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Simulation Results**

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Delay and Dynamics in Labor Market Adjustment: Simulation Results¹

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Abstract. We study numerical simulations of a standard trade model with labor mobility costs added, modeled in such a way as to generate gross flows in excess of net flows. We find that adjustment to a trade shock can take a long time with plausible values of parameter values. In our base case, for the economy to move 95% of the distance to the new steady state takes well over a decade. Gross flows have a large effect on this rate of adjustment and on the normative effects of trade. Announcing and delaying the liberalization can build a constituency for free trade, but it can also destroy one. We study the conditions under which these two different outcomes occur.

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Despite its importance, the imperfect mobility of workers within their economy has usually been ignored in research on international trade. Familiar workhorse models assume either perfect mobility or (less often) perfect immobility of workers across sectors.

This paper studies a recent theoretical model that has been designed to address this gap, by simulating the model numerically to generate answers to questions that are difficult to resolve analytically. Cameron, Chaudhuri and McLaren (2003) present a model of a small open economy with workers who face moving costs to switch sectors or to move geographically within the country. These costs have a common component and a time-varying idiosyncratic component. Workers must choose their location at each date, which amounts to a problem of investment under uncertainty with rational expectations. The presence of the idiosyncratic shocks means that the model produces gross flows in excess of net flows, gradual adjustment of the economy to a trade shock, anticipatory adjustment to an expected future shock, and long-run wage differentials across sectors and locations, all of which are important empirically. Chaudhuri and McLaren (2003a) studies a simple special case of this model in which there are two sectors, each in one geographic location. This is essentially a dynamic version of the familiar Ricardo-Viner model (see Mussa (1975)). Chaudhuri and McLaren (2003b) study another simple variant with two types of imperfectly mobile worker, skilled and unskilled, and no other factor of production. This is essentially a dynamic version of a Heckscher-Ohlin model. Both models show great differences from their static analogues, even in the steady state. This paper studies properties of the model in Chaudhuri and McLaren (2003a)

(henceforth CM) .

Specifically, we consider an economy initially in a steady state with a tariff that is then opened to free trade, in two possible ways: first, sudden, unannounced liberalization, and then delayed, pre-announced liberalization. We study the time-path of the economy's adjustment, the evolution of wages, and the welfare of workers in exporting and import-competing sectors. We find that both the positive and the normative effects of trade can be very different for an anticipated and an unanticipated liberalization, and also for different parameter values that yield different levels of gross flows.

Various approaches have been used to incorporate imperfect labor mobility into trade models. One approach has been to adapt the convex adjustment cost assumed for capital in Mussa (1978) to labor, reinterpreting it perhaps as a retraining cost. Examples of this are Karp and Thierry (1994) and Dehejia (2003). Another is to assume that each worker must pay a fixed cost to switch sectors. Examples include Dixit (1993) and Dixit and Rob (1994) in a dynamic model with stochastic shocks to labor demand across sectors, and Feenstra and Lewis (1994) in a static model. These all have in common the property that if labor moves across sectors, it all moves in the same direction at any one time, or in other words, gross flows are equal to net flows.

An approach that allows for gross flows in excess of net flows is explored in Davidson, Martin and Matusz (1999) and Davidson and Matusz (2001). This approach is based on search theory; workers may leave one sector to find a job in another, but at the cost of temporary unemployment while looking for a vacancy. The approach pursued in the current paper differs from that series in a variety of ways, but most crucially it has been designed to be as close as possible to familiar trade models. For example, Davidson, Martin and Matusz (1999) show that in a model with

the usual sources of comparative advantage shut down, a country can still have gains from trade due to differences in search technology across countries. In our model, by contrast, the gains from trade stem from the same sources as in a Ricardo-Viner model.

A major focus of this paper is the effect of delay in trade liberalization, or the practice of government announcing a *future* elimination of trade barriers in order to allow private agents time to adjust. This is a special case of ‘gradualism,’ or liberalization through scheduled progressive stages, which is an extremely common practice in real-world trade reform. Mussa (1978) showed that in a neoclassical model there is no strictly economic argument for gradualism. Staiger (1995) and Bond and Park (2002) examine different reasons that gradualism can be useful in loosening incentive-compatibility constraints in bilateral liberalization without commitment. Dehejia (2003) shows in a labor-rich Heckscher-Ohlin economy with convex moving costs for labor, gradualism can make the import-competing workers net beneficiaries from trade reform, instead of net losers. This can make the liberalization politically feasible, while a ‘shock therapy’ liberalization would have been infeasible. In this paper, we will explore the Dehejia argument with a different model, one featuring gross flows, and arrive at quite different results.

The next section lays out the model, the following one some baseline simulations showing how changes in the moving cost parameters change the economy’s dynamic adjustment, and the following section studies in detail the possible attractiveness of delayed liberalization as a way of spreading the benefits of trade more widely.

1. The Model.

Consider a small open economy that can produce two goods, X and Y. Good Y is the numeraire, and the price of X is denoted by p . Both goods are produced under competitive conditions with constant-returns-to-scale technology $q^i = Q^i(L^i, K^i)$, where q^i denotes output in sector i , L^i and K^i denote labor and capital employed in sector i respectively. Capital in each sector is inelastically supplied, and is specific to its sector. The total supply of labor in the economy is exogenously given at a value \bar{L} , so at all points the adding-up condition for labor must hold:

$$L^X + L^Y = \bar{L}.$$

Workers can move from one sector to another over time, but at each date the supply of labor to each sector is fixed by location decisions in previous periods. Wages in each sector adjust to clear the spot market for labor at each date:

$$\begin{aligned}\tilde{w}_t^X &= p \partial Q^X(L_t^X, K_t^X) / \partial L^X, \\ \tilde{w}_t^Y &= \partial Q^Y(L_t^Y, K_t^Y) / \partial L^Y,\end{aligned}\tag{1}$$

where a subscript indicates time and \tilde{w}_t^i is the wage in sector i in period t , denominated in terms of the numeraire.

Workers.

All workers discount the future at the common rate $\beta < 1$. Workers are infinitely-lived and risk-neutral. They all have an identical and homothetic utility function, yielding an indirect utility function given by $I/\phi(p)$, where I is income and $\phi(p)$ is a consumer price index. The location decisions of workers are characterised as follows. In each period, each worker receives an idiosyncratic benefit ϵ_t^j if that worker is in sector j at the end of the period. We can denote the pair of benefits by $\epsilon_t = (\epsilon_t^x, \epsilon_t^y)$. These benefits are realized from a continuous distribution with probability density function f and cumulative distribution function F , where $E[\epsilon_t^j] \equiv 0$. These shocks are independently distributed across workers and across time. It is most convenient to think of these benefits as non-pecuniary. For example, a worker in sector i may have tired of his/her existing job, and want to switch (indicating a negative ϵ_t^i); or develop a romantic attachment that requires him/her to move to another part of the country, where the worker's current sector does not operate but the other sector does (indicating a large positive ϵ_t^j).

There is, then, an idiosyncratic cost to switching sectors, as a worker who leaves i in order to enter sector j at time t forgoes the i benefit and reaps the j benefit instead. This implies an idiosyncratic moving cost of:

$$\mu_t^i \equiv \epsilon_t^i - \epsilon_t^j.$$

The cdf for this moving cost is derived from F and denoted G ; similarly, the pdf is denoted g .

In addition to the idiosyncratic moving cost, a worker who changes sectors will also incur a common cost equal to $C \geq 0$.

Worker optimization.

Let $V^i(L_t)$ stand for the expected utility of a worker in sector i at time t (before learning idiosyncratic shocks ϵ_t). Worker optimization implies the Bellman equation:

$$V^i(L_t) = w_t^i + \max\{\epsilon_t^i + \beta V^i(L_{t+1}), \epsilon_t^j - C + \beta V^j(L_{t+1})\},$$

where $i, j \in \{X, Y\}$ and $j \neq k$, and $w_t^i = \tilde{w}_t^i / \phi(p)$ is the real utility wage. It is easy to see that at any date t there is a threshold value of μ_t^i , say $\bar{\mu}_t^i$, such that the worker will stay in i if $\mu_t^i > \bar{\mu}_t^i$, and will move to j if $\mu_t^i < \bar{\mu}_t^i$. Put differently, $\bar{\mu}_t^i$ is the net value of being in j rather than i next period, net of non-idiosyncratic moving costs. This enables us to write:

$$\begin{aligned} \bar{\mu}_t^X &= \beta[V^Y(L_{t+1}) - V^X(L_{t+1})] - C \\ \bar{\mu}_t^Y &= \beta[V^X(L_{t+1}) - V^Y(L_{t+1})] - C, \text{ and so} \\ \bar{\mu}_t^X &= -\bar{\mu}_t^Y - 2C. \end{aligned} \tag{2}$$

Using this notation, the Bellman equation becomes:

$$\begin{aligned} V^i(L_t) &= w_t^i + \beta V^i(L_{t+1}) + E_\mu \max\{0, \bar{\mu}_t^i - \mu_t^i\} \\ &= w_t^i + \beta V^i(L_{t+1}) + \Omega(\bar{\mu}^i), \end{aligned}$$

where $\Omega(\bar{\mu}^i) = E_{\mu} \max\{0, \bar{\mu}^i - \mu\} = G(\bar{\mu}^i)\bar{\mu}^i - \int_{-\infty}^{\bar{\mu}^i} \mu g(\mu) d\mu$ is the option value of a worker in sector i . Using this, we can derive the steady-state condition:

$$\bar{\mu}^X + C = (\beta/(1 - \beta))[w^Y - w^X + \Omega(-\bar{\mu}^X - 2C) - \Omega(\bar{\mu}^X)]. \quad (3)$$

Note that the fraction of workers in X who move to Y in any period is equal to $G(\bar{\mu}^X)$, and the fraction who move from Y to X is equal to $G(-\bar{\mu}^X - 2C)$. Thus, the steady-state values of L^X and L^Y are determined by $\bar{\mu}^X$. This, then, determines w^X and w^Y as a function of $\bar{\mu}^X$ through (1), so the condition (3) is self-contained for any given p . Of course, for an autarkic equilibrium the p will be such that the resulting supply of the two goods is equal to the domestic demand.

This condition, then, determines the steady state. Because the left-hand side of (3) is strictly increasing in $\bar{\mu}^X$ while the right-hand side is strictly decreasing, the steady state is unique. Note that the steady state is characterised by gross flows but no net flows.

CM derive a number of results. First, in the steady state, the larger sector must have a higher wage, and the steady-state allocation of labor is in between the Ricardo-Viner equilibrium and equal division. In addition, the dynamic equilibrium maximizes the present discounted value of aggregate real revenue net of (common plus idiosyncratic) moving costs. (This is the dynamic analogue of the static revenue function, as used in Dixit and Norman (1980).) This is useful in computing the equilibrium numerically. This can be implemented as a straightforward dynamic programming problem. Because the value function is strictly concave, the solution to this optimization problem, and hence the equilibrium, is unique. A few properties of the equilibrium dynamics are also derived. If trade is suddenly opened up in an economy that had been closed, the economy adjusts gradually

and monotonically to the new steady state as the import-competing sector shrinks.

Further, if a *future* opening of trade is credibly announced in advance, labor begins to reallocate immediately from the import-competing sector in anticipation of the policy change. This implies that such an announcement will raise wages in the import-competing sector in advance of the policy change and lower them in the export sector during the same period. This raises questions regarding the incidence of trade policy and how it may be affected by delay in liberalization. Under what conditions are workers in the import-competing sector net beneficiaries of trade? Workers in the export sector? And how are these welfare effects affected by delay of liberalization of the type just described?

A number of local results are derived regarding this in CM, that is, results that are valid if the world price is close enough to the domestic autarkic price. First, starting from an autarkic steady state, it is shown that it is possible for all workers to benefit from a surprise opening of trade (in terms of lifetime expected utility, $V^i(L_t)$). It is also possible for all workers to be hurt, and it is possible for workers initially in the export sector to benefit and workers in the import-competing sector to be hurt. (The benefit to export-sector workers always exceeds the benefit to import-competing workers.) Refer to the first two cases as cases in which workers are ‘unanimous,’ and the last case as one in which workers are ‘split.’ In cases in which the workers are unanimous without delay, delay does nothing to change their minds, but in cases in which they are split a sufficiently long delay will guarantee unanimity. However, it could be a pro-trade or an anti-trade unanimity. CM derive a condition that determines which of the two cases occurs, in the local case. It essentially says that if export-sector labor demand is responsive enough compared to import-competing-sector labor demand, delay leads to pro-trade unanimity, and otherwise it leads to an anti-

trade unanimity. In this paper, we explore these questions numerically to try to quantify these effects and to map out the portions of the parameter space in which these outcomes occur without relying on the assumption of the nearness of the world price to the autarkic price.

2. Parameters and simulation method.

We will study an economy that is initially in a steady state with a tariff, but then has the tariff removed either abruptly or with some warning. Here we will lay out the functional form and parameter assumptions and the method for computing equilibrium responses to these policy changes.

The economy has 1 unit of specific capital in each of the two sectors and 2 units of labor in total. We adopt the following functional-form assumptions. Production functions are of the constant-elasticity-of-substitution (CES) variety:

$$\begin{aligned} Q^i(L_t^i, K_t^i) &= (2^{-1/\rho(i)})((L_t^i)^{\rho(i)} + (K_t^i)^{\rho(i)})^{1/\rho(i)} \text{ if } \rho(i) \neq 0, \text{ and} \\ &= (L_t^i)^{1/2} (K_t^i)^{1/2} \text{ otherwise,} \end{aligned}$$

where $\rho(i) \in (-\infty, 1)$ is a parameter. The elasticity of substitution between labor and capital in sector i is then $\sigma(i) = 1/(1 - \rho(i))$. Note that the production functions have been normalized so that regardless of the elasticity of substitution chosen, the unit isoquant will always go through the point $(1, 1)$.

Preferences are given by the Cobb-Douglas utility function $U(C^X)(C^Y) = 2(C^X)^{1/2}(C^Y)^{1/2}$, where C^i represents consumption of good i , yielding the indirect utility function $I/(p^X)^{1/2}(p^Y)^{1/2}$,

where p^x and p^y are the product prices and I is income. Given that Y is the numeraire, the indirect utility function becomes:

$$I/\phi(p),$$

for given income I and price p for good X, where ϕ the consumer price index is given by $\phi(p) = p^{1/2}$.

It is straightforward to see that as a result of these production and consumption assumptions the value $p = 1$ is always the steady-state equilibrium price in autarky, regardless of the substitution elasticities, with equal wages in the two sectors (equal to $1/2$) and an equal division of labor between the sectors. This is a useful benchmark. We will assume that the world relative price of X is 0.7, and that before the liberalization the tariff is set just high enough that the domestic relative price is equal to unity (an *ad valorem* rate of approximately 43 per cent). In other words, the government has imposed the minimal prohibitive tariff. This makes for a convenient thought experiment, because it facilitates easy comparison of the pre-liberalization situation across different parameter values. Note that since the autarkic relative price of X exceeds the corresponding world price, the economy exports Y.

We assume that the ϵ_i 's have the extreme-value distribution, with cumulative distribution function

$$F(\epsilon) = \exp(-\exp(-\epsilon/\nu - \gamma)),$$

where $\gamma \equiv 0.5772$ is Euler's constant. The means of ϵ is then zero, and its variance is then equal

to $(\pi^2 v^2)/6$ (Patel, Kapadia, and Owen (1976, p.35)). It can be shown that in this case

$$G(\mu) = \frac{\exp(\mu / v)}{1 + \exp(\mu / v)},$$

and that

$$\Omega(\mu) = v \log(1 + \exp(\mu / v)).$$

(Derivations are available from the authors on request.)

As indicated above, in order to compute an equilibrium we solve a social planner's dynamic programming problem. Define the per-period welfare as:

$$U(L_t^X, L_t^Y, \bar{\mu}; p_t) \equiv [p_t Q^X(L_t^X, K_t^X) + Q^Y(L_t^Y, K_t^Y)] / \phi(p) - L_t^X \int_{-\infty}^{\bar{\mu}} (\mu + C) g(\mu) d\mu - L_t^Y \int_{-\infty}^{\bar{\mu}} -2C (\mu + C) g(\mu) d\mu.$$

The first term is aggregate real revenue (or in other words, real GDP). The remaining terms of the welfare expression are realized idiosyncratic and non-idiosyncratic costs of moving from X and Y respectively. From the definition of Ω , we can see that $-\int_{-\infty}^{\bar{\mu}} \mu g(\mu) d\mu = \Omega(\bar{\mu}) - G(\bar{\mu})\bar{\mu}$, and so welfare can be rewritten as:

$$U(L_t^X, L_t^Y, \bar{\mu}; p) \equiv R_t / \phi(p) - v \sum_{i,j=X,Y} L_t^i m^{ij}(\bar{\mu}) \log(m^{XX}(\bar{\mu})) - C [L_t^X m^{XX}(\bar{\mu}) + L_t^Y m^{XX}(\bar{\mu})].$$

Here R_i denotes revenue and the functions m^{ij} give the gross flow rates, the fraction of workers in i who choose to move to j , as a fraction of the current value of the threshold $\bar{\mu}$. Precisely, $m^{XY}(\bar{\mu}) = G(\bar{\mu})$, $m^{YX}(\bar{\mu}) = G(-\bar{\mu} - 2C)$, $m^{XX}(\bar{\mu}) = 1 - m^{XY}(\bar{\mu})$, and $m^{YY}(\bar{\mu}) = 1 - m^{YX}(\bar{\mu})$ for all $\bar{\mu} \in \mathbb{R}$. In this expression for per-period welfare, the term preceded by v is the aggregate realized value of idiosyncratic benefits, and is always positive by virtue of the fact that the $m^{ij}(\bar{\mu})$'s are all less than unity.

The planner's problem is to maximize the present discounted value of this welfare function subject to resource constraints through optimal choice of the $\bar{\mu}$ thresholds over time.

We need to analyze three situations. The first is the tariff-affected steady state. Recall that we set the initial tariff equal to the lowest required to choke off all trade. Put differently, the initial tariff is that which sets the relative price of X equal to what it would have been under autarky, which as noted above equals unity. The second situation is the free-trade steady state. This is analyzed by solving¹ the following Bellman equation.

$$V^{FT}(L^X, L^Y) = \max_{\{\bar{\mu}\}} \{U(L^X, L^Y, \bar{\mu}; p^W) + \beta V^{FT}(\tilde{L}^X, \tilde{L}^Y)\},$$

¹We discretize the state space and the choice space. Thus, we create a grid with a finite number of values for L^X (evenly spaced between 0 and 2, with those endpoints excluded), denoted $L^X[k]$, where k is an index ranging from 1 to K ; and for $\bar{\mu}$ (evenly spaced between $\bar{\mu}^{\min} < 0$ and $\bar{\mu}^{\max} > 0$), denoted $\bar{\mu}[n]$, where n is an index ranging from 1 to N . The value function V^{FT} is then approximated by a vector whose elements are indexed by the same index as $L^X[k]$. Suppose that we have a current approximation for V^{FT} , namely, the $K \times 1$ vector v . For any $l \in [0, 2]$, let $\psi(l)$ denote the index k of the $L^X[k]$ nearest to l . Then, for each k , we set the value $\tilde{v}[k]$ equal to $\max_n \{U(L^X[k], \bar{L} - L^X[k], \bar{\mu}[n]; p^W) + \beta v[\psi(m^{XX}(\bar{\mu}[n])L^X[k] + m^{YX}(\bar{\mu}[n])(\bar{L} - L^X[k]))]\}$. This gives a mapping from the current estimate v of the value function to the updated value function \tilde{v} . We iterate in this way until we reach convergence. The selection of optimal n for each k , then, yields the optimal policy function $\bar{\mu}(L^X)$.

where V^{FT} is the value function, $\tilde{L}^X = m^{XX}(\bar{\mu})L^X + m^{YX}(\bar{\mu})L^Y$ is the next-period employment in X implied by the current choice of $\bar{\mu}$, and $\tilde{L}^Y = m^{XY}(\bar{\mu})L^X + m^{YY}(\bar{\mu})L^Y$ is the next-period employment in Y. The value p^W is the world relative price, which is assumed to be fixed and beyond this economy's control.

Once the value function has been computed, the function $\bar{\mu}(L^X, L^Y)$ giving the optimal choice of $\bar{\mu}$ at any state then can be used to simulate the dynamics of the system, and the new steady state.

Finally, we analyze the case of a trade liberalization. Suppose that the economy is in a steady state with tariff at date $t = 0$, and then it is announced that at date $T \geq 0$ and from that date forward, free trade will prevail. If $T = 0$, this simply means simulating forward adjustment under free trade from a starting point of $L^X = L^Y = 1$. If $T > 0$, some additional value functions must be defined.

$$V^{T-k}(L^X, L^Y) = \max_{\{\bar{\mu}\}} \{U(L^X, L^Y, \bar{\mu}; 1) + \beta V^{T-k+1}(\tilde{L}^X, \tilde{L}^Y)\},$$

for $k = 1, \dots, T$, with associated optimal $\bar{\mu}$ choices denoted $\bar{\mu}^{T-k}(L^X, L^Y)$. Note that p^W has been replaced by the tariff-affected domestic relative price of unity. The interpretation is that V^{T-k} and $\bar{\mu}^{T-k}$ give the value function and optimal allocation rule for period $T - k$, in which workers anticipate free trade but it has not yet occurred.

Once the aggregate allocation of labor at each date has been computed, it is straightforward to compute the real wages w_t^i from (1). Then the welfare of a worker currently in sector X at the date of the policy announcement can be computed as $\sum_{t=0}^{\infty} \beta^t (w_t^X + \Omega(\bar{\mu}_t))$, and welfare can be

computed as $\sum_{t=0}^{\infty} \beta^t (w_t^Y + \Omega(-\bar{\mu}_t - 2C))$ for workers currently in Y.² We compare this to the utility of a worker in the tariff-affected steady-state, $\left(\frac{1}{2} + \Omega(-C)\right) / (1 - \beta)$, to evaluate whether the given worker is made better or worse off by the announced policy. We set β equal to 0.97, which seems reasonable for an annual discount factor and allows us to interpret the ‘periods’ in our simulations as ‘years.’

All of the Fortran code behind the results presented here is available from the authors on request.

To sum up, the fixed parameters are $\beta = 0.97$; $K^X = K^Y = 1$; $\bar{L} = 2$; and $p^{FT} = 0.7$. The pre-liberalization relative price is equal to unity. The free parameters are the two substitution elasticities σ^X and σ^Y ; the parameter ν that governs the variance of idiosyncratic shocks; the common value of moving costs, C ; and T , the length of delay in trade liberalization. We will now show two sets of simulation results: One to study the dynamics of some base-case liberalizations, and show the effect of the idiosyncratic variance parameter ν , and then a second set to identify the conditions under which delay can improve the distributional effects of liberalization.

²There will be no tariff revenues in the initial steady state, because there will be no imports. There will certainly be no tariff revenues after the tariff has been eliminated. In between, there will generally be positive tariff revenue. In order to work out who the net gainers from trade are, we need to make an arbitrary assumption about how the government disposes of the tariff revenue. We assume that all of these revenues are captured by the owners of the fixed factors, conjecturing that alternative assumptions would not make much difference to the results.

3. Dynamics in baseline simulations.

We adopt as a baseline case a choice of $\nu = 1.25$, $C = 4$, and $\sigma^x = \sigma^y = 1$. The moving-cost parameters have been chosen so that the steady-state rate of gross flows with the tariff will be approximately equal to 4 per cent per year.³ This is roughly the order of magnitude for US workers, who change 1-sector industries at approximately that rate. Figure 1 shows the time path of X-sector employment L^x under two situations, a sudden removal of the tariff at date 0 (indicated by the broken curve), and an announcement at date 0 that the tariff will be removed at date 10 (indicated by the solid curve).⁴

Note that the adjustment for either case is gradual, as in each period import-competing workers who have high current moving costs wait to see if their moving costs will be more favorable in the near future. In the case of the surprise liberalization, it takes about 12 years for the economy to move 95% of the distance to the new steady state, while in the case of delayed liberalization the adjustment is even slower. This suggests a possible problem for application of steady state models to data, unless one is willing to assume that trade shocks occur very infrequently.

Note as well that in the case of delayed liberalization, workers begin to move at the date of the policy announcement, as import-competing workers who have very low current moving costs take advantage of them rather than risk being stuck with high moving costs later. In fact, more than two thirds of the adjustment occurs *before* the policy change. This is emphasized by Figure 2, which

³Recalling that in the tariff-affected steady state, wages are equalized across the sectors, $\bar{\mu} = -\bar{\mu} - 2C = -C$, and so $m^{xy} = m^{yx} = G(-4)$, which takes a value of about 4 per cent per year with $\nu = 1.25$.

⁴The grid parameters are $\bar{\mu}^{\min} = -4$, $\bar{\mu}^{\max} = 4$, $N = 4,001$, and $K = 3,999$.

shows $L_t^X - L_{t+1}^X$, the net movement of workers out of the import-competing sector, at each date. In the case of surprise liberalization, this movement peaks on the day of the announcement, while in the delay case it rises to a peak immediately before the tariff comes off. This suggests a possible problem for empirical approaches that are based on comparison of sectoral employment before and after the elimination of the tariff.

In the event of a sudden liberalization, X-sector real wages drop immediately and gradually climb as labor leaves the sector (Figure 3, broken line), while Y-sector real wages jump up due to the reduced cost of living, then gradually fall as workers enter the sector (Figure 4, broken line). The steady-state wage is higher for workers initially in the export sector (0.5309) than for workers initially in the import-competing sector (0.4886). For all of these reasons, the Y workers benefit more from the liberalization than the X workers do; indeed, the welfare of a worker initially in Y rises by 4% while the welfare of a worker initially in X falls by 0.3%.

On the other hand, in the event of delayed liberalization, the X-sector wage begins to rise during the interval between announcement and actual removal of the tariff, as workers leave the sector in anticipation (Figure 3, solid line). The wage drops abruptly when the tariff is removed. At the same time, the wage in the export sector is pushed down as workers enter, and jumps up abruptly when the tariff is removed (Figure 4, solid line). As a result, the net benefit to import-competing workers is greater, and the net benefit to export workers is less, than in the case with no delay. In this case, both groups of worker now see a rise in welfare from the liberalization of about 1.6%. Thus, this is a case in which delay unifies workers in favor of free trade.

In the other two cases examined in this section, we vary ν in order to see how important idiosyncratic shocks and gross flows are to the system's dynamics. In general, the higher is ν , the

more important are idiosyncratic shocks and the larger will be gross flows. Here, we consider a ‘high variance case,’ in which ν^2 , and therefore the idiosyncratic variance, is ten times what it was in the base case; and a ‘low variance case,’ in which the idiosyncratic variance is one-tenth what it was in the base case.⁵ As can be seen from Figures 5 and 6, in the high variance case the new steady-state employment in X is only 5% less than that in the old steady state, compared with 27% in the benchmark case. The reason is that in the high variance case idiosyncratic non-pecuniary factors are much more important to workers relative to wages than was the case in the benchmark case. Thus, the supply side of the economy responds less vigorously to price signals, in the short and long runs (see Figure 6 to see that short run net flows are much lower than they were in the previous case). A corollary is that wages respond much more vigorously than in the previous case, as indicated by the 14% drop in the long-run real wage in the import-competing sector shown in Figure 7 and the 17% rise in the real wage in the export sector shown in Figure 8. The corresponding figures for the benchmark case are 2% and 6% respectively.

Thus, we see a paradoxical result: Although the high-variance case is a case with very high labor mobility,⁶ in the aggregate it looks like a model with very unresponsive labor adjustment, with labor quantities moving very little even in the long run, and wages absorbing the brunt of the effect of trade liberalization. Casual interpretation without taking gross flows into account would suggest that import-competing workers are hurt by the liberalization while export-sector workers benefit,

⁵The high-variance case has $\nu = 3.953$, and the low-variance case has $\nu = 0.3958$. The grid parameters for the high-variance case are $\bar{\mu}^{\min} = -1$, $\bar{\mu}^{\max} = 1$, $N = 4,001$, and $K = 3,999$. The grid parameters for the low-variance case are $\bar{\mu}^{\min} = -4.2$, $\bar{\mu}^{\max} = 4.2$, $N = 4,001$, and $K = 3,999$.

⁶Gross flows in the tariff-affected steady state are equal to $G(-4) \cong 27\%$ per year with $\nu = 3.953$.

but in fact *both* groups of worker benefit, even without delay in the tariff removal. The interpretation is that with such high rates of gross flow, workers do not think of themselves as attached to their current sector, and are cheered by news of higher wages in the other sector because they know that they will likely spend time in that sector soon.

A final contrast with the base case is that given the small net movement of workers needed to reach the new steady state, the adjustment is very fast, and in the absence of delay the economy is essentially at the new steady state within 5 years (13 for the case of delay, which is only 3 years after the actual policy change).

Finally, Figures 9 and 10 show that adjustment is slow in the low variance case. Indeed, even after 35 years of simulation, sector X employment is nowhere close to its long-run value of 0.72, with or without delay in tariff elimination. However, a surprising fact about long-run wages emerges. The long-run wage in the export sector is 0.5198, while in the import-competing sector it is 0.508. Thus, the long-run wage differential between the two sectors is much narrower than it is in the other two parametric cases, despite the sluggishness of labor movements. This is an illustration of a general result shown in Cameron, Chadhuri, and McLaren (2003), that as the idiosyncratic variance becomes vanishingly small, the long-run wage differential across sectors also becomes vanishingly small (even if C does not become small itself). The point is that although labor adjustment is very sluggish, the long run elasticity of intersectoral labor supply with respect to wage differentials is very large when the idiosyncratic variance is small. Thus, even though this is a model with very low mobility of labor,⁷ if one focusses on steady states, one may be deceived into

⁷Gross flows in the tariff-affected steady state are equal to $G(-4) \cong 4 \times 10^{-5}$ per year with $\nu = 0.3958$.

thinking it is a model with a very high degree of mobility; the steady state is close to the equilibrium of a static frictionless model. At the same time, obviously, because adjustment is so slow, the steady state is close to being irrelevant in practice.

Despite the fact that their long-run real wage is higher in the free trade equilibrium than in the tariff equilibrium, workers in the import competing sector suffer a drop in welfare as a result of the liberalization. The reason is clear from Figure 11: The sharp drop in the wage on the date of tariff removal takes a very long time to be reversed, and indeed after 30 years, the wage is still well below its earlier level. In this context, 10 years' delay has little effect on the outcome. Little reallocation occurs during the anticipation period, and the small rise in the import-competing wage during that period is swamped by the large drop at date 10. For similar reasons, export workers benefit from the liberalization with or without delay.⁸

A final point about all three cases is that the short run behaviour of wages is very different from the long-run behaviour. In each case, with an unannounced tariff removal, the real wage in the import-competing sector falls in the neighborhood of 16% on impact, and the wage in the export sector rises in the neighborhood of 17%. However, as we have seen in the discussion of the results, this is very different from the behaviour both of long-run wages and of worker welfare. Most strikingly, for the low variance case the long run wage is 2% higher for import-competing workers and 4% higher for export workers than the old long-run equilibrium. As a result, results from an empirical approach focussed only on comparing wages in the two sectors immediately before and after the tariff reduction must be interpreted with care.

⁸Welfare for import-competing workers falls by 6.5% without delay and by 3.6% with delay. For export-sector workers, the corresponding increases are 9.9% and 6.1%.

4. Delay and Worker Unity.

A point that emerges from the simulations above is that delaying the liberalization tends to increase the gains (or reduce the losses) to import-competing workers, by temporarily raising their wage, and tends to reduce the gains (or increase the losses) to export workers, by temporarily lowering their wages. This can have important effects on the pattern of net beneficiaries from the liberalization. In particular, it was seen that the 10-year delay in implementing the tariff removal in the base case unites all workers in their approval of the policy move, while import-competing workers would have been opposed to an immediate liberalization. In this section, we examine this argument in more detail.

In CM, it is shown that locally the determinant of whether delay will tend to unite workers in favor of or in opposition to free trade is the relative long-run responsiveness of X- and Y-sector output to a change in total labor supply. A natural way to parametrize this is by varying the sectoral elasticities of factor substitution $\sigma(X)$ and $\sigma(Y)$. Of course, if $\sigma(i)$ is close to zero, then the output response of sector i must be close to zero, and the higher is the elasticity the better the sector would be able to absorb and make use of additional supplies of labor.

We have performed the following experiment. For each point in a grid of $(\sigma(X), \sigma(Y))$ values ranging between 0 and 5, we have solved and simulated the model for $T=0$, in other words, for an unannounced immediate tariff removal. All other parameters are as in the base case of the previous section.⁹ Figure 13 represents the grid, with $\sigma(X)$ measured along the horizontal axis and

⁹The grid parameters used here are $\bar{\mu}^{\min} = -4$, $\bar{\mu}^{\max} = 4$, $N = 1,201$, and $K = 1,199$. Both $\sigma(X)$ and $\sigma(Y)$ take on 60 different values spaced evenly from 0.4 to 5.0.

$\sigma(Y)$ along the vertical. If the welfare of workers in both sectors increases as a result of the removal, we record this in Figure 13 as a point for which ‘Sudden liberalization benefits all workers.’ If the welfare of workers in both sectors falls, we record the point as one for which ‘Sudden liberalization hurts all workers.’ On the other hand, if the workers are split, meaning that export workers benefit from the liberalization while import-competing workers are hurt, then we solve the model again for $T = 1$, or a one-period delay. If this policy brings about an increase in welfare (measured at the announcement date $t = 0$) for workers in both sectors, we record that point as one for which ‘Delayed liberalization benefits all workers.’ If the workers are still split, we add 1 to T and repeat. If all workers are hurt by the delayed liberalization, then we record the point in the figure accordingly.

In other words, we search for the minimal delay required to achieve unanimity among the workers regarding their support for free trade.

Note that if $\sigma(X)$ is low enough, then all workers will benefit from free trade even if it is sprung by surprise, as reflected in the fact that the ‘Sudden liberalization benefits all workers’ region lies against the vertical axis. This is because free trade will raise the demand for export-sector workers; if labor demand in the import-competing sector is very inelastic (as would be the case with Leontieff technology), this will result in a sharp increase in import-competing sector wages, which will dominate other effects. Similarly, if $\sigma(Y)$ is low enough, then all workers will be hurt by free trade if it is sprung by surprise, as reflected in the fact that the ‘Sudden liberalization hurts all workers’ region lies against the horizontal axis. This is because free trade will lower the demand for import-competing-sector workers; if labor demand in the export sector is very inelastic, this will result in a sharp decrease in export-sector wages, which will dominate other effects. It is the region

in between in which the workers are split.

A broken line divides that region of worker disunity into two sections. The section above the broken line contains parameter values for which a sufficient delay makes all workers net beneficiaries from liberalization. For these points, labor demand in the import-competing sector is sufficiently inelastic relative to the export sector that the rise in import-competing wages during the period of anticipation is the dominant effect, converting import-competing workers into net beneficiaries of the process. The section below the broken line contains parameter values for which a sufficient delay makes all workers net *losers* from liberalization. This is the paradoxical case in which giving private agents time to adjust to the new trade regime unites all workers in opposition to free trade. For these points, labor demand in the export sector is sufficiently inelastic relative to the export sector that the fall in export sector wages during the period of anticipation is the dominant effect, converting export workers into net victims of the process.¹⁰

Thus, in contrast to Dehejia (2003), we find that the use of delay to soften political resistance to liberalization is rather treacherous. In this framework, it creates constituencies for liberalization only in a small portion of the parameter space, which is right adjacent to a portion of the parameter space where delay *destroys* constituencies for liberalization.

The minimum delay required to achieve worker unanimity varies widely over the parameter space, and is plotted in the shark's fin diagram of Figure 14. The horizontal axes measure the elasticities of substitution in the two sectors, and the vertical axis measures the number of periods

¹⁰Along the broken line are noted four points for which workers remained split even with 30 years' delay, at which point our computer program stopped looking. We conjecture that a sufficient delay would still have achieved unanimity, but with such a long delay the present discounted value of the aggregate benefits of liberalization are likely to be small.

of delay required to reach unanimity. These figures are truncated at 30 years. The flat water surrounding the fin shows the zero delay required to achieve unanimity either for or against trade if one sector has a much lower elasticity than the other. The face of the fin facing the $\sigma(X)$ axis corresponds to the points in Figure 13 for which delayed liberalization hurts all workers, and the other face corresponds to the points for which delayed liberalization benefits all workers. The ridge joining the two faces corresponds to the points along the broken curve in Figure 13.

Not surprisingly, the points near the regions in which workers are unanimous without delay are the ones for which the shortest delay is required. As we move farther from those boundaries, the delay required becomes longer, thus reducing the aggregate benefit from liberalization. Thus, delay is most attractive the closer the economy is to the upper solid curve in Figure 13 (while still being below it). It is least attractive near the broken curve in Figure 13, where not only is a very long delay necessary to win the support of import-competing workers, but a small perturbation in parameter values would lead to the paradoxical case in which the support of export workers would be destroyed. Thus, if there was any uncertainty about parameter values, the delay strategy could be very risky.

A fuller analysis of policy options would include the possibility of compensatory transfers or direct labor market interventions rather than, or in addition to, delay. Such policies are studied in detail in Feenstra and Lewis (1994) and Davidson and Matusz (2002). It seems sensible to speculate that delay would be more attractive relative to those other options the closer the parameters are to the upper solid curve. However, analysis of this question is beyond the scope of this paper.

5. Conclusion.

We have studied numerical simulations of a standard trade model with labor mobility costs added, modeled in such a way as to generate gross flows in excess of net flows. Major conclusions can be summarized as follows.

(1) Adjustment to a trade shock can take a long time with plausible values of parameter values. In our base case, for the economy to move 95% of the distance to the new steady state took well over a decade.

(2) Gross flows matter a great deal. In our model version with high gross flows (the ‘high variance’ model of Section 4), there was very little net movement of workers, so trade liberalization resulted in a sharp rise in wage in the one sector and a sharp drop in the other in the short run and in the long one. However, because of the high mobility of workers, actual welfare of workers even in the import-competing sector rose. On the other hand, with low gross flows (the ‘low variance’ model), long-run net movement of workers is large, but the adjustment takes more than 40 years. Thus, empirical estimates of the parameters that govern rates of gross flow would be valuable in studying hypothetical policy changes through simulation.

(3) Announcing and delaying the liberalization can build a constituency for free trade, but it can also destroy one. We have studied the conditions under which these two different outcomes occur.

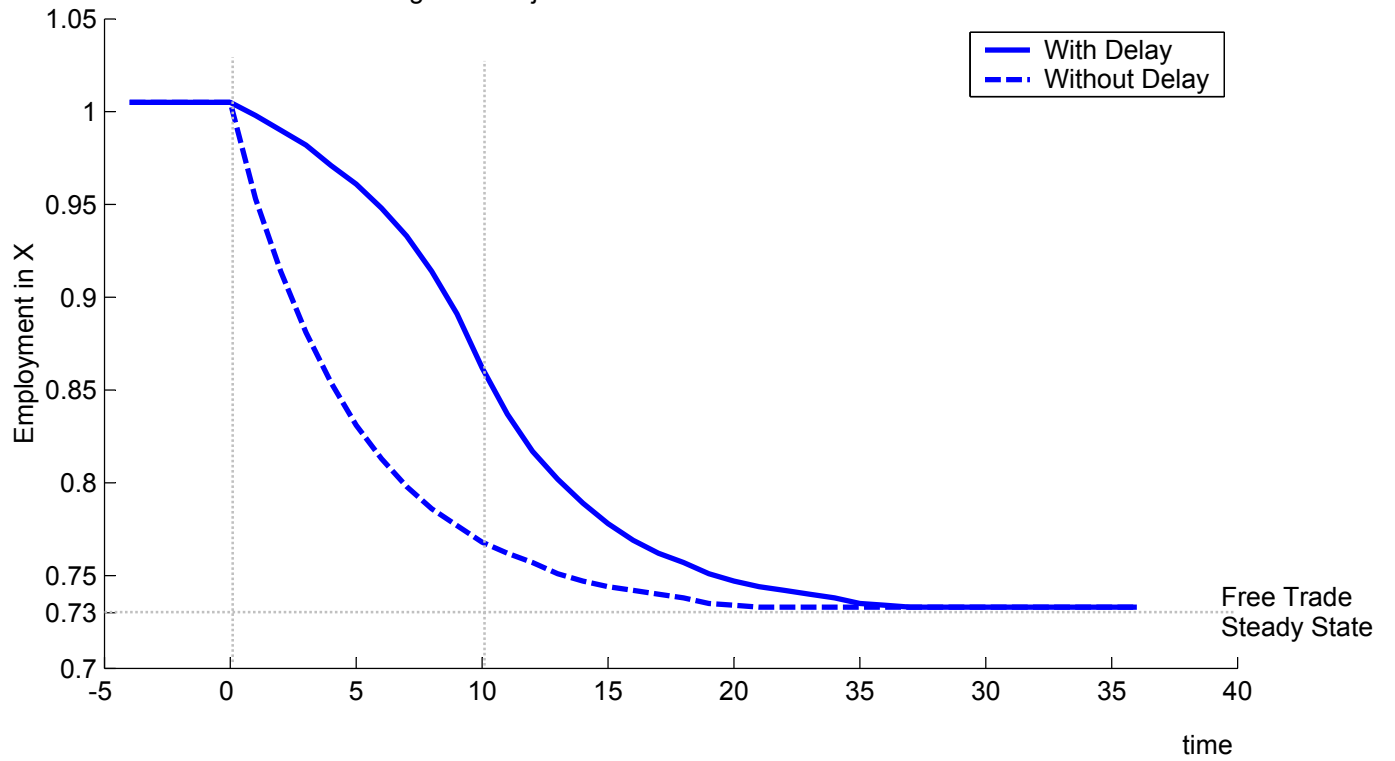
In addition, we have shown how equilibrium in this model can be computed and a variety of policy experiments simulated.

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Figure 1: Adjustment of Labor: Benchmark Case

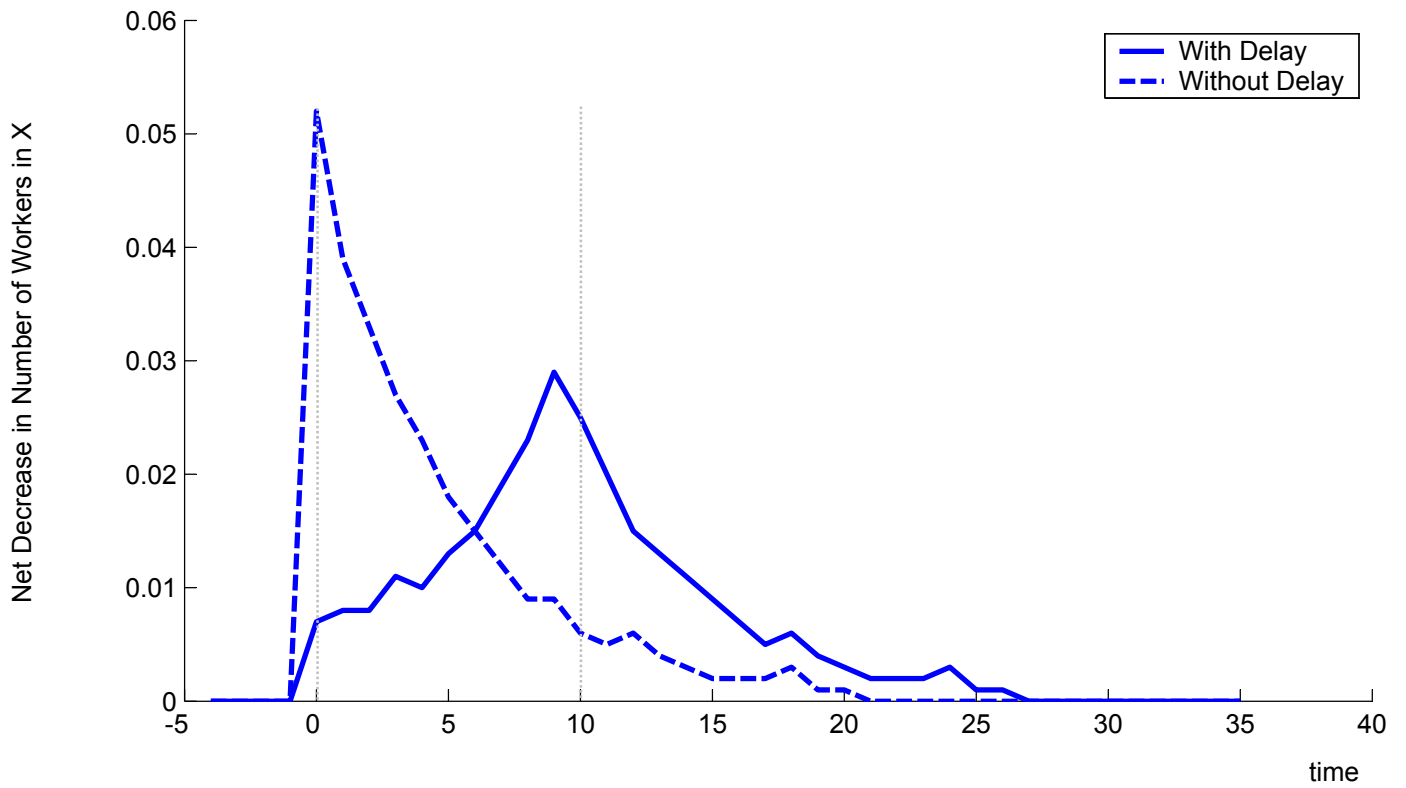


Parameters:

$$v = 1.25 \quad C = 4 \quad K_x = 1 \quad K_y = 1 \quad \sigma_x = 1 \quad \sigma_y = 1$$

$$P_x^{\text{autarcy}} = 1 \quad P_x^{\text{free_trade}} = 0.7 \quad P_y = 1 \quad \beta = 0.97$$

Figure 2: Net Flows Of Labor: Benchmark Case

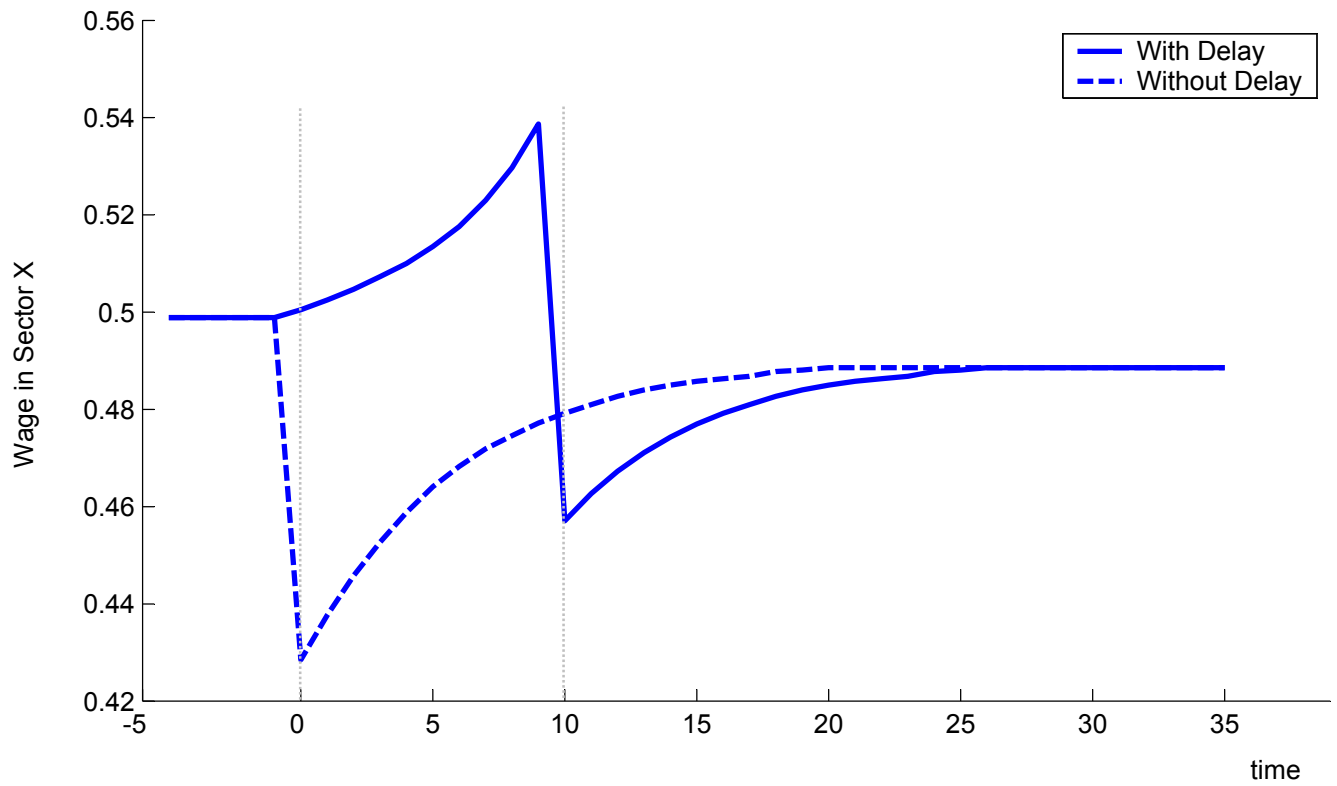


Parameters:

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$P_x^{\text{autarcy}} = 1$ $P_x^{\text{free_trade}} = 0.7$ $P_y = 1$ $\beta = 0.97$

Figure 3: Wages of Import Competing Workers: Benchmark Case

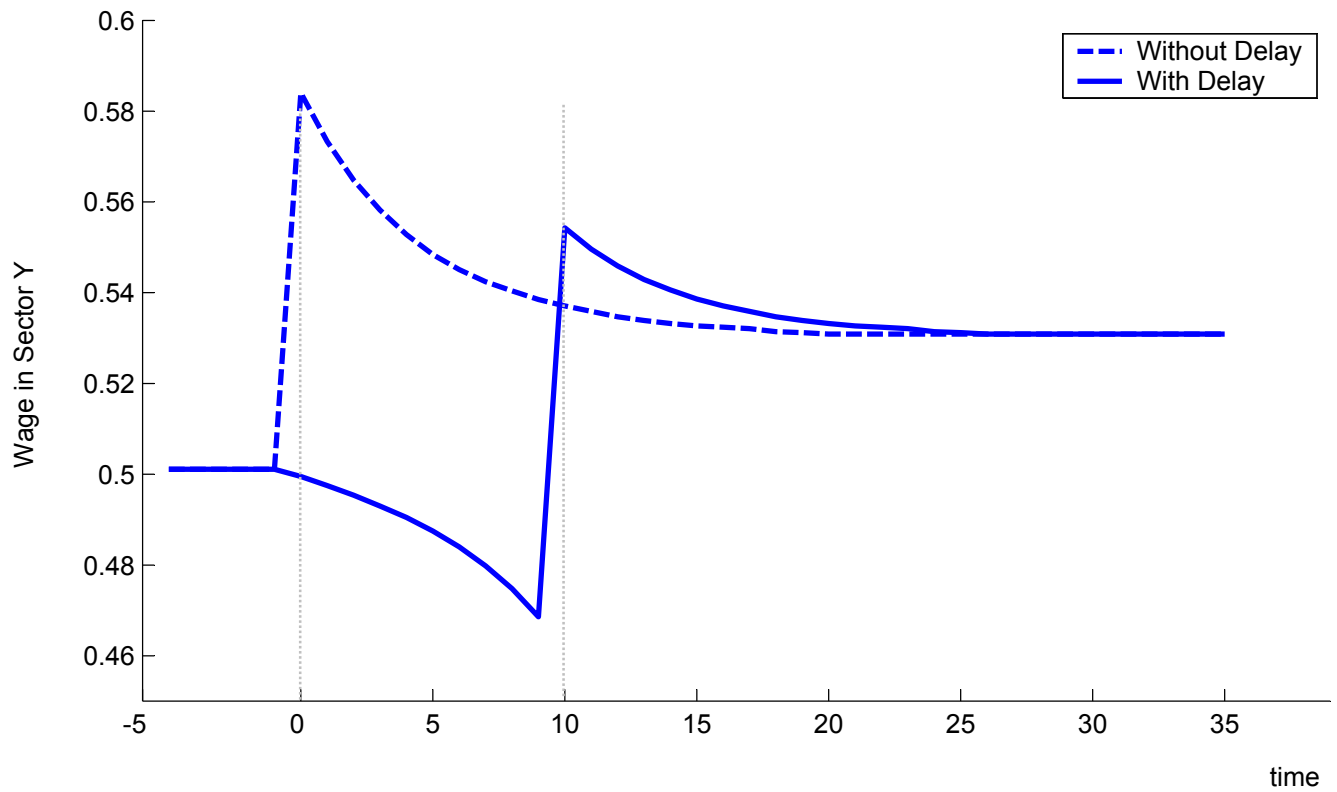


Parameters:

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$P_x^{\text{autarcy}} = 1$ $P_x^{\text{free_trade}} = 0.7$ $P_y = 1$ $\beta = 0.97$

Figure 4: Wages of Export Sector Workers: Benchmark Case

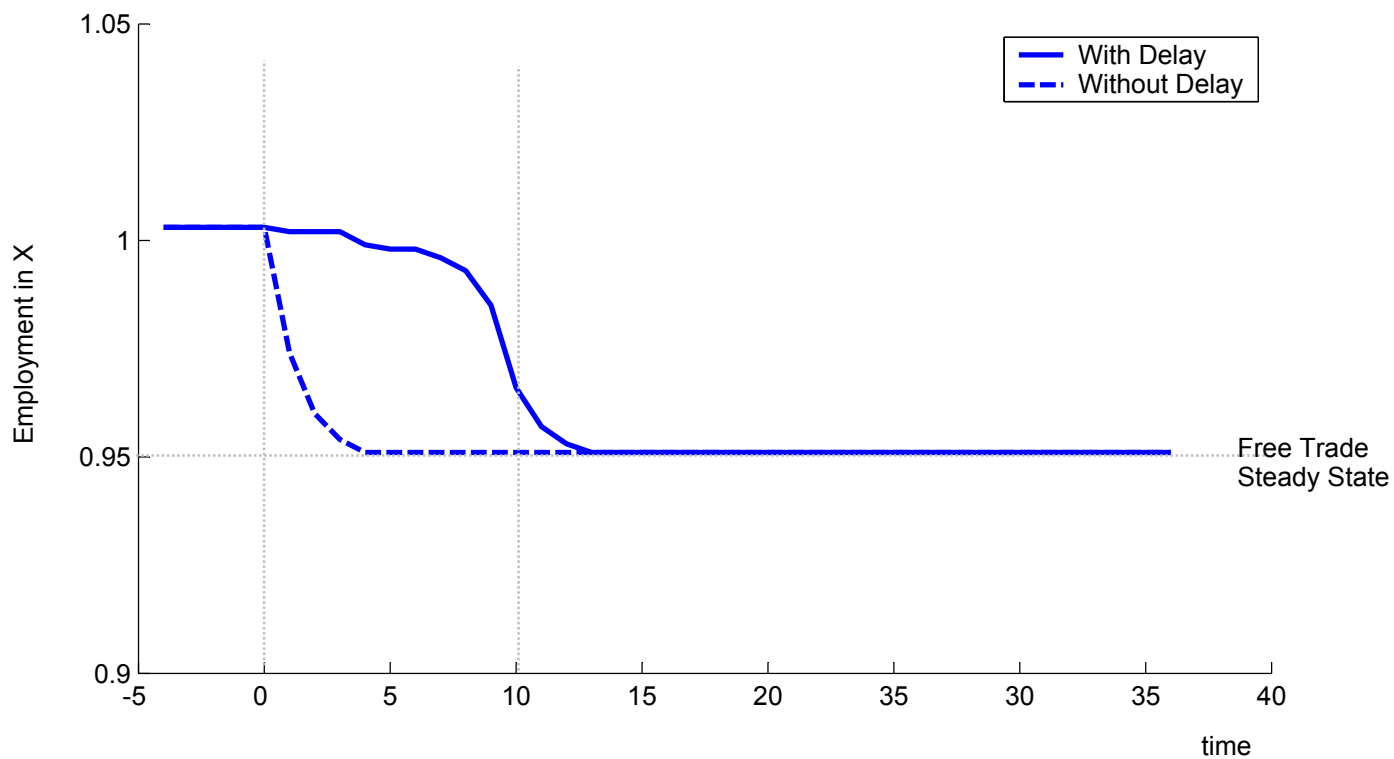


Parameters:

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$P_x^{\text{autarcy}}=1$ $P_x^{\text{free_trade}}=0.7$ $P_y=1$ $\beta=0.97$

Figure 5: Adjustment of Labor: High Variance Case

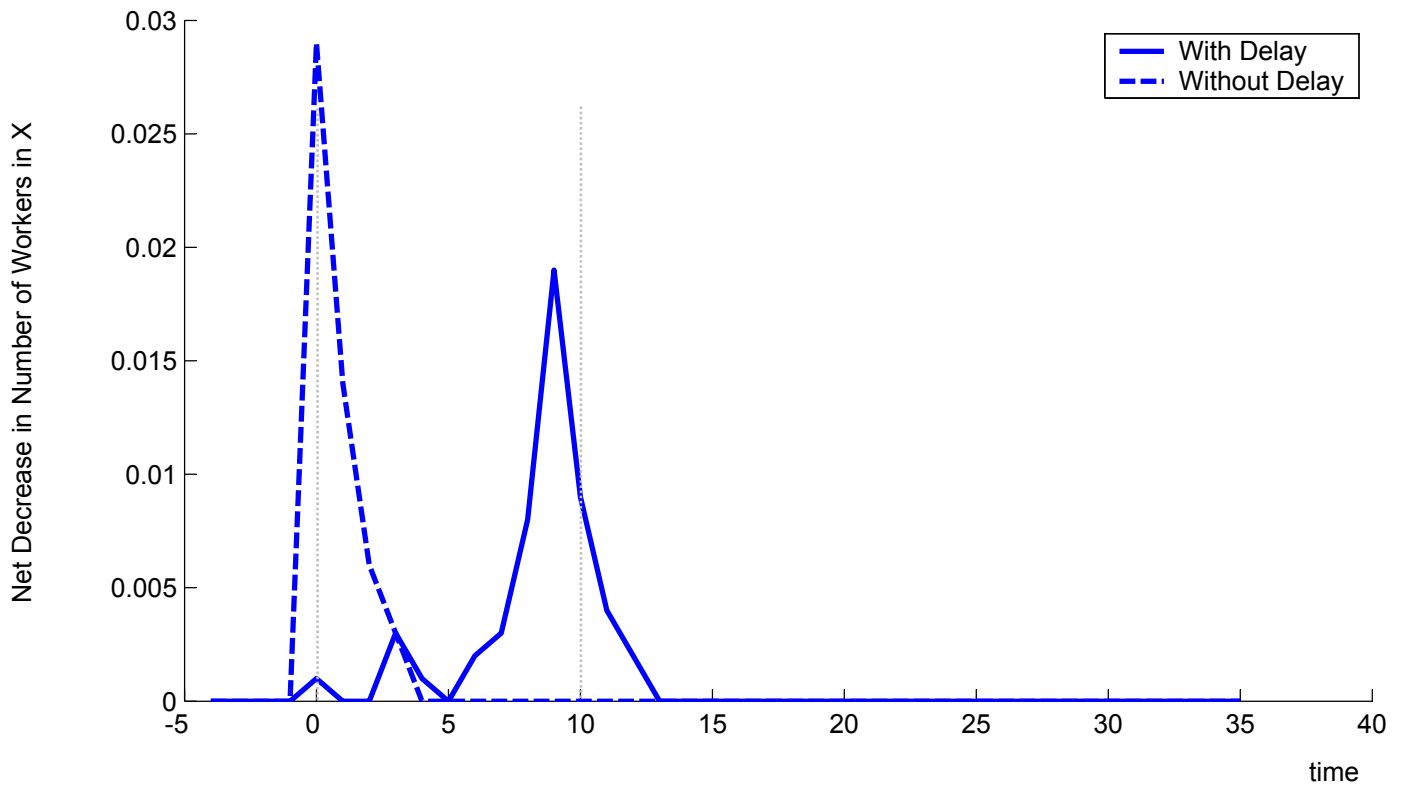


Parameters:

$$v = 3.95 \quad C = 4 \quad K_x = 1 \quad K_y = 1 \quad \sigma_x = 1 \quad \sigma_y = 1$$

$$P_x^{\text{autarcy}} = 1 \quad P_x^{\text{free_trade}} = 0.7 \quad P_y = 1 \quad \beta = 0.97$$

Figure 6: Net Flows Of Labor: High Variance Case

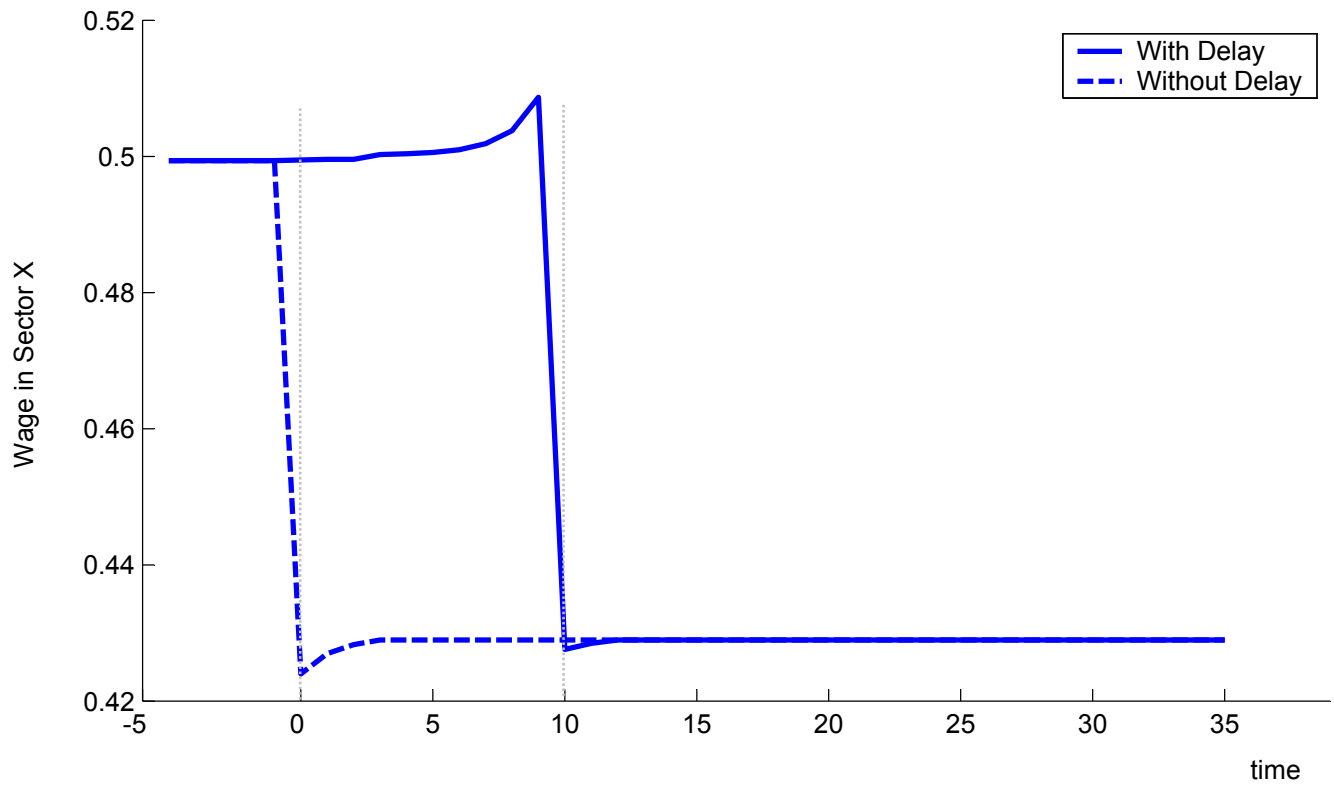


Parameters:

$v=3.95$ $C=4$ $K_x=1$ $K_y=1$ $\sigma_x=1$ $\sigma_y=1$

$P_x^{\text{autarcy}}=1$ $P_x^{\text{free_trade}}=0.7$ $P_y=1$ $\beta=0.97$

Figure 7: Wages of Import Competing Workers: High Variance Case

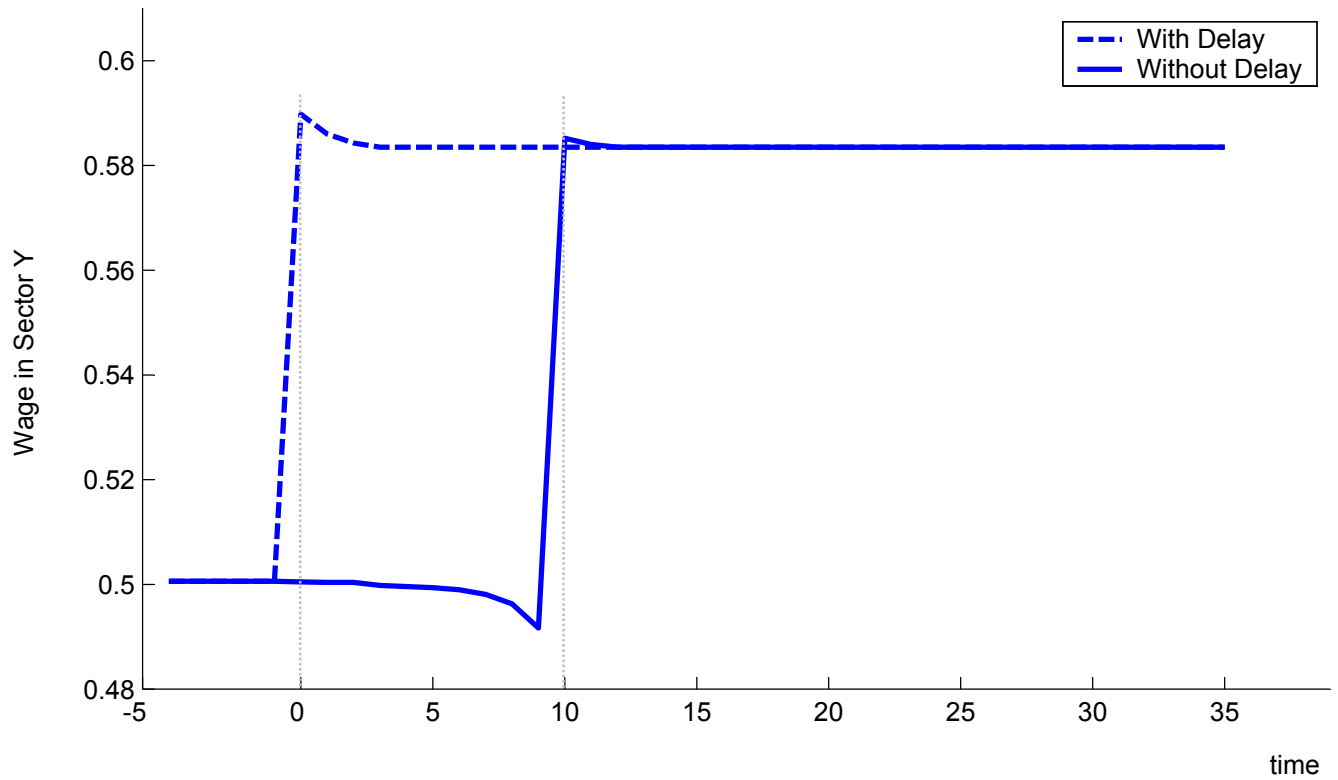


Parameters:

$$v = 3.95 \quad C = 4 \quad K_x = 1 \quad K_y = 1 \quad \sigma_x = 1 \quad \sigma_y = 1$$

$$P_x^{\text{autarcy}} = 1 \quad P_x^{\text{free_trade}} = 0.7 \quad P_y = 1 \quad \beta = 0.97$$

Figure 8: Wages of Export Sector Workers: High Variance Case

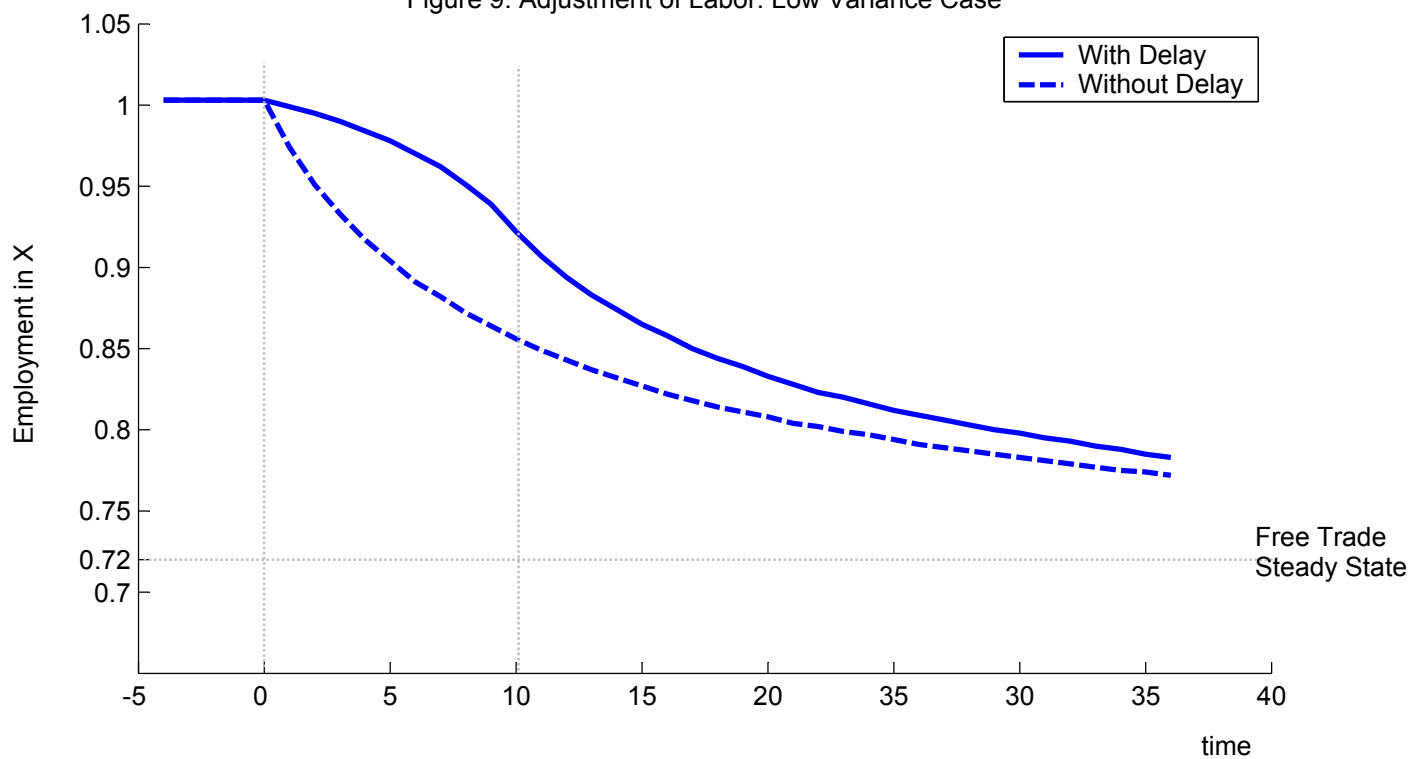


Parameters:

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$P_x^{\text{autarcy}}=1$ $P_x^{\text{free_trade}}=0.7$ $P_y=1$ $\beta=0.97$

Figure 9: Adjustment of Labor: Low Variance Case

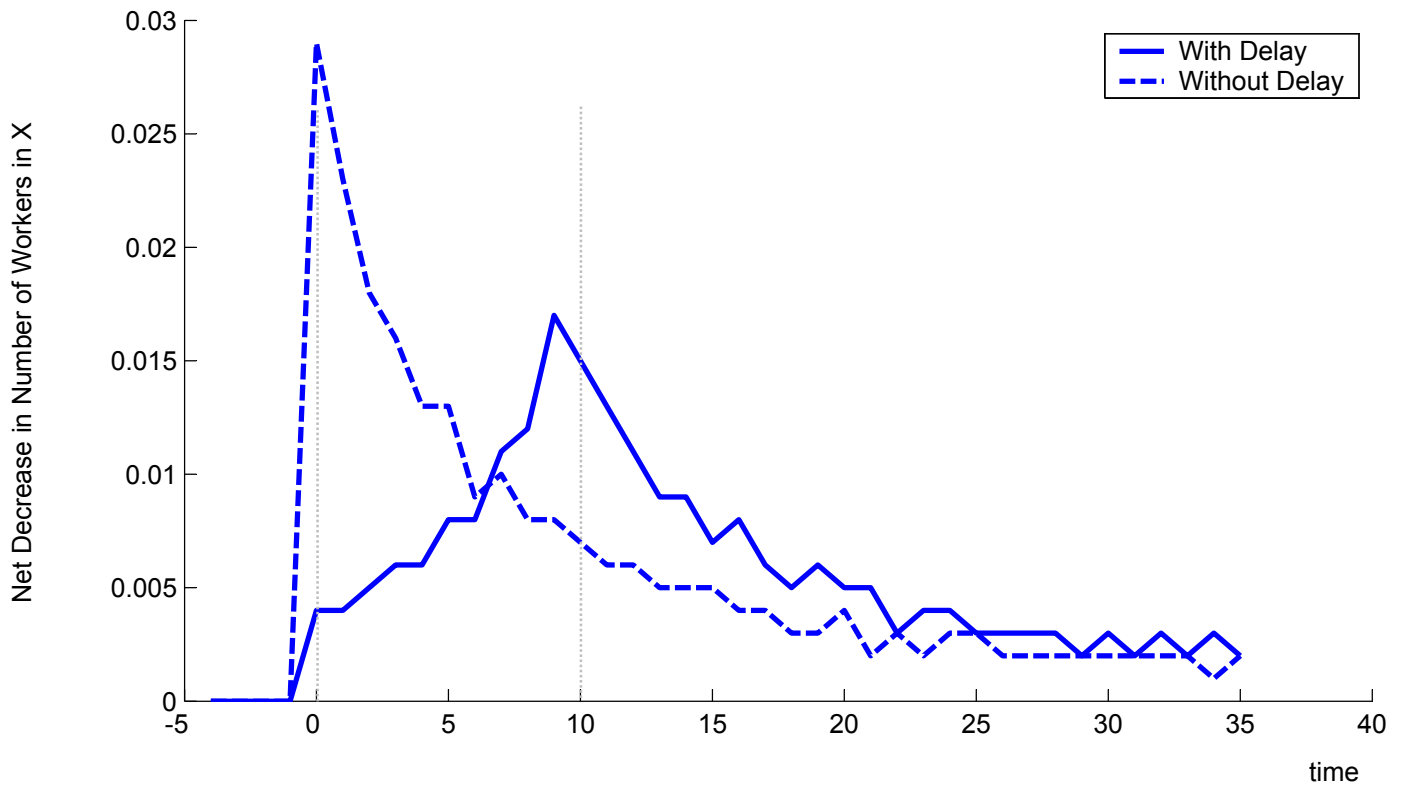


Parameters:

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$P_x^{\text{autarcy}} = 1$ $P_x^{\text{free_trade}} = 0.7$ $P_y = 1$ $\beta = 0.97$

Figure 10: Net Flows Of Labor: Low Variance Case

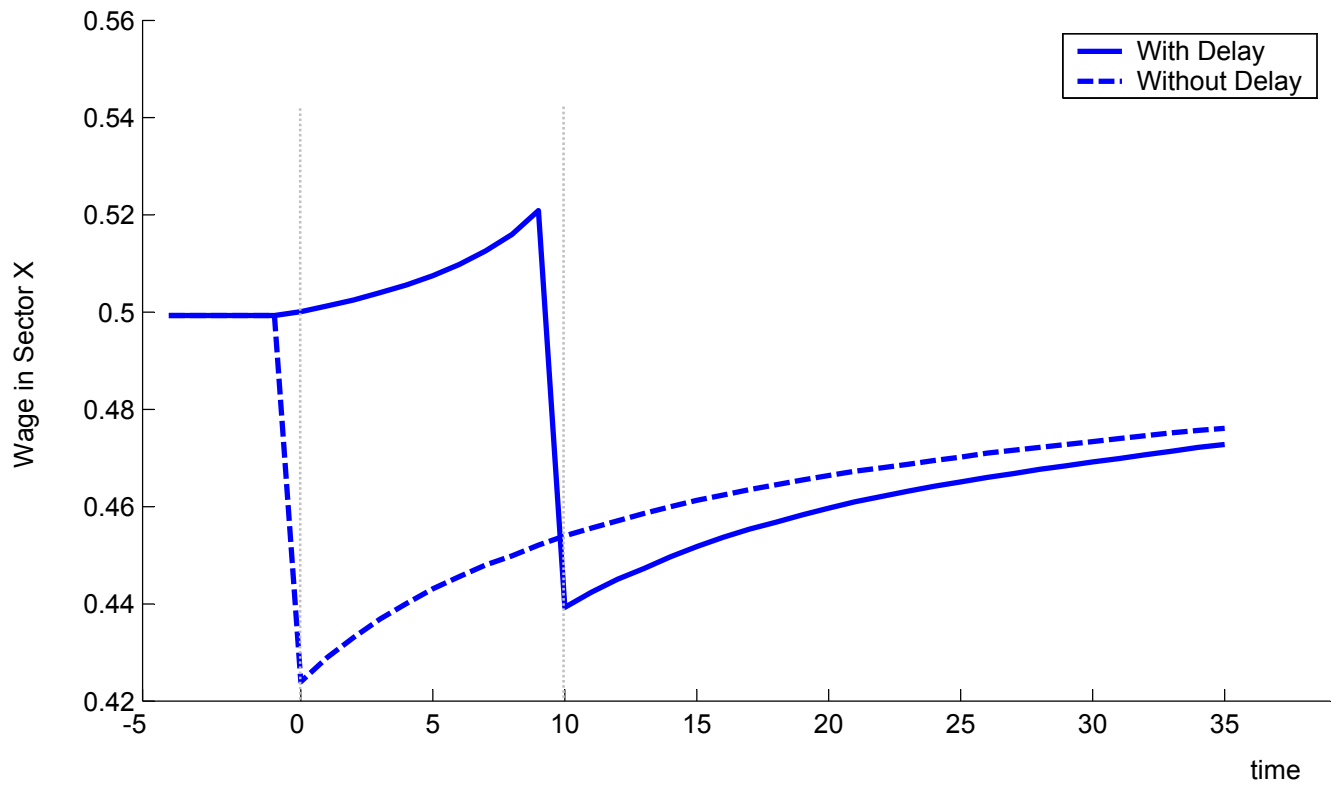


Parameters:

$v = 0.395$ $C = 4$ $K_x = 1$ $K_y = 1$ $\sigma_x = 1$ $\sigma_y = 1$

$P_x^{\text{autarcy}} = 1$ $P_x^{\text{free_trade}} = 0.7$ $P_y = 1$ $\beta = 0.97$

Figure 11: Wages of Import Competing Workers: Low Variance Case

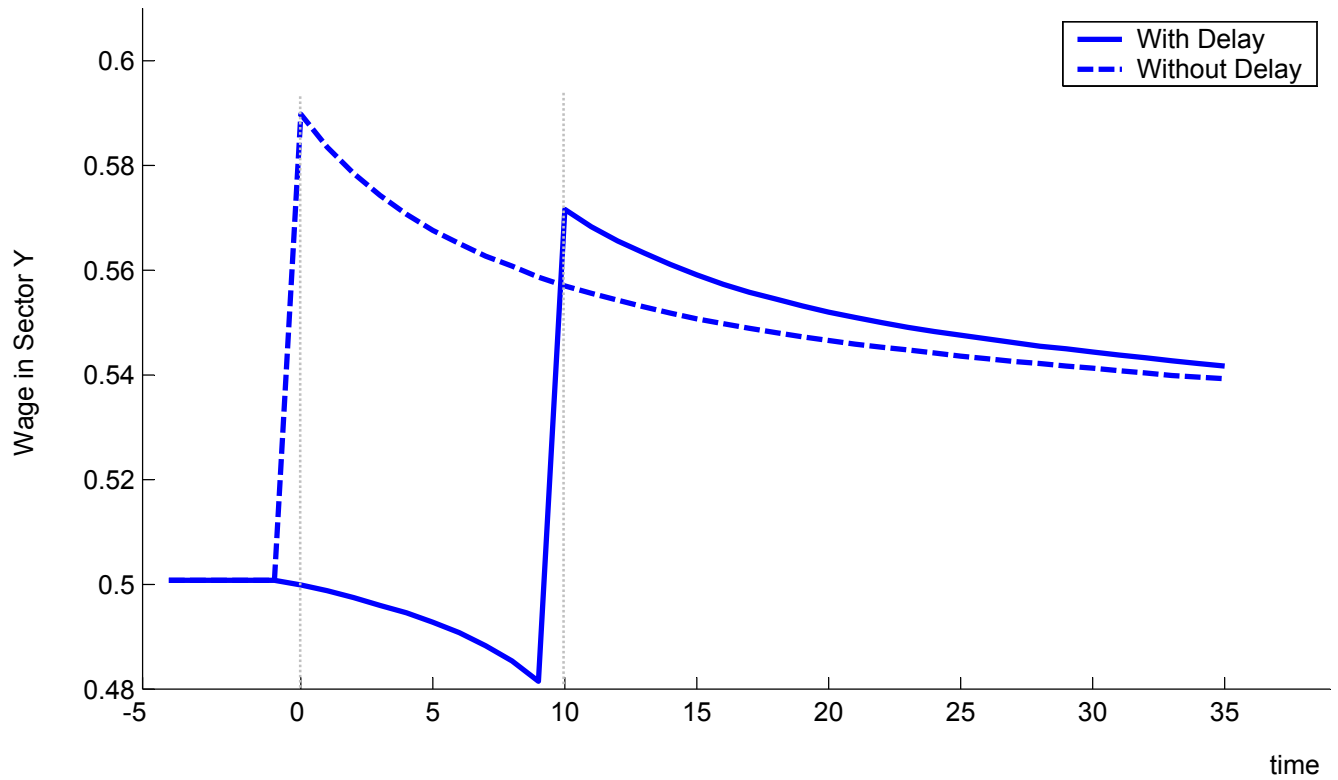


Parameters:

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Figure 12: Wages of Export Sector Workers: Low Variance Case

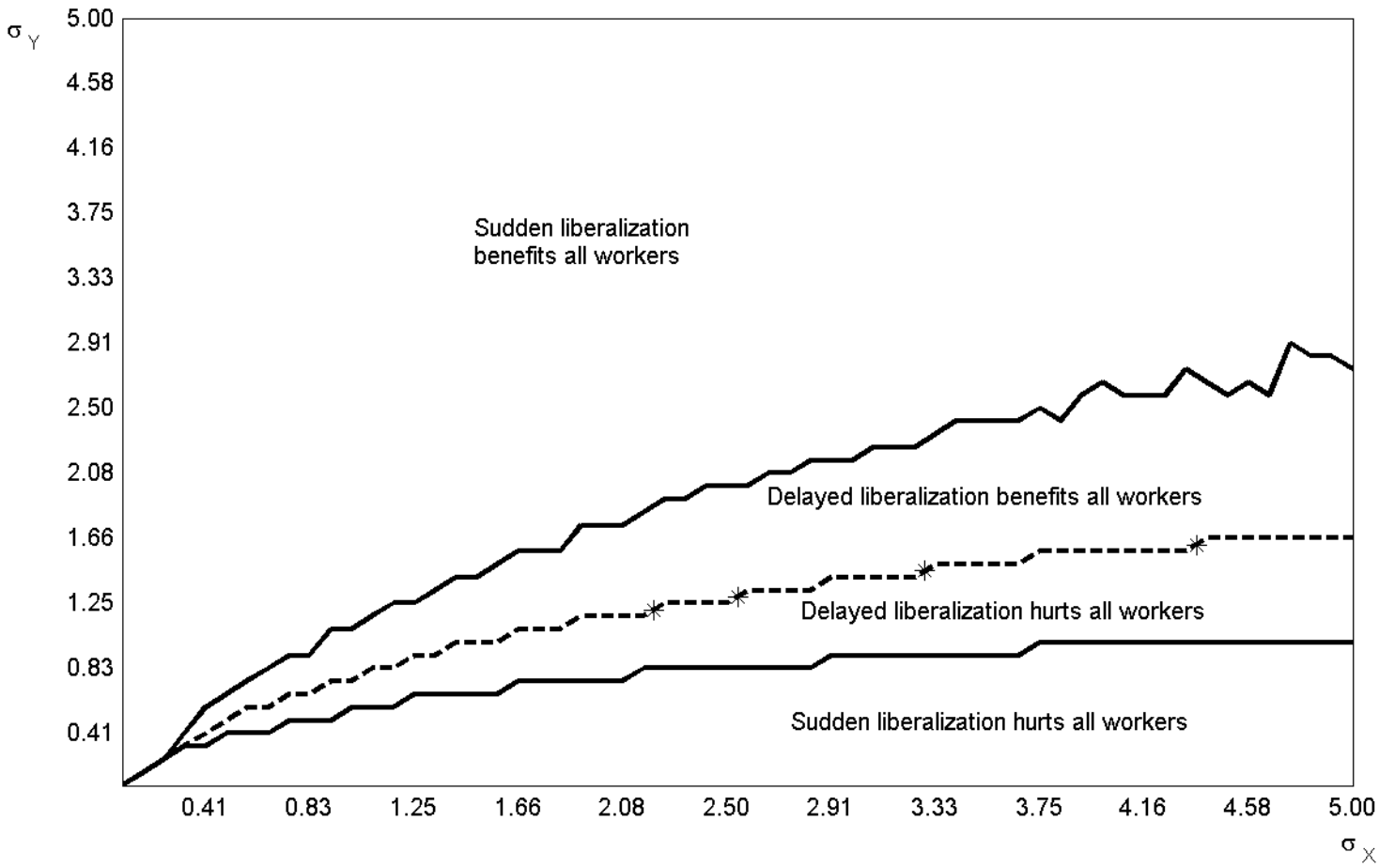


Parameters:

$v = 0.395$ $C = 4$ $K_x = 1$ $K_y = 1$ $\sigma_x = 1$ $\sigma_y = 1$

$P_x^{\text{autarcy}} = 1$ $P_x^{\text{free_trade}} = 0.7$ $P_y = 1$ $\beta = 0.97$

Figure 13: Delay and Worker Unity



* Points for which unanimity was not reached with 30 periods of delay

Figure 14: Length Of Delay Required For Unanimity

