have a larger pool of workers to hire.

Finally, we explore the relationship of the complementarity and the size of the shock in Figure 5. For capital, employment, output and exports in Food and Beverages, we find as above that the complementarity is much larger when both capital and labor costs are lower (dashed lines vs. solid lines). Also, the complementarity for employment is much stronger when C is lower because lower labor mobility costs facilitate labor reallocation after a price shock. This effect, combined with a stronger complementarity for capital as well, shows up for output and exports too. For wages, the opposite happens and the complementarity becomes negative. In all cases, the complementarity is smaller as the size of shock becomes larger. The intuition is the same as before: with lower costs of adjustment, a sufficiently large price shock induces a more profound adjustment for all firms and induces more firms (and workers) to react in the short-run, leaving thus little room for any complementarity to operate.

5 Conclusions

We have developed a structural dynamic general equilibrium model of trade and the labor market with factor adjustment costs that we have fitted to household survey panel data and plant-level panel data from Argentina in order to recover 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.

Our model features a complementarity of trade shocks and domestic reforms. This is because the cost of factor adjustments create inaction regions for both firms and workers and the incentives for inaction (and for action) depend jointly on the trade shock and on the costs of adjusting labor and capital. We have explored this theme by simulating counterfactual scenarios with trade shocks and reductions in capital and labor adjustment costs. As expected, the economy reacts more to a combined shock. More importantly, the complementarity is stronger when the trade shock occurs in an environment with lower factor adjustment costs. The trade-capital complementarity is very responsive to the capital adjustment costs, while the trade-employment complementarity is more responsive to the labor mobility costs. In addition, the complementarity is stronger in the short-run than in the long-run. This is because, with lower capital and labor adjustment costs that affect investment and worker inaction, adjustment occurs more quickly and strongly. As the economy adjust, the complementarity losses strength. Finally, the complementarity becomes less relevant under larger trade shocks because larger shocks can create incentive to adjust even under adjustment costs.

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. As a consequence, joint trade and domestic reforms may significant boost the gains from trade.

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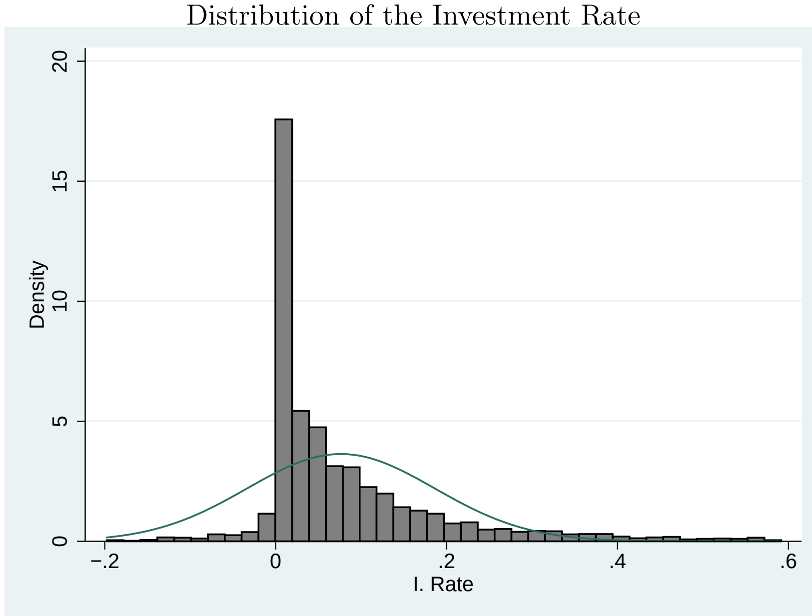
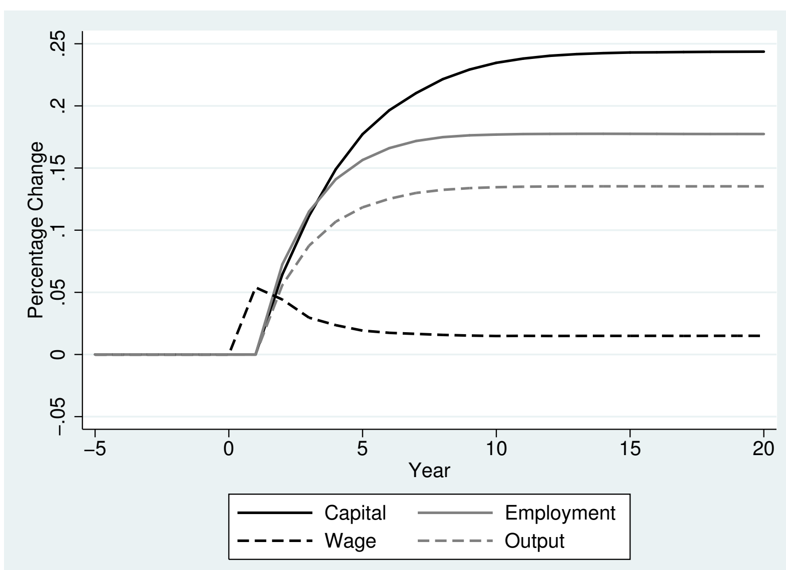
Figure 1
Distribution of the Investment Rate



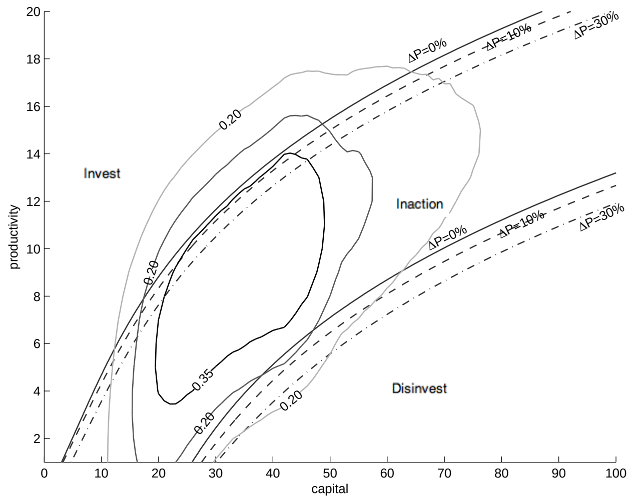
Source: Encuesta Industrial Anual (Annual Industrial Survey), Argentina 1994-2001. The investment rate is the ratio of investment to capital stock.

Figure 2
Responses to a Trade Shock
Capital, Real Wage, Employment and Output



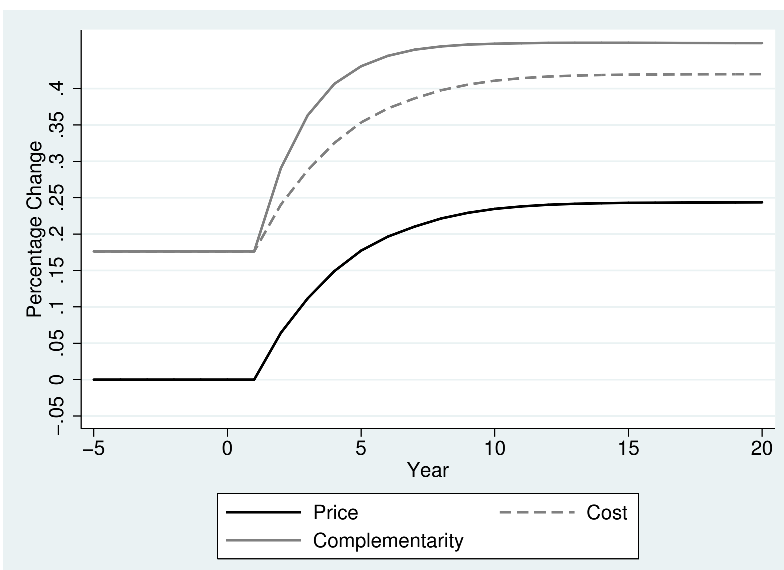
Simulation of a 10 percent increase in the price of Food & Beverages. Dynamic responses of capital, real wage, employment and output in the shocked sector.

Figure 3
Inaction Regions and Firm Distribution



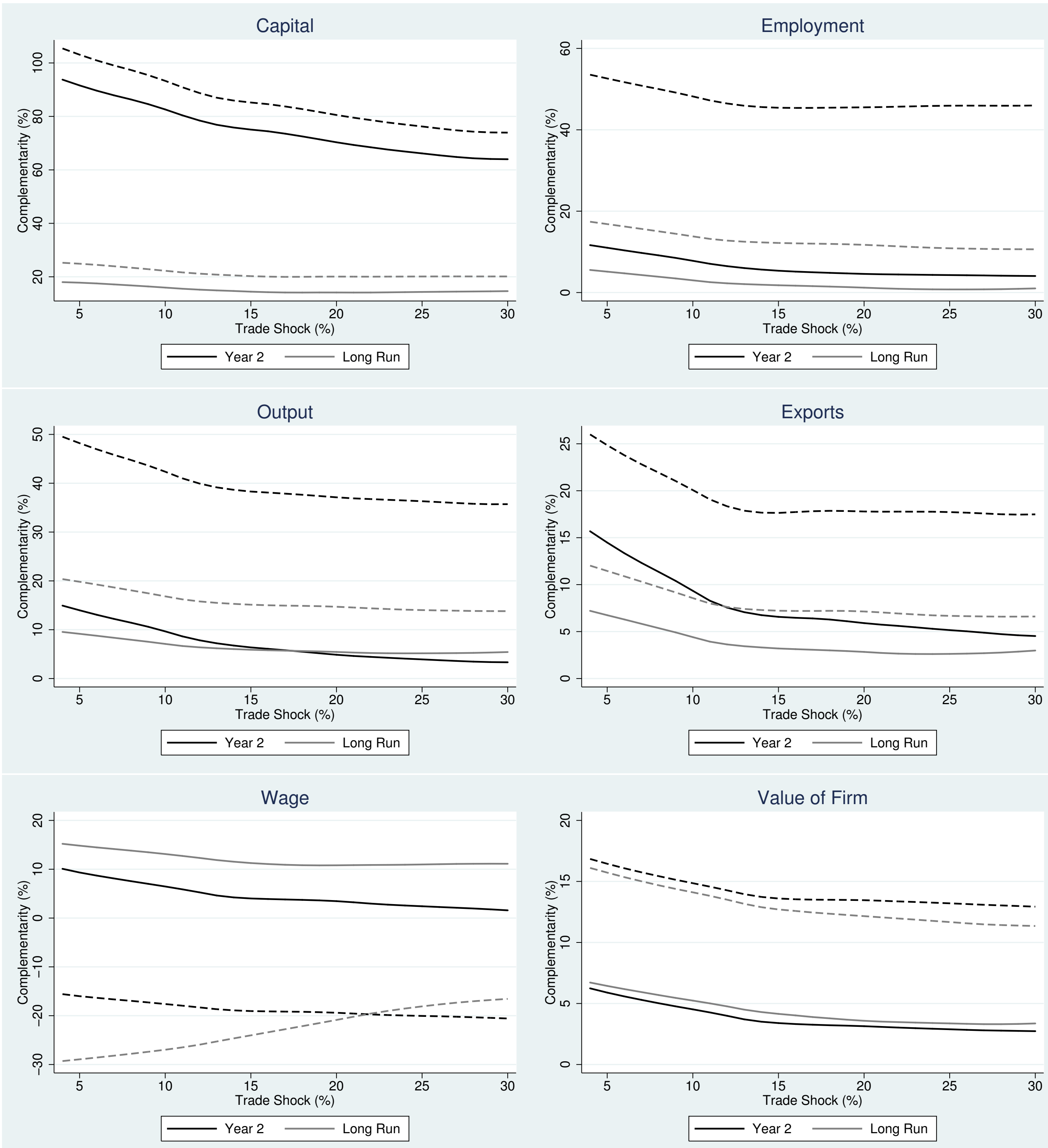
Curves delimit long run equilibrium regions of positive investment, inaction, and negative investment for a baseline situation without changes in prices ($\Delta p = 0$, solid), a 10 percent price increase ($\Delta p = 10\%$, dashed) and a 30 percent price increase ($\Delta p = 30\%$, dotted-dashed). Contour curves denote the distribution of capital and productivity at the baseline.

Figure 4
Complementarity of Trade Shock and Capital Adjustment Costs



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).

Figure 5
Complementarity of Trade Shock and Capital and Labor Adjustment Costs
Relationship to the Size of the Shock



Black and gray solid lines are the short-run (year 2) and long-run (steady state) relative complementarities with reduced capital adjustment costs. Black and gray dashed lines are the short-run and long-run complementarities with reduced capital and labor adjustment costs.

Table 1
Production Function and Capital Adjustment Costs
Structural Parameters

A) Production Function				
Parameters	labor (α_L)	capital (α_K)		
Manufacturing	0.5892***	0.1420***		
	(0.0131)	(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***	0.1132***	0.9143***	
	(0.0358)	(0.0245)	(0.0705)	
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. The moments are the serial correlation in investment ($corr(i, i_{-1})$), the correlation between investment and profitability ($corr(i, a)$), the percentage of firms with investment above and below 20% ($spike^+$ and $spike^-$).

Table 2
Labor Mobility Costs
Data and Parameters

A) 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

B) Estimates of Labor Mobility Costs

	Baseline		Single C	
	η	no η	η	no η
	(1)	(2)	(3)	(4)
C^m/ν	3.740***	3.740***		
	(0.084)	(0.084)		
C^{nm}/ν	2.596***	2.596***		
	(0.104)	(0.104)		
C/ν			3.258***	3.258***
			(0.032)	(0.032)
$1/\nu$	1.448**	1.826***	1.361**	1.776***
	(0.611)	(0.220)	(0.563)	(0.175)
η_2/ν	-0.365***		-0.399***	
	(0.074)		(0.067)	
η_3/ν	-0.365		-0.318	
	(0.297)		(0.272)	
η_4/ν	-0.596***		-0.692***	
	(0.132)		(0.121)	
η_5/ν	-0.494***		-0.521***	
	(0.183)		(0.166)	
η_6/ν	0.174		0.265*	
	(0.147)		(0.139)	
C^m	2.583***	2.048***		
	(0.819)	(0.241)		
C^{nm}	1.793***	1.421***		
	(0.685)	(0.208)		
C			2.393***	1.834***
			(0.747)	(0.179)

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.

Table 3
Responses to 10 Percent Trade Shock to the Food & Beverages Sector

	Year 1	Year 2	Year 3	Year 5	Steady State	Years to Convergence
A) Food & Beverages						
Capital Stock	–	6.43	11.15	17.73	24.38	10
Employment	–	7.25	11.51	15.65	17.73	7
Output	–	5.59	8.76	11.84	13.52	7
Exports	28.93	68.01	81.14	96.38	103.57	6
due to production	0.00	0.48	0.63	0.72	0.76	–
due to consumption	1.00	0.52	0.37	0.28	0.24	–
B) Other Tradables						
Capital Stock	–	-0.29	-1.68	-3.78	-6.37	12
Employment	–	-2.95	-5.12	-7.45	-9.50	10
Output	–	-1.85	-3.43	-4.92	-6.08	9
Exports	17.36	17.47	30.09	39.33	47.09	10
due to production	0.00	0.43	0.46	0.51	0.53	0
due to consumption	1.00	0.57	0.54	0.49	0.47	0
C) Non-Tradables						
Capital	–	1.31	1.42	2.55	4.46	13
Employment	–	-0.06	-0.03	0.02	0.17	16
Output	–	0.22	0.18	0.36	0.62	12
D) Factor Rewards						
Wages in F&B	5.40	4.42	2.96	1.92	1.51	8
Value of Firms in F&B	16.48	17.60	17.99	18.87	19.69	5
Wages in Other Tradables	-4.19	-2.43	-2.32	-1.80	-1.30	11
Wages in Non-Tradables	-0.90	-1.63	-0.95	-0.56	-0.26	12

Simulation of a 10% trade shock in the Food & Beverages Sector. Percentage responses for capital, employment, output, exports, and wages. Year 1: Year of shock. Long Run: Year 30. Transition: number of years to converge to 95% of the long run value.

Table 4
Complementarity of Trade Shock and Capital Adjustment Costs
Response of Capital to a 10 Percent Trade Shock to the Food & Beverages Sector

	Year 2	Year 3	Year 5	Steady State	Years to Convergence
A) Response of Aggregate Capital Stock					
Total response	29.06	36.32	43.07	46.23	6
(i) Trade shock	6.43	11.15	17.73	24.38	10
(ii) Cost structure	17.62	17.62	17.62	17.62	–
(iii) Complementarity	5.01	7.54	7.72	4.23	–
Relative complementarity (iii)/(i)	77.90	67.60	43.55	17.33	–
B) Response of Capital Stock Initially Inactive Firms					
Total response	14.50	16.24	17.43	18.15	5
(i) Trade shock	4.26	4.92	5.40	6.24	7
(ii) Cost structure	4.15	4.15	4.15	4.15	–
(iii) Complementarity	6.09	7.17	7.88	7.76	–
Relative complementarity (iii)/(i)	142.94	145.76	145.84	124.25	–
C) Contribution of Initially Inactive Firms to Response of Aggregate Capital Stock					
Total response	38.81	34.80	31.50	30.56	–
(i) Trade shock	51.53	34.32	23.72	19.93	–
(ii) Cost structure	18.32	18.32	18.32	18.32	–
(iii) Complementarity	94.55	74.00	79.43	142.87	–

All results refer to changes in aggregate capital in the shocked sector.
Panel A): total response of aggregate capital to a trade shock of 10% and a change in the cost structure in which fixed costs and irreversibility of investment are eliminated. Row (i) is the trade shock component; row (ii) is the change in cost structure component; and row (iii) is the incremental price response or complementarity. See equation (25).
Panel B): extensive margin. Capital response of firms that do not invest in the baseline steady state to the same trade shock and change in cost structure as in Panel A).
Panel C): Contribution of the extensive margin to response of aggregate capital stock.

Table 5
Complementarity of Trade Shocks and Capital Adjustment Costs
Responses of Employment, Output, and Exports

	Year 2	Year 3	Year 5	Steady State	Years to Convergence
A) Employment Food & Beverages					
Total response	15.17	19.72	23.81	25.58	6
(i) Trade shock	7.25	11.51	15.65	17.73	7
(ii) Cost structure	7.42	7.42	7.42	7.42	–
(iii) Complementarity	0.50	0.79	0.74	0.43	–
Relative complementarity (iii)/(ii)	6.88	6.90	4.75	2.45	–
B) Output Food & Beverages					
Total response	16.65	20.28	23.58	25.03	6
(i) Trade shock	5.59	8.76	11.84	13.52	7
(ii) Cost structure	10.61	10.61	10.61	10.61	–
(iii) Complementarity	0.45	0.92	1.14	0.90	–
Relative complementarity (iii)/(i)	8.10	10.45	9.60	6.66	–
C) Exports Food & Beverages					
Total response	123.47	140.06	153.49	158.47	5
(i) Trade shock	68.01	81.14	96.38	103.57	6
(ii) Cost structure	50.98	50.98	50.98	50.98	–
(iii) Complementarity	4.49	7.95	6.14	3.92	–
Relative complementarity (iii)/(i)	6.60	9.79	6.37	3.79	–
E) Wages Food & Beverages					
Total response	6.73	5.47	4.36	3.89	7
(i) Trade shock	4.42	2.96	1.92	1.51	8
(ii) Cost structure	2.19	2.19	2.19	2.19	–
(iii) Complementarity	0.12	0.31	0.25	0.19	–
Relative complementarity (iii)/(i)	2.65	10.62	12.84	12.90	–
F) Firm Value Food & Beverages					
Total response	27.15	28.21	29.19	29.63	3
(i) Trade shock	17.60	17.99	18.87	19.69	5
(ii) Cost structure	9.03	9.03	9.03	9.03	–
(iii) Complementarity	0.52	1.19	1.29	0.91	–
Relative complementarity (iii)/(i)	2.95	6.61	6.84	4.62	–
G) Wages Other Tradables					
Total response	-1.79	-1.43	-0.99	-0.51	13
(i) Trade shock	-2.43	-2.32	-1.80	-1.30	11
(ii) Cost structure	0.62	0.62	0.62	0.62	–
(iii) Complementarity	0.03	0.27	0.19	0.17	–
Relative complementarity (iii)/(i)	-1.06	-11.66	-10.74	-12.82	–
H) Wages Non-tradables					
Total response	-0.38	0.26	1.02	1.38	8
(i) Trade shock	-1.63	-0.95	-0.56	-0.26	12
(ii) Cost structure	1.34	1.34	1.34	1.34	–
(iii) Complementarity	-0.09	-0.14	0.25	0.30	–
Relative complementarity (iii)/(i)	5.40	14.42	-43.99	-116.86	–

Total response of aggregate variables to a trade shock of 10% and a change in the cost structure in which fixed costs and irreversibility of investment are eliminated. Row (i) is the trade shock component; row (ii) is the change in cost structure component; and row (iii) is the incremental price response or complementarity. See equation (25).

Table 6
Complementarity of Trade Shocks, Capital and Labor Adjustment Costs

	Year 2	Year 3	Year 5	Steady State	Years to Convergence
A) Capital Food & Beverages					
Total response	29.56	38.03	45.51	47.50	5
(i) Trade shock	6.43	11.15	17.73	24.38	10
(ii) Cost structure	17.36	17.36	17.36	17.36	–
(iii) Complementarity	5.77	9.52	10.43	5.75	–
Relative complementarity (iii)/(i)	89.77	85.32	58.85	23.58	–
B) Employment Food & Beverages					
Total response	17.78	23.03	26.62	27.19	5
(i) Trade shock	7.25	11.51	15.65	17.73	7
(ii) Cost structure	7.13	7.12	7.12	7.14	–
(iii) Complementarity	3.40	4.40	3.85	2.32	–
Relative complementarity (iii)/(i)	46.91	38.24	24.63	13.10	–
C) Output Food & Beverages					
Total response	18.26	22.45	25.53	26.14	5
(i) Trade shock	5.59	8.76	11.84	13.52	7
(ii) Cost structure	10.40	10.39	10.39	10.41	–
(iii) Complementarity	2.27	3.30	3.30	2.21	–
Relative complementarity (iii)/(i)	40.54	37.63	27.89	16.32	–
D) Exports Food & Beverages					
Total response	163.93	183.43	195.42	196.06	4
(i) Trade shock	68.01	81.14	96.38	103.57	6
(ii) Cost structure	84.30	84.12	84.09	84.37	–
(iii) Complementarity	11.62	18.17	14.95	8.12	–
Relative complementarity (iii)/(i)	17.09	22.40	15.51	7.84	–
E) Wages Food & Beverages					
Total response	8.41	7.01	6.11	5.98	5
(i) Trade shock	4.42	2.96	1.92	1.51	8
(ii) Cost structure	4.88	4.87	4.87	4.87	–
(iii) Complementarity	-0.90	-0.82	-0.68	-0.40	–
Relative complementarity (iii)/(i)	-20.29	-27.79	-35.51	-26.35	–
F) Value of Firm Food & Beverages					
Total response	31.52	32.58	33.62	33.91	3
(i) Trade shock	17.60	17.99	18.87	19.69	5
(ii) Cost structure	11.62	11.60	11.60	11.62	–
(iii) Complementarity	2.30	2.99	3.16	2.60	–
Relative complementarity (iii)/(i)	13.06	16.62	16.73	13.22	–

Total response of aggregate variables to a trade shock of 10% and a change in the cost structure in which fixed costs and irreversibility of investment are eliminated and in which labor mobility costs are reduced by 50%. Row (i) is the trade shock component; row (ii) is the change in cost structure component; and row (iii) is the incremental price response or complementarity. See equation (25). Results refer to aggregate variables in the shocked sector.

Trade Shocks and Factor Adjustment Frictions: Implications for Investment and Labor

by Erhan Artuç, Germán Bet, Irene Brambilla, and Guido Porto

On-line Appendix

A.1 Calibration of the Production Function Parameters in the Non-Tradable Sector

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 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.

A.2 Estimation of the Adjustment Cost Parameters Γ by SMM

We estimate the vector of capital adjustment cost parameters $\Gamma = (\gamma_1, \gamma_2, \gamma_3)$ by simulated method of moments or SMM (McFadden, 1989; Pakes and Pollard, 1989). 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. In this appendix we discuss some details about how the simulated moments are computed and about how the search over the parameters is implemented.

To compute the simulated moments we first need to obtain the firm-level policy function $I^j(A_{ijt}, K_{ijt}; s_t; \Gamma)$ for a given value of Γ and then to use it to simulate the behavior of firms. In order to do this, we first discretize the state space of variables K, K' (the next period capital stock), 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). We then solve the Bellman equation (6) iteratively and obtain the policy function I for each grid point in the state space. See Rust (1996) for a detailed discussion of the conditions that ensure convergence of a Value Function. We then simulate a panel of artificial firms by taking random draws of initial capital and a series of profitability shocks. The simulation is performed by drawing a Markov Chain with 1100 time periods for each of 568 firms. We drop the first 100 periods from the simulated data so that the simulation is independent of the initial conditions. From the simulated firms and the firm-level policy function I, we compute the vector of simulated moments $\Psi^s(\Gamma)$.

The estimator of the adjustment cost parameters minimizes the difference between the empirical and simulated moments given by equation (17). 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. 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.

Each iteration over Γ involves solving the Bellman equation and computing the empirical moments. The panel of simulated firms is kept fixed across iterations.

We use the optimal weighting matrix given by the inverse of the variance covariance matrix of $[\Psi - \Psi^s(\Gamma)]$. 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.

Standard errors for the estimates are computed analytically, as in Bloom (2009).

A.3 Robustness of Capital Adjustment Costs Parameters

Here, we assess the robustness of our capital adjustment costs estimates to variants of the choice of moments. We report results in Table A1 In the main specification, we match four moments: the serial correlation of the investment rate, the correlation between the investment rate and profitability, positive spikes at 20 percent and negative spikes at −20 percent (positive and negative spikes refer to the percentage of firms that invest and disinvest at different thresholds). In the specifications in the Table, we keep the first two moments (see Bloom, 2009; and Cooper and Haltiwanger, 2006) and we experiment with different spikes as well as with percentiles of the investment rate instead of the spikes. As it can be seen, the estimates are pretty robust to changes in moments that capture investment bursts.

A.4 Solution of the Counterfactual Simulations

To solve for the equilibrium of a counterfactual simulation we discretize the firm-level state variables A and K into 20 and 154 grid points 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 (T is equal to 30). Second, 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 $\{I_0^j(A,K), I_1^j(A,K), \ldots, I_T^j(A,K)\}$. 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 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.

A.5 Responses to a Trade Shock in Other Sectors

Figures A1 and A2 display aggregate responses to a trade shock in Food & Beverages in other tradable products and non-tradable products.

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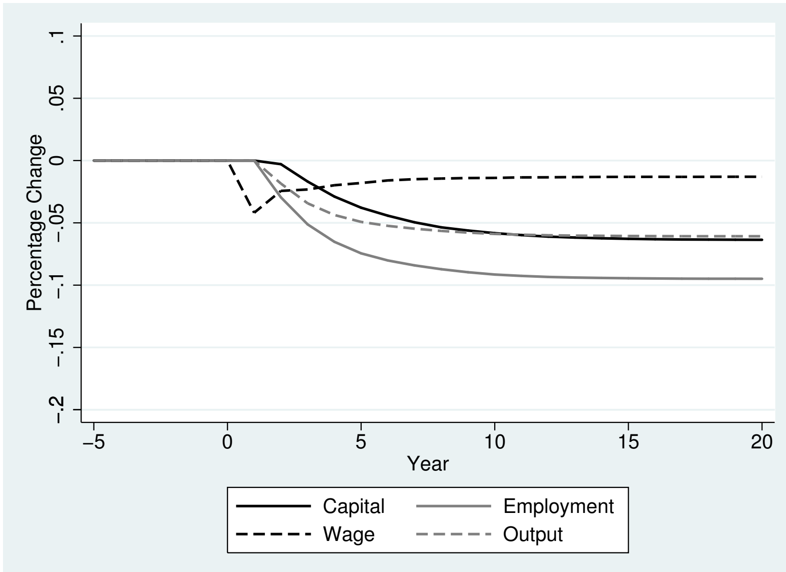
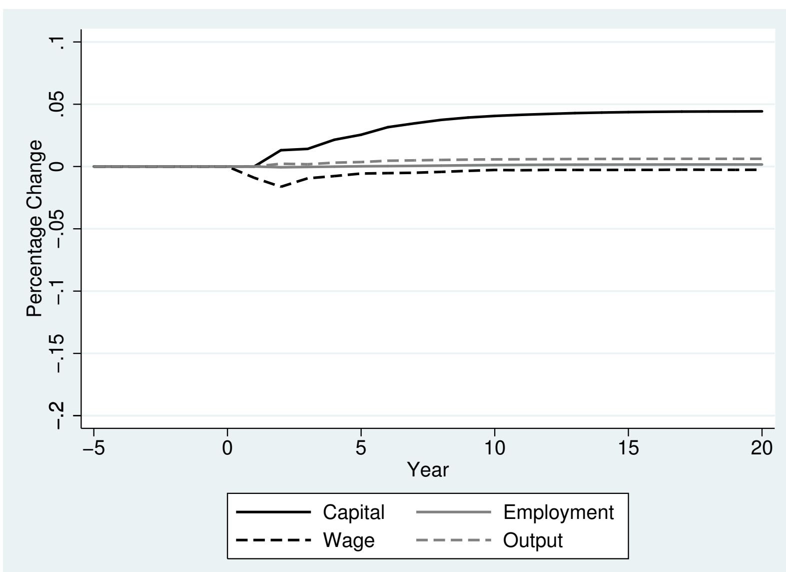
Figure A1
Responses to a Trade Shock. Other Tradable Products



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

Figure A2
Responses to a Trade Shock. Non-tradables



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

Table A1
Capital Adjustment Costs Robustness

	Fixed Cost (1)	Convex Cost (2)	Irreversibility Cost (3)
A) Preferred Specification			
Positive Spikes=20%; Negative Spikes=–20%	0.1451	0.1132	0.9143
	(0.0358)	(0.0245)	(0.0705)
B) Other Specifications			
Positive Spikes=20%; Negative Spikes=–5%	0.1407	0.0538	0.9995
	(0.0799)	(0.0552)	(0.1910)
Positive Spikes=20%; Negative Spikes=–10%	0.1498	0.0756	0.9740
	(0.0412)	(0.0150)	(0.0815)
Pctile 80 Pctile 5	0.0902	0.1312	0.9878
	(0.0047)	(0.0359)	(0.0153)
Positive Spikes=15%; Negative Spikes=–5%	0.0977	0.1063	0.9969
	(0.0440)	(0.0245)	(0.1072)
Positive Spikes=25%; Negative Spikes=–5%	0.0614	0.0000	0.7560
	(0.0601)	(0.0007)	(0.1473)
Positive Spikes=15%; Negative Spikes=–10%	0.1142	0.1329	0.9994
	(0.0541)	(0.0531)	(0.1481)
Positive Spikes=25%; Negative Spikes=–10%	0.1499	0.0247	0.8800
	(0.1106)	(0.0353)	(0.2545)
Positive Spikes=15%; Negative Spikes=–20%	0.0018	0.0077	0.4461
	(0.0016)	(0.0067)	(0.0123)
Positive Spikes=25%; Negative Spikes=–20%	0.1489	0.0386	0.8229
	(0.2530)	(0.1004)	(0.4143)
Pctile 80; Pctile 3	0.0020	0.0183	0.5158
	(0.0104)	(0.0247)	(0.1115)
Pctile 80; Pctile 8	0.0865	0.0659	0.9998
	(0.0109)	(0.0164)	(0.0308)
Pctile 75 Pctile 5	0.0016	0.0489	0.5853
	(0.0003)	(0.0146)	(0.0040)
Pctile 85; Pctile 5	0.1499	0.0618	0.9556
	(0.1642)	(0.0618)	(0.2672)

Notes: All specifications include four moments and all share the serial correlation of the investment rate and the correlation between the investment rate and profitability. Positive and Negative Spikes refer to the percentage of firms that invest and disinvest at different thresholds. Pctile refers to the percentiles of the investment rate.