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Some Simple Analytics of Trade and Labor Mobility

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Abstract

This paper studies a simple, tractable model of labor adjustment in a trade model that allows researchers to analyze the economy's dynamic response to trade liberalization. Since it is a neoclassical market-clearing model, duality techniques can be employed to study the equilibrium and, despite its simplicity, a rich variety of properties emerge. The model generates gross flows of labor across industries, even in the steady state; persistent wage differentials across industries; gradual adjustment to a liberalization; and anticipatory adjustment to a pre-announced liberalization. Pre-announcement induces anticipatory flight from the liberalizing sector, driving up wages there temporarily and giving workers remaining there what this paper calls "anticipation rents." By this process, pre-announcement makes liberalization less attractive to export-sector workers and more attractive to import-sector workers, eventually making workers unanimous either in favor of or in opposition to liberalization. Based on these results, the paper identifies many pitfalls to conventional methods of empirical study of trade liberalization that are based on static models.

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Some Simple Analytics of Trade and Labor Mobility[1]

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1 Introduction

This paper presents a model of labor mobility incorporated into a simple trade model. The goal is to provide a general-equilibrium framework that is rich enough to capture the main empirical features of labor mobility in practice and yet simple enough to be tractable with the tools of analysis familiar to trade economists. We thus hope that this framework can become a useful part of a trade economist's toolkit.

All aspects of an economy's response to trade policy, and particularly the distributional aspects, depend crucially on how labor adjusts, and the costs workers face in doing so (see Davidson and Matusz (2009), Harrison and McMillan (2007), Slaughter (1998), and Magee (1989) for extensive discussions of this point from different angles). However, with important exceptions discussed below, for the most part trade theory has avoided realistic modelling of labor mobility, assuming either frictionless mobility or complete immobility. Moreover, most of the few existing theoretical treatments of labor mobility are hard to reconcile with key empirical features of labor mobility, in particular with the evidence on gross flows. Here, we set up a model that takes on these questions head on.

One can identify three ways in which trade theorists have handled labor adjustment in trade models. First is the traditional static approach used as a benchmark by many trade economists, which uses a model with 'specific factors,' factors that cannot adjust at all, for analysis of the short run, but a model with frictionless adjustment for analysis of the long run. Mussa (1974), for example, uses the 'Ricardo-Viner' model for the short run, which features instantaneous adjustment for labor but no adjustment for any other factors, and the Heckscher-Ohlin model, which assumes no mobility costs for any factor, for the long-run. Of course, this approach offers no insight into dynamics, and assumes away mobility costs for workers.

Second are explicitly dynamic models with only net flows, such as Mussa's (1978) seminal model of intersectoral capital adjustment, in which adjustment is gradual because of convex adjustment costs for capital. A similar approach has sometimes been adopted for labor, by stipulating convex retraining costs, as in Karp and Paul (1994) and Dehejia (1997). A feature of these models is that marginal adjustment costs are assumed to be zero when net movements of labor are zero, and so the long-run steady state is the same as in a model with no adjustment costs (as in Heckscher-Ohlin). Dixit and Rob (1994) present a model with a constant cost to switching sectors, equal for all workers, in a stochastic environment. Feenstra and Lewis (1994) use a one-period model of worker adjustment to study compensation policies. Matsuyama (1992) models intergenerational labor adjustment.

All of the above papers have the property that all workers who switch sectors move in the same direction: Gross flows always equal net flows. This is a problem, since empirically gross flows of labor tend to be an order of magnitude larger than net flows (see Artuc, Chaudhuri and McLaren (2010), or Jovanovic and Moffitt(1990), Table 1). The third approach meets this difficulty by adopting search models of labor reallocation. Hosios (1990), Davidson, Martin and Matusz (1999), and Davidson and Matusz (2004) explore different aspects of this type of model, in which reallocation in response to liberalization is gradual because it takes time for workers to find jobs in the expanding sector. The pioneering paper by Lucas and Prescott (1974) fits into this category as well, but it is not useful for analyzing adjustment to trade policy because it is a steady-state analysis only, and the model is restricted to have a large number of industries, each of which is small so that a shock to any one industry would have a negligible effect on the economy. Helpman and Itskhoki (2007) and Helpman and Itskhoki and Redding (2010) use search frameworks in trade models in a one-period setting, and Itskhoki and Helpman (2014) in a dynamic setting. The rich implications of the search approach as applied to trade are explored exhaustively in Davidson and Matusz (2009). The search approach is complementary to the approach of this paper, which is much more amenable to analysis of transition paths but does not allow for unemployment.

What we do in this paper is to develop a perfect-foresight *neoclassical* model of labor adjustment within a simple trade model, which does generate gross flows in excess of net flows, as the search models do, but does so through idiosyncratic shocks to workers' mobility costs rather than through search. This has the advantage that it allows us to use the powerful tools of duality theory, well known in trade theory, to derive a wide variety of analytical results not only about the steady state but also about the whole transition path. This latter point is important for the potential usefulness of this approach: *In order for a model to be* *really useful in analyzing a trade shock*, it must allow us to analyze the welfare effects along the whole transition path – including (i) announcement effects, (ii) impact effects, (iii) the path to the new steady state, and (iv) changes to the steady state. Our approach achieves this.

We thus combine a desirable feature of the neoclassical models (duality) with a desirable property of the search models (gross flows).

This is a simplified and more tractable version of a more general model presented in Cameron, Chaudhuri and McLaren (2007). The general version is stochastic, can accommodate any number of industries and geographic regions within the country under study, and has the virtue that its main parameters can be econometrically estimated, as described in that paper. Here, we focus on the implications of the model for trade theory in a simple two-sector special case with one type of labor, which is simple and intuitive to use, allowing us to derive *analytic results* for effects of trade shocks on *lifetime welfare* taking into account the full transition path to the steady state. A companion paper (Artuç, Chaudhuri and McLaren (2008)) study the model through numerical simulations. Finally, Artuç, Chaudhuri and McLaren (2010) estimate the structural parameters of the model on US data and simulate the adjustment process, while Artuç and McLaren (2010, 2012) do the same for Turkish data and for sectoral as well as occupational mobility, respectively.

The main results from this paper are:

(i) Gross flows of labor always exceed net flows, so there are always workers moving across sectors, even in the steady state.

(ii) Equilibrium is unique, and there is no hysteresis, despite the presence of an unavoidable fixed cost to switching sectors.

(iii) Wage differentials persist across locations or sectors even in the long run, despite the fact that there are always some workers changing sectors. In particular, cancellation of a sector's tariff protection leads not only to a short-run drop in that sector's wage relative to the other sector, but also to a (smaller but still positive) drop in its relative wage in the long run. Thus, *a frictionless model is not a good predictor for the steady state behavior of the model*.

(iv) This last point remains true even if moving costs for workers are zero on average.

(v) The economy adjusts only gradually to changes in policy. This is consistent with findings by Topel (1986), Blanchard & Katz (1992), and others. This complicates empirical work on trade and wages, however, because changes in wages and labor allocation will continue long after the change in policy has occurred.

(vi) The economy begins to adjust to a policy change as soon as it is anticipated. This complicates empirical work even more, because it means that adjustment begins *before* the policy change takes effect, and in fact changes in wages can reverse their direction when the policy change actually is executed.

(vii) The incidence of trade policy needs to be analyzed on the basis of lifetime utility, taking worker mobility and option value into account, and not simply on the basis of wage levels. We show how to do this. The correction is important: It is theoretically possible, for example, for a policy change to lower real wages in a sector both in the short run and in the long run, and yet for the workers in the sector to be better off as a result of it, because it raises those workers' option value. This is far from being only a theoretical possibility, as Artuç, Chaudhuri and McLaren (2010) show using US worker data.

(viii) Announcing a trade liberalization in advance tends to reduce the difference between its effect on export-sector workers and its effect on import-competing workers. This is because it causes workers to begin to leave the liberalizing sector in advance, pushing up wages for those who remain, and pushing down wages for workers in the export sector. We say that this process confers 'anticipation rents' on workers in the liberalizing sector. We show that this leads to worker unanimity in the limit, meaning that all workers agree on the desirability of the liberalization if it is announced far enough in advance.[2] However, it is

[2]Note that there are three separate reasons that delayed liberalization attenuates losses for import-competing workers. The first and least interesting is simply that if losses from liberalization are postponed, with time discounting the effect on present value of utility will be diminished. This will of course not change the *sign* of the effect on those workers' welfare, but the other two reasons can. The second reason is that postponement can give a worker a chance to time her switch to another sector optimally before the change takes place, lowering adjustment costs; this is a benefit that results only in a model such as ours, where time-varying idiosyncratic shocks create option value for workers' reallocation decisions. The third, the anticipation rent, is a much more subtle effect that results from general-equilibrium forces. We offer empirical evidence for such rents in Section 6.

crucial to note that this can have the effect in the limit of making all workers *beneficiaries* of trade liberalization or of making them all *net losers* from it. Thus, the common presumption that a phased-in liberalization helps to cushion the blow to affected workers can be exactly wrong in some cases. We offer a simple condition that determines which way it will go.

Note that the dynamics of wages described in our model present a problem for empirical work. Many studies have used reduced-form regressions to study the effect of trade shocks on wages, either across industries (Revenga, 1992), across locations within a country (Kovak, 2013), or both (Hakobyan and McLaren, 2010). An implication of a dynamic model such as ours is that such regressions should be interpreted as measuring the effect of a trade shock on the wage at one point along its evolution to the new steady state, and of course the steady-state effect can be very different from the short-run effect (and as our model makes clear, can even be of the opposite sign).[3] The hazards that these properties present for empirical work are eliminated if one estimates the structural parameters of a dynamic model and uses it as the basis for policy simulations. That is the approach taken in Artuç, Chaudhuri and McLaren (2010) and Artuç and McLaren (2012) on US data; Dix-Carneiro (2014) on Brazilian data; Artuç and McLaren (2010) on Turkish data; and Artuç, Lederman and Porto (2014) on multiple countries' data.

At the same time, our approach can offer an important piece of assistance to empirical work: In equilibrium, any change that raises the welfare of workers in one location or industry relative to another will result in a rise in flows of workers toward that location or industry, and a reduction of workers in the opposite direction. This can provide a simple but powerful way of looking for welfare effects in a reduced-form study. For example, Kovak (2013) finds that Brazilian workers tend to move out of a state that receives tariff reductions on its major industries, and Hakobyan and McLaren (2010) find an analogous result for US blue-collar workers in response to NAFTA tariff cuts. These can be taken as *prima facie* evidence that welfare for workers in those locations was reduced relative to other locations.[4]

[3] Another problem for reduced-form studies is that a change in tariff in one industry will affect the wages in all industries. This is generally not accounted for in reduced-form regressions.

[4] Although this is an inference about welfare in one industry or location *relative* to another, at times it can be used to make a case for an absolute welfare change. Hakobyan and McLaren (2010) cite evidence in the literature that the aggregate welfare effects of NAFTA were negligible; given this, the evident large

The anticipatory effects the model generates resemble the dynamic adjustment observed in a number of real-life episodes of trade shocks. Section 6 presents a range of evidence from a variety of sources including from data on the end of the Multifibre Arrangement that can be interpreted quite naturally with the story in the model.

Plan of the paper: The following section lays out the basic model. Then Section 3 presents results on the steady state of the model, and the following section presents results on dynamic adjustment. Section 5 discusses the incidence of policy changes in the model, taking lifetime utility into account, and analyzes the effect of pre-announcement of liberalization on the distribution of gains and losses. Section 6 discusses empirical support for the model. A final section summarizes.

2 The Basic Model

There are two sectors, X and Y, each with a large number of competitive employers, who combine a sector-specific fixed (latent) factor with labor for production. The two sectors may be located in two separate regions and may require different skills, making it costly for workers to move between them. Without any costs of moving between sectors, and without any idiosyncratic shocks to workers, the economy would be a Ricardo-Viner model (Jones, 1971). We shall see that its equilibrium is very different from that model, both in its dynamic character and in its steady state.

The economy's workers form a continuum of measure L.

2.1 Production

The quantity of aggregate output in sector i in period t is given by:

$$q_t^i = Q^i(L_t^i),$$

negative effect on relative welfare of certain classes of worker can be taken as evidence that their welfare fell in absolute terms.

where L_t^i denotes labor used in sector i in period t and we suppress the fixed factor in each industry to simplify notation. Assume that $Q^i(\cdot)$ is increasing, continuously differentiable, and strictly concave.

The domestic price of good i, p^i, is treated as exogenous. A central example, which will be treated explicitly, is of a small open economy in which the domestic price is equal to the given world price plus a tariff (export subsidy) for a good that is imported (exported). For now, we will assume that domestic goods prices are constant over time, but later we will extend the analysis to the case of an unanticipated or anticipated change due to a trade liberalization. Cameron, Chaudhuri and McLaren (2007) and Artuç, Chaudhuri and McLaren (2010) allow for the more general case of a stochastic process for domestic prices.

The wage in sector i at date t is competitively determined:

$$\widetilde{w}_t^i = p^i \frac{\partial Q^i(L_t^i)}{\partial L_t^i},$$

where $\widetilde{w}_t^i$ denotes the nominal wage paid by sector i at date t and p^i denotes the domestic price of good i. Thus, the competitive employers in each sector each take the wage as given and maximize profit; the wage adjusts so that this wage just clears the spot labor market in that sector.

2.2 Labor Mobility

A worker θ who is in industry i at the end of period t receives a non-pecuniary benefit $\varepsilon_{\theta,t}^i$. This can be thought of as enjoyment of the work or of living in the region where industry i is located, for example. We assume that the $\varepsilon_{\theta,t}^i$ are independently and identically distributed across workers and sectors and over time, with cdf $F(\cdot)$, pdf $f(\cdot)$, and full support:

$$f(\varepsilon) > 0 \forall \varepsilon \in \Re,$$

and mean zero:

$$E(\varepsilon) = \int \varepsilon f(\varepsilon) d\varepsilon = 0.$$

The cost to a worker θ, who was in i during period t, of moving from i to $j \neq i$ at the end of t is, then:

$$\varepsilon^i_{\theta,t} - \varepsilon^j_{\theta,t} + C,$$

where $C \geq 0$ is the deterministic component of mobility costs, common to all workers (such as retraining or relocation costs, or psychic costs of moving to a new occupation). The variable $\varepsilon^i_{\theta,t} - \varepsilon^j_{\theta,t}$ is the idiosyncratic component of moving costs, which can be negative as easily as it can be positive. For example, a worker may be bored with her current job and long for a change in career ($\varepsilon^i_{\theta,t} - \varepsilon^j_{\theta,t} < 0$), and a worker with a child in the final year of high school may have a non-pecuniary reason to stay in the current location rather than move, as might be necessary to change jobs ($\varepsilon^i_{\theta,t} - \varepsilon^j_{\theta,t} > 0$).

Further, we make the boundedness assumption:

$$E(\max\{\varepsilon^X, \varepsilon^Y\}) = 2\int \varepsilon f(\varepsilon)F(\varepsilon)d\varepsilon < \infty.$$

This ensures that the worker's problem is meaningful; if it was violated, the worker could ensure infinite utility simply by choosing the sector with the higher value of ε in each period.

Since what is important for workers' decisions is the difference between ε^i and ε^j, we can simplify notation by defining:

$$\mu^i_{\theta,t} = \varepsilon^i_{\theta,t} - \varepsilon^j_{\theta,t},$$

for a worker currently in sector i, where $\mu^i_{\theta,t}$ is symmetrically distributed around mean zero, with cdf $G(\cdot)$ and pdf $g(\cdot)$ derived from $F(\cdot)$ and $f(\cdot)$.

The transition equations governing the allocation of labor are:

$$m^{ii}_t L^i_t + m^{ji}_t L^j_t = L^i_{t+1} \qquad i = X, Y \; ; \; j \neq i,$$

where m^{ji}_t denotes the fraction of labor force in j at the beginning of t that moves to i by the end of t, or in other words, the gross flow from j to i.

The timing of events can be summarized thus:

$$
\begin{array}{ccccccccc}
 & & & & \varepsilon^X_{\theta,t}, \varepsilon^Y_{\theta,t} & & & & \\
 & & & & \downarrow & & & & \\
 & L^X_t & \longrightarrow & w^X_t & \longrightarrow & m^{XX}_t, m^{XY}_t & & L^X_{t+1} \\
\overset{t\mapsto}{\Longrightarrow} & & & & & & \overset{t+1\mapsto}{\Longrightarrow} & \\
 & L^Y_t & \longrightarrow & w^Y_t & \longrightarrow & m^{YY}_t, m^{YX}_t & & L^Y_{t+1}
\end{array}
$$

The stock of workers in each sector in each period is determined by events in the previous period. The current labor allocations together with current product prices determines wages through spot labor-market clearing. Then each worker learns her ε's and decides whether to remain in her current sector or move. In the aggregate, these decisions determine the following period's labor allocation.

2.3 Preferences and Expectations

All agents are risk neutral, have rational expectations and have a common discount factor $\beta < 1$. Further, all workers have identical and homothetic prferences, which allows us to identify a common cost-of-living index. Letting good X be the numeraire, let the cost-of-living index be denoted $\phi(p^Y)$, an increasing function that has an elasticity (by Shepherd's lemma) equal to good Y's share in consumption. Thus, the real wage w^i_t received by a worker in sector i at date t is given by:

$$
\begin{aligned}
w^X_t(L^X_t, p^Y) &\equiv \widetilde{w}^X_t/\phi(p^Y) = \frac{1}{\phi(p^Y)}\frac{\partial Q^X(L^X_t)}{\partial L^X_t} \\
w^Y_t(L^Y_t, p^Y) &\equiv \widetilde{w}^Y_t/\phi(p^Y) = \frac{p^Y}{\phi(p^Y)}\frac{\partial Q^Y(L^Y_t)}{\partial L^Y_t}.
\end{aligned} \tag{1}
$$

Note that an increase in p^Y will shift w^X_t down as a function of L^X_t and shift w^Y_t up as a function of L^Y_t.

Each worker makes a location decision in each period to maximize the expected present discounted value of real wage income, net of common (C) and idiosyncratic (μ) moving costs. (Henceforth we will drop the worker-specific subscript θ, recalling always that the ε_t and μ_t terms are worker-specific variables.) Let $u^i(L_t, \varepsilon_t)$ denote the (maximized) value to a worker of being in i given $L_t = (L_t^X, L_t^Y)$ and idiosyncratic shocks $\varepsilon_t = (\varepsilon_t^X, \varepsilon_t^Y)$ realized by the worker. Then $v^i(L_t) \equiv E_\varepsilon(u^i(L_t, \varepsilon_t))$ gives the expected value of u^i before idiosyncratic shocks are realized, but conditional on (L_t).

Since the worker is optimizing, $u^i(L_t, \varepsilon_t)$ can be written:

$$
\begin{aligned}
u^i(L_t, \varepsilon_t) &= w_t^i + \max\{\varepsilon_t^i + \beta E_t v^i(L_{t+1}), \varepsilon_t^j - C + \beta E_t v^j(L_{t+1})\} \\
&= w_t^i + \beta E_t v^i(L_{t+1}) + \varepsilon_t^i + \max\{0, \overline{\mu}_t^i - \mu_t^i\},
\end{aligned}
$$

where

$$
\overline{\mu}_t^i = \beta[E_t v^j(L_{t+1}) - E_t v^i(L_{t+1})] - C, \tag{2}
$$

and $i \neq j$. The expression $\overline{\mu}_t^i$ is the common value of the net benefit of moving from i to j. If this is greater than the idiosyncratic cost μ, the worker will move; otherwise, the worker will stay.

Taking expectations with respect to the ε's (and hence the μ's):

$$
v^i(L_t) = w_t^i + \beta E_t v^i(L_{t+1}) + \Omega(\overline{\mu}_t^i), \tag{3}
$$

where:

$$
\Omega(\overline{\mu}) = E_\mu \max\{0, \overline{\mu} - \mu\} = G(\overline{\mu})\overline{\mu} - \int_{-\infty}^{\overline{\mu}} \mu dG(\mu). \tag{4}
$$

In other words, the value, v^i, of being in i is the sum of: (i) the wage, w_t^i, that is received; (ii) the base value, $\beta E_t v^i(L_{t+1})$, of staying on in i; and (iii) the additional value, $\Omega(\overline{\mu}_t^i)$, of having the option to move. The expression $\Omega(\overline{\mu}_t^i)$ is thus interpreted as representing option value.

2.4 Key Equilibrium Conditions

An equilibrium is a moving rule characterized by a value of $(\overline{\mu}_t^X, \overline{\mu}_t^Y)$ each period (where a worker in i moves if and only if $\mu < \overline{\mu}_t^i$), such that the aggregate movements of workers induced by that rule generate a time path for wages in each sector that make the proposed moving rule optimal. Here we derive a key equation that is useful in characterizing equilibrium.

From (2), together with (3) applied to period $t+1$, we know that

$$C + \overline{\mu}_t^i = \beta E_t \left([w_{t+1}^j - w_{t+1}^i] + \beta E_{t+1}(v_{t+2}^j - v_{t+2}^i) \right.$$
$$\left. + \, \Omega(\overline{\mu}_{t+1}^j) - \Omega(\overline{\mu}_{t+1}^i) \right),$$

but using (2) applied to period $t+1$, this becomes:

$$C + \overline{\mu}_t^i = \beta E_t \left([w_{t+1}^j - w_{t+1}^i] + C + \overline{\mu}_{t+1}^i \right.$$
$$\left. + \, \Omega(\overline{\mu}_{t+1}^j) - \Omega(\overline{\mu}_{t+1}^i) \right). \tag{5}$$

This is an important relationship for characterising the equilibrium behavior of the model. The interpretation is as follows. The cost of moving $(C + \overline{\mu}_t^i)$ for the marginal mover from i to j equals the expected future benefits of being in j instead of i at time $t+1$. This has three components: (i) the expected wage differential next period, $[w_{t+1}^j - w_{t+1}^i]$; (ii) the difference in expected continuation values, captured by the expected cost borne by the marginal mover from i to j at time $t+1$, $C + \overline{\mu}_{t+1}^i$; and (iii) the difference in option values associated with being in each sector, $\Omega(\overline{\mu}_{t+1}^j) - \Omega(\overline{\mu}_{t+1}^i)$.

Note that from (2), $\overline{\mu}^X$ and $\overline{\mu}^Y$ are related:

$$\overline{\mu}_t^X = -\overline{\mu}_t^Y - 2C.$$

Given this and the symmetry of the distribution of μ, the equilibrium reallocations of labor are given by the following relationships:

$$m_t^{ij} = G(\overline{\mu}_t^i) \quad ; \quad m_t^{ii} = G(-\overline{\mu}_t^i) \tag{6}$$
$$m_t^{ji} = G(\overline{\mu}_t^j) = G(-\overline{\mu}_t^i - 2C) \quad ; \quad m_t^{jj} = G(\overline{\mu}_t^i + 2C).$$

As a result, the intersectoral allocation of labor follows the following law of motion:

$$G(-\overline{\mu}_t^i)L_t^i + G(-\overline{\mu}_t^i - 2C)(L - L_t^i) = L_{t+1}^i. \tag{7}$$

3 Characteristics of the Steady State

Here we will derive properties of the steady state, deferring discussion of the path to the steady state until the next section.

In discussing steady states, we will naturally drop time subscripts. The steady-state level of L^X will be denoted $\overline{L}^X$. In addition, we will let $\overline{\mu}$ stand for the steady-state value of $\overline{\mu}^X$, and so the steady-state value of $\overline{\mu}^Y$ is given by $-\overline{\mu} - 2C$. Then $\overline{L}^X$ can be derived from (7) as a function of $\overline{\mu}$, and written $\overline{L}^X(\overline{\mu})$.

The first result is a uniqueness property:

Proposition 1. *There is a unique steady-state level of $\overline{\mu}$ and L^X.*

Proof. Because the $\overline{m}^{ij}$ and $\overline{L}^i$ derive uniquely from $\overline{\mu}$, it suffices to prove uniqueness of the threshold $\overline{\mu}$. The value of $\overline{\mu}$ is implicitly defined by the equilibrium condition, which comes directly from (5):

$$\overline{\mu} + C = \frac{\beta}{1-\beta}\left[w^Y(L - \overline{L}^X(\overline{\mu}); p^Y) - w^X(\overline{L}^X(\overline{\mu}); p^Y)\right] \tag{8}$$
$$+ \frac{\beta}{1-\beta}\left[\Omega(-\overline{\mu} - 2C) - \Omega(\overline{\mu})\right].$$

Since

$$\frac{\partial \Omega(\overline{\mu})}{\partial \overline{\mu}} = G(\overline{\mu})$$

and

$$\overline{L}^X = \frac{\overline{m}^{YX}}{\overline{m}^{YX} + \overline{m}^{XY}} L = \frac{G(-\overline{\mu} - 2C)}{G(-\overline{\mu} - 2C) + G(\overline{\mu})} L, \tag{9}$$

it is easily shown that the right-hand side of (8) is continuous and strictly decreasing in $\overline{\mu}$. Since the left-hand side is continuous and increasing on $\overline{\mu}$ on $(-\infty, \infty)$, there is a unique solution for $\overline{\mu}$.

This result demonstrates the striking difference that the idiosyncratic effects make for the behavior of the model. If there were only common moving costs ($C > 0$) with no idiosyncratic shocks ($\mu \equiv 0$), then there would be a range of steady states. Any allocation of labor such that $|w^X - w^Y| < C(1 - \beta)$ would then be a steady state, and this would be a non-degenerate interval of values of L^X.

These differences are illustrated in Figure 1, which is the standard Ricardo-Viner diagram adapted to our model. The length of the box is L, the downward-sloping curve is the marginal value product of labor in X, where the quantity L^X is measured from the left axis, and the upward-sloping curve is the marginal value product of labor in Y, where the quantity L^Y is measured from the right axis. All marginal products are deflated by the consumer price index $\phi(p^Y)$. The top panel shows the unique equilibrium for the Ricardo-Viner model, in which there are no moving costs at all. The equilibrium point is marked as $\overline{L}^X_{RV}$, where wages in the two industries are equalized. The middle panel shows the range of labor allocations for which it would be unprofitable for workers to move for a model with $C > 0$ but $\mu \equiv 0$, thus the range of steady states for a model with common, but not idiosyncratic, moving costs. Thus, in such a model, there would be hysteresis: The value of L^X at which the system comes to rest would be determined by the initial conditions.

The bottom panel shows the outcome for the present model with both common and idiosyncratic moving costs. In the present model with gross flows, every year a trickle of people moves from one cell to another, and this constant stirring of the pot eventually removes the effect of initial conditions, yielding a unique steady state.

A second result, concerning wage differentials, makes it clear that the frictionless model does not predict behavior in the steady state of the model.

Proposition 2. *In the steady state, the larger sector must have a higher wage:* $\overline{L}^X \lesseqgtr \overline{L}^Y \Rightarrow \overline{w}^X \lesseqgtr \overline{w}^Y$.

Proof. Suppose $\overline{L}^X < \overline{L}^Y$ but $\overline{w}^X \geqslant \overline{w}^Y$. Then:

$$\begin{aligned} \overline{m}^{YX} &< \overline{m}^{XY} \qquad \text{since } \overline{m}^{XY}\overline{L}^X = \overline{m}^{YX}\overline{L}^Y \text{ in steady state; so} \\ \overline{\mu}^X &> \overline{\mu}^Y \qquad \text{since } \overline{m}^{YX} = G(\overline{\mu}^Y) < G(\overline{\mu}^X) = \overline{m}^{XY}\text{; so} \\ \beta[\overline{v}^Y - \overline{v}^X] &> 0 \qquad \text{since } \overline{\mu}^X = \beta[\overline{v}^Y - \overline{v}^X] - C\text{; so} \\ \overline{v}^Y &> \overline{v}^X. \end{aligned}$$

But:

$$\begin{aligned} \overline{v}^X &= \frac{\overline{w}^X}{1-\beta} + \frac{1}{1-\beta}\Omega(\overline{\mu}^X) \\ &> \frac{\overline{w}^Y}{1-\beta} + \frac{1}{1-\beta}\Omega(\overline{\mu}^Y) \\ &= \overline{v}^Y \qquad \text{since } \Omega(\overline{\mu}) \text{ is increasing in } \overline{\mu}, \end{aligned}$$

which yields a contradiction.

Thus, we can say that *the long-run intersectoral elasticity of labor supply is finite.* Note that this implies persistent wage differentials, even in long-run equilibrium, and even though in each period some fraction of the workers in each sector move to the other. The point is that if a given sector is to be larger than the other in the steady state, it must have a lower rate of worker exit than the other sector does. In order for that to be the case, it must have a higher wage. Put differently, suppose for the sake of argument that X and Y had the same wage and $\overline{\mu}^X = \overline{\mu}^Y$ while $L^X > L^Y$. Then the rate of exit from each sector would be the same, so a larger group of X workers would arrive in Y each period than the group leaving Y. This would put downward pressure on the wage in Y, opening up a wage differential in favor of X, the larger sector.[5]

Note as well that this remains true even if $C = 0$, so that average moving costs are equal to zero. Idiosyncratic moving costs, sometimes positive and sometimes negative, are sufficient to ensure steady-state wage differentials.

There is also an unambiguous relationship between the steady state of this model and the Ricardo-Viner equilibrium (which, recall, is the equilibrium of the model with $C, \mu \equiv 0$). Specifically, the steady-state intersectoral allocation of workers always lies somewhere between the Ricardo-Viner model and equal division of workers between the sectors. To see this, first let the allocation of workers to the X sector in the Ricardo-Viner model, L^X_{RV}, be defined implicitly by:

$$w^X(L^X_{RV}, p^Y) = w^Y(L - L^X_{RV}, p^Y).$$

Proposition 3. *The following inequalties must hold in the steady state:*

$$\begin{aligned} L^X_{RV} < \frac{L}{2} &\Rightarrow L^X_{RV} < \overline{L}^X < \frac{L}{2} \\ L^X_{RV} = \frac{L}{2} &\Rightarrow L^X_{RV} = \overline{L}^X = \frac{L}{2} \\ L^X_{RV} > \frac{L}{2} &\Rightarrow L^X_{RV} > \overline{L}^X > \frac{L}{2} \end{aligned}$$

Proof. The result follows directly from the labor demand curves being downward sloping and Proposition 2. Suppose $L^X_{RV} > \frac{L}{2}$, which means the demand curves cross to the right of the midway point as shown in Figure 1. If $\overline{L}^X$ were, in contradiction to the claim, to lie to the right of L^X_{RV}, i.e., $\frac{L}{2} < L^X_{RV} < \overline{L}^X$, then $\overline{w}^X$ would have to be less than $\overline{w}^Y$. This follows from the definition of L^X_{RV} and the fact that the labor demand curves are downward sloping. (Look at the diagram.) But that would contradict the earlier result that the larger sector (in this case X) has to have the higher wage in steady state. We thus conclude that $\overline{L}^X < L^X_{RV}$; but this also implies that $\overline{w}^X > \overline{w}^Y$ (again, from the definition of L^X_{RV} and the fact that labor demand curves slope downward), so from the previous proposition, we must

[5] This result should be taken with caution when the model is brought to data. An industry could also have high wages because of harsh or dangerous conditions; a region could have high wages because of unpleasant living conditions. These reasons for compensating wage differentials are absent from this simple model, but are accounted for in Artuç and McLaren (2012), for example.

have $\frac{L}{2} < \overline{L}^X$.

An immediate implication is that, unlike a frictionless model, the equilibrium does not maximize national income, even at domestic prices, and even in the steady state. The reason is that each worker has non-pecuniary motives as well as pecuniary ones, and this has its effect on the aggregate allocation of labor. It is also clear that this is not an indication of market failure; workers *should* consider their non-pecuniary motives when making their decisions.

3.1 Steady State Impact of Policy Changes

Let us assume that sector Y is the import-competing sector, and that it is initially protected by a tariff that raises the domestic price above the world price. The following two results analyze what happens to steady-state labor allocations and wages as a result of a change in the tariff.

First, the steady-state impact on labor allocations goes in the same direction as in a model with no mobility costs. For concreteness, consider two models, model I (for 'initial') and model N (for 'new'), identical except that in model N the tariff, and hence p^Y, is lower than in model I. Denote the steady-state sector-X employment in the two models by $\overline{L}_I^X$ and $\overline{L}_N^X$ respectively, and denote the Ricardo-Viner equilibrium of the two models by $\widehat{L}_I^X$ and $\widehat{L}_N^X$ respectively. Then, of course, $\widehat{L}_N^X > \widehat{L}_I^X$. Let the domestic price of Y in the two models be p_I^Y and p_N^Y, with $p_I^Y > p_N^Y$, and let the values of $\overline{\mu}$ be $\overline{\mu}_I$ and $\overline{\mu}_N$ respectively. We will show that the direction of the steady-state impact of a labor demand shock is the same in our model as it is in the model with no mobility costs:

Proposition 4. *Under the stated assumptions,* $\overline{L}_N^X > \overline{L}_I^X$.

Proof. Suppose instead that $\overline{L}_N^X \leq \overline{L}_I^X$. Then $\overline{\mu}_I \leq \overline{\mu}_N$ because $\frac{\partial \overline{L}^X(\overline{\mu})}{\partial \overline{\mu}} < 0$ from (9). At the same time:

$$\begin{aligned}
\overline{\mu}_N + C &= \frac{\beta}{1-\beta}\left\{w^Y(L-\overline{L}_N^X, p_N^Y) - w^X(\overline{L}_N^X, p_N^Y) + \Omega(-\overline{\mu}_N - 2C) - \Omega(\overline{\mu}_N)\right\} \\
&< \frac{\beta}{1-\beta}\left\{w^Y(L-\overline{L}_N^X, p_I^Y) - w^X(\overline{L}_N^X, p_I^Y) + \Omega(-\overline{\mu}_N - 2C) - \Omega(\overline{\mu}_N)\right\} \\
&\text{(since } w^Y \text{ is increasing in } p^Y \text{ while } w^X \text{ is decreasing in } p^Y\text{)} \\
&\leq \frac{\beta}{1-\beta}\left\{w^Y(L-\overline{L}_I^X, p_I^Y) - w^X(\overline{L}_I^X, p_I^Y) + \Omega(-\overline{\mu}_N - 2C) - \Omega(\overline{\mu}_N)\right\} \\
&\text{(since we assumed } \overline{L}_N^X \leq \overline{L}_I^X\text{)} \\
&\leq \frac{\beta}{1-\beta}\left\{w^Y(L-\overline{L}_I^X, p_I^Y) - w^X(\overline{L}_I^X, p_I^Y) + \Omega(-\overline{\mu}_I - 2C) - \Omega(\overline{\mu}_I)\right\} \\
&\text{(since } \Omega(-\overline{\mu} - 2C) - \Omega(\overline{\mu}) \text{ is decreasing in } \overline{\mu} \text{ and } \overline{\mu}_N \geq \overline{\mu}_I\text{)} \\
&= \overline{\mu}_I + C
\end{aligned}$$

which is a contradiction.

Finally, as a last comparative static result, we note that wage differentials induced by policy persist in the steady state. When the tariff on Y is removed, not only does the X-industry wage rise relative to the Y-industry wage in the short run, but as Proposition 4 shows, it will also do so in the long run.

Proposition 5. *Using the notation of the previous problem, given that $p_N^Y < p_I^Y$, it must be the case that $[\overline{w}_N^X - \overline{w}_N^Y] > [\overline{w}_I^X - \overline{w}_I^Y]$.*

Proof. Suppose not. Then:

$$[\overline{w}_N^Y - \overline{w}_N^X] \geq [\overline{w}_I^Y - \overline{w}_I^X], \text{ so from (8)}$$
$$\frac{1-\beta}{\beta}[\overline{\mu}_N + C] + \Omega(\overline{\mu}_N) - \Omega(-\overline{\mu}_N - 2C) \geq \frac{1-\beta}{\beta}[\overline{\mu}_I + C] + \Omega(\overline{\mu}_I) - \Omega(-\overline{\mu}_I - 2C),$$
$$\text{which implies } \overline{\mu}_N \geq \overline{\mu}_I.$$

But we already know from the previous proposition that $\overline{L}_N^X > \overline{L}_I^X$, which implies that $\overline{\mu}_I > \overline{\mu}_N$, given (9). This yields a contradiction.

In sum, the steady state of the model is unique and qualitatively different from the equilibrium of a frictionless model. It exhibits persistent wage differentials in favor of larger industries, produces more evenly-sized industries than a frictionless model, and does not maximize GDP. Now, we turn attention to the whole time-path of adjustment.

4 Dynamic Adjustment

4.1 Preliminaries

It is in analyzing dynamics and welfare effects along the transition path that the tools of duality are useful for this model. Here we will see how. First, we will show the optimization problem that equilibrium solves (as noted above, it is not maximization of GDP). In the next subsection, we will see how that establishes basic dynamic properties, and in the next section we will use it to derive results on distributional effects along the transition path.

A general rule for labor allocation in this model could be characterized by two functions. The function $d^{XY}(L^X, \mu^X)$ gives the probability that a worker in X will move to Y in the current period, given the current stock L^X of workers in X and the worker's idiosyncratic cost μ^X of moving from X to Y. The function $d^{YX}(L^X, \mu^Y)$ gives the probability that a worker in Y will move to X in the current period, given L^X and the worker's idiosyncratic cost μ^Y of moving from Y to X. These functions define a feasible allocation rule if and only if $d^{ij} \in [0, 1]$ over the whole domain. For any given L_0^X, these functions induce a sequence L_t^X for $t = 1, \infty$. The following proposition is proven (in a more general form) as Proposition 1 in Cameron, Chaudhuri and McLaren (2007):

Proposition 6. *Any equilibrium maximizes:*

$$\begin{array}{c}\sum_{t=0}^{\infty}\beta^t[Q^X(L_t^X)+p^YQ^Y(L-L_t^X)\\ -L_t^X\int(\mu^X+C)d^{XY}(L_t^X,\mu^X)g(\mu^X)d\mu^X-L_t^Y\int(\mu^Y+C)d^{YX}(L_t^X,\mu^Y)g(\mu^Y)d\mu^Y]\end{array} \tag{10}$$

within the class of feasible allocation rules d^{XY} and d^{YX}, subject to L_0^X and L_0^Y given, and with L_t^i determined by the choice of the d^{ij} functions for $i = X, Y$, $t > 0$.

Therefore, studying optimization problem (10) can tell us about the equilibrium. Note that this is a dynamic analogue to the revenue function maximized by equilibrium in a static neoclassical trade model (see Dixit and Norman 1980, Ch. 2). Let $V(L^X, L^Y)$ denote the maximized value of the objective function (10) from an initial condition of L^X workers in X and L^Y workers in Y. Equivalently, since L is fixed, we can write the value function as $W(L^X) \equiv V(L^X, L - L^X)$.

Since the problem is stationary, the usual dynamic programming logic will apply, and the function W can be computed by solving a Bellman equation. Conditional on the domestic relative price p^Y, for any bounded function $\widetilde{W}$ on $[0, L]$, define the operator T by:

$$
\begin{aligned}
T(\widetilde{W})(L^X; p^Y) \equiv \max_{\{d^{XY}, d^{YX}\}} & [Q^X(L_t^X) + p^Y Q^Y(L - L_t^X) & (11)\\
& - L_t^X \int (\mu + C) d^{XY}(L_t^X, \mu) g(\mu) d\mu \\
& - (L - L_t^X) \int (\mu + C) d^{YX}(L_t^X, \mu) g(\mu) d\mu & (12)\\
& + \beta \widetilde{W}(L_{t+1}^X)],
\end{aligned}
$$

where $L_{t+1}^X = \int \{(1 - d^{XY}(L_t^X, \mu)) L_t^X + d^{YX}(L_t^X, \mu)(L - L_t^X)\} g(\mu) d\mu$. The Bellman equation is then $T(W; p^Y) = W$. It is easy to show that T satisfies the usual Blackwell properties with respect to W, and that as a result T has a unique fixed point, which can be found as the unique uniform limit of iterations on the Bellman equation starting from any bounded candidate function.

The following observation is helpful in characterizing the system's dynamics, and is also proven as Proposition 5 in Cameron, Chaudhuri and McLaren (2007):

Proposition 7. *The function W is strictly concave.*

This result tells us that the equilibrium is unique, since in strictly concave optimization problems the optimum is unique. It also tells us that the function $W'(L^X)$ is strictly decreasing in L^X. The following tells us that the value of this function is always equal to $v^X - v^Y$, which is very useful for analyzing dynamics, as will be seen shortly.

Proposition 8. *In equilibrium at each date $v^X - v^Y$ is equal to W'.*

Proof. First, note that in the optimization it is never optimal to have workers moving from i to j and at the same time other workers with lower values of μ who are remaining in i. (In that case, an equal number of workers from the two groups could have their actions reversed, leaving the future allocation of workers unchanged but reducing aggregate idiosyncratic moving costs.) Therefore, in an optimal allocation there is for each value of L^X at each date a number $\overline{\mu}^X$ such that $d^{XY}(L^X, \mu) = 1$ if $\mu < \overline{\mu}^X$ and $d^{XY}(L^X, \mu) = 0$ if $\mu > \overline{\mu}^X$. Simlarly, there is for each value of L^X at each date a number $\overline{\mu}^Y$ such that $d^{YX}(L^X, \mu) = 1$ if $\mu < \overline{\mu}^Y$ and $d^{XY}(L^X, \mu) = 0$ if $\mu > \overline{\mu}^Y$. This means that we can rewrite the Bellman equation as follows.

$$\begin{aligned}
&W(L_t^X) \\
&= \max_{\{\overline{\mu}^X, \overline{\mu}^Y\}} [Q^X(L_t^X) + p^Y Q^Y(L - L_t^X) \\
&- \left(L_t^X \int_{-\infty}^{\overline{\mu}_t^X} (\mu + C) g(\mu) d\mu + (L - L_t^X) \int_{\infty}^{\overline{\mu}_t^Y} (\mu + C) g(\mu) d\mu \right) \\
&+ \beta W((1 - G(\overline{\mu}_t^X)) L_t^X + G(\overline{\mu}_t^Y)(L - L_t^X))].
\end{aligned}$$

The first-order conditions for this with respect to $\overline{\mu}^X$ and $\overline{\mu}^Y$ are

$$\begin{aligned}
\overline{\mu}_t^X + C &= -\beta W(L_{t+1}^X)' \text{ and} \\
\overline{\mu}_t^Y + C &= \beta W(L_{t+1}^X)'.
\end{aligned} \tag{13}$$

But then from (2), the result follows.

This tells us that in equilibrium, the attractiveness of either sector relative to the other is a strictly decreasing function of the number of workers who are located in that sector. Now we can use this to analyze the economy's dynamics.

4.2 Gradual Adjustment to Unanticipated Changes

The preceding analysis can be used to show a number of properties of the model's dynamic adjustment. First, labor market adjustments to any change, such as terms of trade shocks or policy changes, will be sluggish. In particular, suppose that the economy is in a steady state associated with an initial value of p^Y, say p'. If a one-time shock occurs (say, elimination of the tariff on good Y) that results in a new value of p^Y, say p'', the economy will not reach the steady state associated with p'' in finite time.

To see this, consider Figure 2. This illustrates the first-order condition (2), or equivalently, (13), for choice of $\overline{\mu}_t^Y$ and hence of L_{t+1}^X given the current value of L_t^X. The solid upward sloping curve indicates the locus of points $(L_{t+1}^X, \overline{\mu}_t^Y + C)$ such that $L_{t+1}^X = G(\overline{\mu}_t^Y)(L - L_t^X) + (1 - G(-\overline{\mu}_t^Y - 2C))L_t^X$, which we can write as $L_{t+1}^X(L_t^X, \overline{\mu}_t^Y)$. One can, thus, interpret it as the marginal cost curve for the supply of X-workers: the height is the moving cost for the marginal worker moving to X, given that the total number who wind up in X at the end of this period is equal to L_{t+1}^X. The downward sloping curve gives $\beta(v_{t+1}^X - v_{t+1}^Y) = \beta W'(L_{t+1}^X)$. This can be interpreted as the marginal benefit of moving a worker from Y to X. Given L_t^X, the values of L_{t+1}^X and of $\overline{\mu}_t^Y$ are determined as the intersection of these two curves.

Now, note that if $C > 0$, increasing L_t^X by Δ units shifts the marginal cost curve to the right at each point by an amount strictly between 0 and Δ.[6] Since the marginal benefit curve is strictly decreasing, this implies an increase in L_{t+1}^X that lies strictly between 0 and Δ. This can be summarized in Figure 3, which shows the transition function that gives L_{t+1}^X as a function of L_t^X. Provided that $C > 0$, this curve must be strictly increasing, with a slope strictly less than 1. Thus, there is a unique steady state, and if the system begins at a point other than the steady state, it will move toward it without ever reaching or overshooting it.[7]

[6] The function $L_{t+1}^X(L_t^X, \overline{\mu}_t^Y)$ can be written as $G(\overline{\mu}_t^Y)(L - L_t^X) + (1 - G(-\overline{\mu}_t^Y - 2C))L_t^X$, or $G(\overline{\mu}_t^Y)L + [1 - G(\overline{\mu}_t^Y) - G(-\overline{\mu}_t^Y - 2C)]L_t^X$. By the symmetry of G, the expression in square brackets is strictly between zero and 1 if $C > 0$.

[7] In the event that $C = 0$, from the previous footnote we know that $L_{t+1}^X(L_t^X, \overline{\mu}_t^Y) = G(\overline{\mu}_t^Y)L$. Therefore, the upward-sloping line in Figure 2 will be vertical, and so both $\overline{\mu}$ and L_{t+1}^X will be the same regardless of L_t^X. Therefore, the economy jumps right away to its steady state. However, note that the outcome is not the same as for the frictionless model: As noted in previous sections, even with $C = 0$, intersectoral wages will not be equalized, and the equilibrium will not maximize GDP.

This provides the result. For example, if the system is initially at a steady state with a high tariff that is expected to continue permanently, and then the tariff is suddenly removed never to be restored, then the system will move toward the new steady state each period, attaining it only in the limit.

Gradual labor-market adjustment to external shocks and policy changes, and the persistent wage differentials that they imply, have been documented empirically by, among others, Topel (1986), Blanchard & Katz (1992) and Rappaport (2000). They appear in the model of Davidson and Matusz (2004), due to re-training and search delays and exogenous rates of individual job separation. They can also be rationalized by convex training costs for labor (as in Karp and Paul (1994) or Dehejia (1997), in analogy with convex adjustment costs for capital as in Mussa (1978)). Here, they result from the presence of time-varying idiosyncratic shocks to workers (even though those shocks are serially uncorrelated). Even if a worker is suffering low wages as a result of loss of protection to that worker's sector, it will often be in that worker's interest to wait until her personal moving costs are sufficiently low before leaving the sector.

4.3 Anticipatory Adjustment to Pre-announced Changes

Another feature of the model's dynamics is anticipatory adjustment. Suppose the economy is in an initial steady state with a tariff on imported good Y, and a domestic price of $p^Y = p'$. At time $t = 0$, the government announces a surprise policy change—elimination of the tariff—starting at some date $t^* > 0$. At that date and thenceforth, the domestic price of Y will be equal to the world price, $p'' < p'$. We will see that anticipatory net outflows of labor from sector Y will begin immediately from the time of the announcement.

Although the environment is no longer stationary as in the previous sections, the logic of Proposition 6 still applies, and the perfect-foresight equilibrium still solves the planner's problem (10) with $p^Y = p'$ for $t = 0, \ldots, t^*$ and $p^Y = p''$ for $t > t^*$. The value function will, however, depend on the date as well as the current labor allocation, and it is useful to write it as $W^t(L_X; p', p'', t^*)$ to keep track of the parameters of the problem.

Note from (1) that *ceteris paribus*, a rise in p^Y will raise the real wage in the Y sector and lower it in the X sector, or $w_2^X(L^X, p^Y) < 0$ and $w_2^Y(L - L^X, p^Y) > 0$. This leads to the following.

Lemma 1. *Assume that $C > 0$. (i) Let $\widetilde{W}$ be a bounded, concave, and differentiable function on $[0, L]$. Then $\partial T(\widetilde{W}; p'')(L^X)/\partial L^X > \partial T(\widetilde{W}; p')(L^X)/\partial L^X$. (ii) Let $\widetilde{W}$ and $\widehat{W}$ be bounded, concave, and differentiable functions on $[0, L]$, with $\widetilde{W}' > \widehat{W}'$ everywhere. Then, for any value of p^Y, $\partial T(\widetilde{W}; p^Y)(L^X)/\partial L^X > \partial T(\widehat{W}; p^Y)(L^X)/\partial L^X$.*

Proof. By the envelope theorem, we have:

$$\begin{aligned}\partial T(\widetilde{W}; p^Y)(L_t^X)/\partial L_t^X &= w^X(L_t^X, p^Y) - w^Y(L - L_t^X, p^Y) \\ &\quad - \int_{-\infty}^{\overline{\mu}^X} (\mu + C) g(\mu) d\mu + \int_{\infty}^{\overline{\mu}^Y} (\mu + C) g(\mu) d\mu \\ &\quad + \beta \widetilde{W}'(L_{t+1}^X)[1 - G(\overline{\mu}_t^X) - G(\overline{\mu}_t^Y)].\end{aligned}$$

Using (13) and (4) and rearranging, this becomes the following.

$$\partial T(\widetilde{W}; p^Y)(L_t^X)/\partial L_t^X = w^X(L_t^X, p^Y) - w^Y(L - L_t^X, p^Y) + \Omega(-\overline{\mu}_t^Y - 2C) - \Omega(\overline{\mu}_t^Y) + \overline{\mu}_t^Y + C. \quad (14)$$

(i) Comparing p' with p'', (13) shows that the optimal choice of $\overline{\mu}_t^Y$ for a given L_t^X will be the same for both. This implies that the only difference in (14) is in the first two terms, which take a higher value for p'' since the X wage is higher and the Y wage is lower. This proves the result. (ii) If we replace $\widehat{W}$ with $\widetilde{W}$, then in the first-order condition for the optimization in $T(\widetilde{W}; p^Y)(L_t^X)$, the marginal benefit curve shifts up (recall Figure 2). Thus, for any L_t^X, we have a rise in the value of $\overline{\mu}_t^Y$ that is chosen. The first two terms of (14) are unchanged. The derivative of the last three terms with respect to $\overline{\mu}_t^Y$ is equal to $-G(-\overline{\mu}_t^Y - 2C) - G(\overline{\mu}_t^Y) + 1$, which by the symmetry of the distribution of μ is equal to $G(\overline{\mu}_t^Y + 2C) - G(\overline{\mu}_t^Y) > 0$. Therefore, the value of (14) has gone up, proving the result.

Now, consider a model in which $p_t^Y \equiv p'$ forever and call it model I (for 'initial'), with value function W^I and steady-state value of L^X equal to L_I^X. Consider in the same way a model in which $p_t^Y \equiv p''$ forever and call it model N (for 'new'), with value function W^N and steady-state value of L^X equal to L_N^X. The two comparative statics results just derived, applied to the recursions on the Bellman operator T, imply that $W_1^I(L_X) < W_1^N(L_X)$ for any $L_X \in [0, L]$, and that $L_I^X < L_N^X$.

Now, return to the problem of the model with the announced policy change at time t^*. From time t^* on, the value function and the transition function mapping L_t^X into L_{t+1}^X and will be exactly as they are in model N. Consider date $t^* - 1$. For a given value of L^X, the value function for date $t = t^* - 1$ is given by $T(W^N; p')(L^X)$ (the next–period value function is W^N, but the current value of p^Y is p'). By the lemma, we can conclude:

$$W_1^I(L^X) < \frac{\partial T(W^N; p')(L^X)}{\partial L_t^X} < W_1^N(L^X) \tag{15}$$

for any L_X. The first inequality results from part (ii) of the Lemma because $W^I = T(W^I; p')$, and $W_1^I < W_1^N$. The second inequality results from part (i) of the Lemma because $p' > p''$. However, referring again to the first-order condition for the choice of L_{t+1}^X given L_t^X (see Figure 2), we see that (15) implies that the transition function for period $t^* - 1$ lies strictly in between the transition function for model I and that for model N. This is illustrated in Figure 5. By the same logic, the transition function for period $t^* - 2$ must lie strictly between that for $t^* - 1$ and that for model I, and so on. Then if we were already in a steady state of model I and it was announced (to everone's surprise) at date 0 that the tariff would be removed at date t^*, the dynamics of the system would follow the path indicated in Figure 4, drawn for the assumption that $t^* = 3$. Adjustment toward the new steady state would begin immediately at date 0, and would continue permanently, always moving toward the new steady state but never reaching it.

Of course, anticipatory labor adjustments also imply anticipatory wage changes. In particular, anticipatory outflows from Y prior to the actual tariff removal will progressively raise w^Y up to the time of the policy change, at which point it will fall discretely, and will progressively push down w^X up to the time of the policy change, at which point it will rise discretely due to the drop in the consumer's price index. This has obvious implications for empirical analyses of the impact of trade liberalization on wages.

In particular, suppose that a researcher obtains data on wages and employment levels at dates $t^* - 1$ and $t^* + 1$, and compares the values before and after the liberalization. If the differences thus observed are interpreted to be the effects of the liberalization, then because the anticipatory effects are omitted, the study will greatly overestimate the wage effects and underestimate the sectoral employment effects.

5 Welfare and Incidence

A large part of the reason for studying the workings of a model with labor mobility costs is to refine our understanding of who gains and who is hurt from a change in trade policy. Here we will look at two different angles of this question. First, a simple envelope result shows how the effect on a given worker can be expressed in terms of flow probabilities and changes in wages only. This result shows the importance of gross flows in analyzing incidence, which is ignored in the vast majority of empirical work. Second, we derive some results on how delayed trade liberalization can affect who gains and who loses from a reform.

5.1 An Envelope Result

Return again to the case with constant p^Y. Consider again an unannounced and permanent change in tariff, which changes the value of p^Y once and for all. Returning to (3), we can see that the change in the utility of a worker in sector i would be:

$$dv_t^{i*}/dp^Y = dw_t^{i*}/dp^Y + \beta dv_{t+1}^{i*}/dp^Y + \Omega'(\overline{\mu}_t^i)d\overline{\mu}_t^{i*}/dp^Y,$$

where w_t^{i*}, v_t^{i*} and $\overline{\mu}_t^{i*}$ denote the equilibrium values of the wage, worker's utility, and moving threshold in sector i and at date t respectively. Noting that $\Omega'(\mu) = G(\mu)$, this means:

$$dv_t^{i*}/dp^Y = dw_t^{i*}/dp^Y + \beta dv_{t+1}^{i*}/dp^Y + G(\overline{\mu}_t^i)\beta[dv_{t+1}^{j*}/dp^Y - dv_{t+1}^{i*}/dp^Y], \text{ or}$$

$$dv_t^{i*}/dp^Y = dw_t^{i*}/dp^Y + \beta(1 - G(\overline{\mu}_t^i))dv_{t+1}^{i*}/dp^Y + \beta G(\overline{\mu}_t^i)dv_{t+1}^{j*}/dp^Y.$$

Recalling (6) and following the recursive logic forward, this becomes:

$$dv_t^{i*}/dp^Y = \sum_{n=0}^{\infty} \beta^n \sum_{k=X,Y} \pi_{t+n}^{ik} dw_{t+n}^{k*}/dp^Y,$$

where π_t^{ik} is the probability that a worker who was in i at time 0 will be in k at time t. Thus, despite the moving costs, a properly constructed discounted sum of wages alone, using gross flows to average across sectors, is sufficient for evaluating incidence.

Note again that this has implications for empirical work. It suggests that looking at change in an industry's wages is not enough to tell whether workers in that industry have benefitted or not. In particular, it is quite possible to construct examples in which a drop in tariff lowers wages in sector Y in the short run and in the long run, and yet every worker in the economy benefits, including those in Y.[8] The reason is that real wages in X rise by enough, and the economy is fluid enough, that current Y workers expect to make up in future employment in X for what they have lost in Y. This also stands in stark contrast to the convex-adjustment cost approach (Karp and Paul, 1994; Dehejia, 1997); in equilibrium in those models, a Y-worker must be indifferent between leaving Y and remaining there permanently, and so would definitely be worse off if Y wages were to fall permanently.

Of course, the need, in principle, to examine the effect on all wages now and in the future is a problem econometrically. However, the model does offer one useful tool for inferring welfare effects in a reduced-form regression: Examining mobility decisions. Recalling (2) and (6), it is clear that if a change in policy results in fewer workers choosing to enter an industry or location and more workers choosing to leave it, then the welfare in that industry or location must have declined relative to others. This simple revealed-preference test can

[8]For example, consider a model with Ricardian technology. If $Q^i(L_t^i) \equiv A^i L_t^i$ for positive constants A^i, $i = X, Y$, then $w^X = A^X/\phi(p^Y)$ and $w^Y = p^Y A^Y/\phi(p^Y)$. Suppose that the two goods are perfect substitutes in consumption so that $\phi(p^Y) \equiv \min\{1, p^Y\}$. Then for $p^Y > 1$, $w^X = A^X$ and $w^Y = p^Y A^Y$, while for $p^Y \leq 1$, $w^X = A^X/p^Y$ and $w^Y = A^Y$. Then if p^Y is initially slightly above 1 but then drops to a point well below 1, w^Y will fall slightly but by letting p^Y fall sufficiently close to 0, w^X can be made arbitrarily large. Eventually, Y-workers will value the option of moving to X enough to compensate them for their small current wage loss.

be implemented in a wide variety of situations.

5.2 The Effects of Policy Delay on Incidence

Trade liberalization measures are usually phased in over time. For example, the elimination of the Multi-Fibre Arrangement in the Uruguay round was scheduled to be phased in over ten years, with most of the reduction loaded at the end of the phase-in period. One reason for this is to soften the effects of the reform on workers likely to be hurt by it, giving them time to adjust and perhaps removing an incentive to oppose the reform politically. This motive is studied by Dehejia (2003), in a Heckscher-Ohlin model with convex adjustment costs for workers (and zero steady-state flows of workers). In that model, it is shown that gradual phase-in can bring all workers behind a trade liberalization that would otherwise have been opposed by import-competing workers, making the reform politically feasible.

We will here study the effect of delayed trade liberalization in the present model. To study a simple version of the problem that makes the mechanisms clear, we focus on a stark liberalization that brings the economy from autarchy to free trade. Beginning from an autarchic steady state, the opening of trade may either occur immediately or be announced (with full commitment) to occur at a later date. In contrast to Dehejia, we find that delay does not, in general, soften the blow of trade liberalization to workers. What it does do, is to induce movement of workers out of the import-competing sector beginning the movement the announcement is made. This forces the wage *up* in the import-competing sector in the interval of time between the announcement and the actual liberalization, conferring what we may call *anticipation rents* on the remaining workers in that industry. At the same time, it pushes wages *down* in the other sector. If the period of delay is long enough, the effect is to *unite* all workers, so that they all either benefit from trade or lose from it. To anticipate, it turns out that if an increase in labor supply increases the economy's long-run relative supply of export goods (as it does in Dehejia's model), then delay fosters unification of workers *behind* free trade, but if an increase in labor supply *decreases* long-run relative supply of export goods, delay fosters unification of workers *in opposition* to free trade.

Consider an economy that is as of period 0 in an autarchic steady-state with a relative price of good Y given by $p = p'$. At date 0 it is announced that the economy will be opened up to free trade as of date t^* (which could be equal to zero, representing the case of unanticipated liberalization). Suppose that the world relative price of good Y is given by $p = p''$. It is useful to rewrite the period-t value function for the planner's problem that the equilibrium solves as $W^t(L_t^X, L_t^Y; p', p'', t^*)$. (Of course, the value function is not stationary before t^*, although it will be afterward, hence the time superscript for the value function.) Let $t^* = \infty$ represent the case in which no trade liberalization is announced.

It is straightforward to check from the envelope theorem applied to the Bellman equation for the planner's problem that the payoff to an individual worker in the X sector at the beginning of period 0, just after the policy announcement, is equal to $v_0^X = W_1^0(L_t^X, L_t^Y; p', p'', t^*)$, or the marginal value of an X worker from the planner's point of view. Similarly, the payoff to a Y worker is given by $v_0^Y = W_2^0$. Given that, the question of the value of advance notice is essentially the question of whether or not an increase in t^* changes the sign of $W_i^0(L_t^X, L_t^Y; p', p'', t^*) - W_i^0(L_t^X, L_t^Y; p', p'', \infty) = W_i^0(L_t^X, L_t^Y; p', p'', t^*) - W_i^0(L_t^X, L_t^Y; p', p', \infty)$ for $i = 1, 2$. Call this difference an i worker's 'willingness to consent.' It is difficult to obtain general results on this, but if one can find results on the cross derivative $W_{i4}^0(L_t^X, L_t^Y; p', p', t^*)$, or the derivative of a worker's payoff with respect to the world price, evaluated at a value of the world price equal to the domestic autarchic price, then (since $W_i^0(L_t^X, L_t^Y; p', p', t^*) - W_i^0(L_t^X, L_t^Y; p', p', \infty) = 0$) one has signed the i worker's willingness to consent in an interval for p'' that includes p'. That is the approach taken here.

Denote the equilibrium employment in sector i at time t, as a function of initial labor stocks, by $L_t^i(L_0^X, L_0^Y)$. Denote the steady state employment similarly by $L_\infty^i(L_0^X, L_0^Y)$. Define $q_t^i(L_0^X, L_0^Y)$ and $q_\infty^i(L_0^X, L_0^Y)$ respectively as output in the i sector at time t and in the steady state. (In general these functions would be conditioned on p', p'', and t^* as well as L_0^X, L_0^Y, but we will need to evaluate these functions only at the point $p'' = p'$, so these additional arguments will be suppressed.) The following will be useful; the proof is in the Appendix.

Lemma 2. *Assume that the value function is twice continuously differentiable in (L_t^X, L_t^Y). Then:*

(i) The functions L_t^X and L_t^Y are differentiable in (L_0^X, L_0^Y).

(ii) The derivatives $L_{t1}^X \equiv \partial L_t^X(L_0^X, L_0^Y)/\partial L_0^X$ and $L_{t1}^Y \equiv \partial L_t^Y(L_0^X, L_0^Y)/\partial L_0^X$ are all non-negative, and $L_{t1}^X + L_{t1}^Y = 1 \forall t > 0$. Further, L_{t1}^X is decreasing in t.

(iii) The derivatives L_{t2}^X and L_{t2}^Y are all non-negative, and $L_{t2}^Y + L_{t2}^X = 1 \forall t > 0$. Further, $L_{t2}^X$is increasing in t.

(iv) $L_{t1}^i \to L_{\infty 1}^i$ as $t \to \infty$, for $i = X, Y$.

Parts (i) and (iv) are technical preliminaries. The result in (iv) requires proof, since even when a series of functions converges uniformly to a limit function, in general the sequence of derivatives does not converge to the derivative of the limit series. In this case the result follows because the functions are solutions to an optimisation problem. Parts (ii) and (iii) follow directly from the model's dynamics. For example, if one was to add some workers to X in period 0, that would result in more X workers in each period, but the number of X workers would fall over time, as workers reallocate toward the Y sector. With a slight abuse of notation, we will write $L_{01}^X = 1$, $L_{02}^X = 0$, $L_{01}^Y = 0$, and $L_{02}^Y = 1$.

Henceforth, we will assume that the planner's value function is twice continuously differentiable in all arguments.

With this notation, the effect on the payoff of a worker in X is:

$$\frac{\partial v_0^X}{\partial p''}|_{p''=p'} = W_{14}^0(L_0^X, L_0^Y; p', p', t^*) = W_{41}^0(L_0^X, L_0^Y; p', p', t^*)$$

by Young's theorem, which by the envelope theorem becomes:

$$\frac{\partial}{\partial L_0^X} \sum_{t=t^*}^{\infty} \beta^t \left[\frac{\partial}{\partial p''} \left(\frac{1}{\phi(p'')} \right) Q_t^X + \frac{\partial}{\partial p''} \left(\frac{p''}{\phi(p'')} \right) Q_t^Y \right] |_{p''=p'}$$

$$= \frac{1}{\phi(p')} \sum_{t=t^*}^{\infty} \beta^t \left[(1-\alpha) Q_{t1}^Y - \frac{\alpha}{p'} Q_{t1}^X \right]$$

$$\equiv \frac{1}{\phi(p')} \sum_{t=t^*}^{\infty} \beta^t B_t,$$

where $\alpha \equiv p'\phi'(p')/\phi(p')$ is the share of good Y in autarchic consumption expenditure.[9] Note that this provides a simple way of analyzing the effects of delay; the *only* effect of an increase in t^* on this exression is to eliminate some of the terms from the summation. This is the key to the results that follow.

Since Q^X_{t1} is decreasing in t and Q^Y_{t1} is increasing in t, B_t is increasing in t, as shown in Figure 6. Since $\frac{\alpha}{p'(1-\alpha)}$ is the autarchic steady-state ratio of Y consumption to X consumption (and hence the ratio of production as well), $B_\infty \equiv \lim_{t\to\infty} B_t$ has the same sign as $\left[\frac{Q^Y_{\infty 1}}{Q^Y_\infty} - \frac{Q^X_{\infty 1}}{Q^X_\infty}\right]$. Put differently, $B_\infty > 0$ if and only if an increase in the economy's total labor supply would increase Q^Y_∞/Q^X_∞ at a fixed world price of $p'' = p'$, and $B_\infty < 0$ if an increase in labor supply would decrease Q^Y_∞/Q^X_∞. Figure 5 illustrates the case in which $B_\infty < 0$. In addition, $Q^Y_{01} = 0$, since an exogenous increase in the stock of labor in one sector cannot have a contemporaneous effect on output in the other sector. Thus, $B_0 < 0$.

As a result, if $B_\infty < 0$, then $B_t < 0$ for all t, and $\frac{\partial v^X_0}{\partial p''}|_{p''=p'} < 0$. However, if $B_\infty > 0$, then B_t is negative for t below some threshold and positive for t above the threshold. The implication is that $\exists \bar{t}$ such that if $t^* \geq \bar{t}$, $\frac{\partial v^X_0}{\partial p''}|_{p''=p'} > 0$.

Analogously, it can be seen that

$$\frac{\partial v^Y_0}{\partial p''}|_{p''=p'} = \frac{1}{\phi(p')} \sum_{t=t^*}^{\infty} \beta^t D_t,$$

where $D_t \equiv (1-\alpha)Q^Y_{t2} - \frac{\alpha}{p'}Q^X_{t2}$. Clearly, since $Q^X_{t2} = 0$, Q^X_{t2} is increasing in t, and Q^Y_{t2} is decreasing in t, while Q^X_{t2} and Q^Y_{t2} are non-negative for all t, we can conclude that $D_0 > 0$ and that D_t is decreasing in t. Again, this is illustrated in Figure 5. Further, by part (iv) of the lemma and the uniqueness of the steady state which implies that $L^X_{\infty 1} = L^X_{\infty 2}$ and $L^Y_{\infty 1} = L^Y_{\infty 2}$, we conclude that $D_\infty = B_\infty$. This all implies that $B_t < D_t$ for all t. Given that $B_0 < 0 < D_0$, we conclude that $\frac{\partial v^X_0}{\partial p''}|_{p''=p'} < \frac{\partial v^Y_0}{\partial p''}|_{p''=p'}$.

By extension of the logic just used, if $D_\infty < 0$, then $\exists \bar{t}$ such that if $t^* \geq \bar{t}$, $\frac{\partial v^Y_0}{\partial p''}|_{p''=p'} < 0$. Further, if $B_\infty = D_\infty = 0$, then $B_t < 0 < D_t$ for all t, and $\frac{\partial v^X_0}{\partial p''}|_{p''=p'} < 0 < \frac{\partial v^Y_0}{\partial p''}|_{p''=p'}$

[9] The switch in the order of differentiation is analogous to the demonstration that in a static trade model derivatives of factor prices with respect to output derivates is dual to the derivative of output with respect to factor prices, as in Dixit and Norman (1980, pp.54-55).

regardless of t^*. To help interpret the sign of D_∞, recall that α is the autarkic share of spending on Y, so the ratio of α/p' to $(1-\alpha)$ is the same as the ratio of autarkic output of Y to autarkic output of X. Therefore, $D_\infty < 0$ means that the steady state autarkic supply of X increases when labor is added to the economy.

In addition, since $B_0 < 0 < D_0$, it is clear that increasing t^* from 0 to 1, by chopping off a term that is negative in the first case and positive in the second, increases $\frac{\partial v_0^X}{\partial p''}|_{p''=p'}$ and decreases $\frac{\partial v_0^Y}{\partial p''}|_{p''=p'}$. Thus, workers in the export sector are hurt by a bit of delay, while workers in the import competing sector benefit from a bit of delay.

This can all be summarized as follows. The first proposition treats the case with $B_\infty = D_\infty \neq 0$, and the second treats the case with $B_\infty = D_\infty = 0$.

Proposition 9. *Suppose that, at the autarchy relative price p', steady state relative supply of the export good is increased [decreased] by an increase in labor supply. Then, there is an open interval containing p' such that if the world price p'' is in that interval:*

(i) Workers in the export [import-competing] sector as of period 0 will benefit from [be hurt by] immediate unanticipated opening of trade.

(ii) The net benefit to workers in the import-competing sector from the opening up of trade is strictly less than the benefit to export sector workers, whether the opening is delayed or not.

(iii) A one-period delay hurts export-sector workers and benefits import-competing workers.

(iv) A sufficiently long delay before the opening of trade will make workers in both sectors net beneficiaries [net losers] from trade.

Proposition 10. *Suppose that, at the autarchy relative price p', steady state relative supply of the export good is unchanged at the margin by an increase in labor supply. Then there is an open interval containing p' such that if the world price p'' is in that interval:*

(i) Workers in the export sector as of period 0 will benefit from the opening of trade, whether it is delayed or not.

(ii) Workers in the import-competing sector as of period 0 will be hurt by the opening of trade, whether it is delayed or not.

(iii) A one-period delay hurts export-sector workers and benefits import-competing workers.

Some examples. Four simple special cases illustrate the different effects delay can have. For all examples, assume that $p'' < p'$, so that Y is the import good, and that the difference between the world price and the domestic autarchy price is small enough that the propositions apply. (As a result, sector-i workers benefit from trade if $\frac{\partial v_0^i}{\partial p''}|_{p''=p'} < 0$.)

(i) *Ricardian technology.* If $Q^i(L_t^i) \equiv A^i L_t^i$ for positive constants A^i, $i = X, Y$, an increase in total labor supply will result in an equiproportionate increase in output of both sectors. (Note that w^X and w^Y are both independent of labor supplies, and so, by (8), $\overline{\mu}$ is unchanged by a change in labor supply.) Therefore, $B_\infty = 0$, and in this case delay has no role: export sector workers benefit from trade and import-competing workers are hurt by it, regardless of t^*.[10]

(ii) *Inelastic import-competing labor demand.* Suppose that both X and Y are produced by a sector-specific asset in fixed supply (K^X and K^Y respectively) together with labor. Suppose further that the production function for Y is Leontieff: $Q^Y(K^Y, L^Y) = \min\{K^Y, L^Y\}$, and that the production function for X is CES: $Q^X(L^X, K^X) = ((L^X)^\rho + (K^X)^\rho)^{1/\rho}$, with $\rho < 1$, $\rho \neq 0$ (implying an elasticity of substitution equal to $1/(1-\rho)$). In this case, $Q_{t1}^Y = Q_{t2}^Y = 0 \forall t$. Therefore, $B_t, D_t \leq 0 \forall t$, with strict inequality for $t > 0$, so both groups of worker will benefit from trade with or without delay. The interpretation is that the increased labor demand in the export sector forces wages up in the import-competing sector because of its inelastic labor demand, benefitting all workers.[11]

(iii) *Inelastic export-sector labor demand.* Now, reverse the production functions for the two sectors. In this case, $Q_{t1}^X = Q_{t2}^X = 0 \forall t$. Therefore, $B_t, D_t \geq 0 \forall t$, with strict inequality for $t > 0$, so both groups of worker will be hurt by trade with or without delay. The interpretation is that the reduced labor demand in the import-competing sector forces wages

[10] Recall that these are 'local' results, in the sense that they depend on p'' being close to p'. On the other hand, where p'' is substantially below p', workers in both industries can benefit from trade (even though the real wage for sector Y falls both in the short run and the long run), as illustrated in Footnote 8.

[11] This is analogous to a parallel result on the role of elasticities of substitution in Mussa's (1974) static Ricardo-Viner model.

down in the export sector because of its inelastic labor demand, hurting all workers. In this example, all of the gains from trade are captured by the owners of the fixed factors.

(iv) *An example in which delay tips the scales in favor of trade.* Now consider a general CES specification, in which $Q^i(L^i, K^i) = ((L^i)^{\rho^i} + (K^i)^{\rho^i})^{1/\rho^i}$, $i = X, Y$, with $\rho^i < 1$, $\rho^i \neq 0$. Example (ii) shows that with any finite ρ^X and with ρ^Y sufficiently large and negative, import-competing workers strictly benefit from an unannounced liberalization. Example (iii) shows that with any finite ρ^Y and with ρ^X sufficiently large and negative, import-competing workers are strictly hurt by an unannounced liberalization. Choose any two such parameter pairs, and connect them with a curve in (ρ^X, ρ^Y) space. There must be a point on the curve at which import-competing workers are indifferent between a sudden trade opening and the autarchic steady state. For this parameter pair, by part (ii) of Proposition 9, export workers are strict beneficiaries of sudden trade. In addition, export workers will remain net beneficiaries of trade if the opening is delayed (B_∞ must be negative, because in order for Y workers to be indifferent, D_∞ must be negative; but then $B_t < 0 \forall t$). Furthermore, since $D_0 > 0$ and D_t is decreasing in t, any delay will make the Y workers strict beneficiaries of trade. Thus, an immediate liberalization would benefit X workers but not Y workers, but a delayed liberalization would strictly benefit both classes of worker. (A slight perturbation of the (ρ^X, ρ^Y) pair could then make the Y workers stictly hurt by immediate trade opening, making them strict beneficiaries of delayed opening.)

The interpretation of this result is as follows. An unexpected trade opening pushes down the real wages of Y workers immediately, while pushing up the real wages of X workers. The Y workers move only gradually to take advantage of the higher X wages because of the moving costs. However, if the trade opening is announced in advance, Y workers who happen to have low moving costs at the moment begin moving to X *in anticipation.* This makes Y workers more scarce, pushing up wages for those who do not move (while pushing X wages down), even though no change in output prices has yet occurred. If the elasticity of labor demand in the Y sector is sufficiently low, this anticipatory wage increase is the dominant effect.

(v) *An example in which delay tips the scales against trade.* Exactly the same logic as in

(iv) can be used to construct a case in which *export* sector workers are indifferent between immediate trade and the autarchic steady state. In this case, by part (ii) of Proposition 9, import-competing workers are strictly hurt by trade whether it is delayed or not (since D_∞ must be positive, because in order for X workers to be indifferent, B_∞ must be positive; but then $D_t > 0 \forall t$). Furthermore, since $B_0 < 0$ and B_t is increasing in t, any delay will make the X workers strictly harmed by trade. Thus, in the event of an immediate liberalization, workers would be divided over trade, while delay would unite all workers in their opposition. (Again, a slight perturbation of the example can make X workers strict beneficiaries of immediate trade.)

The interpretation of this example is as follows. From the point of view of the X workers, immediate trade has three effects. It lowers real wages in the Y sector; it provides an immediate increase in real wages in the X sector; and it pushes a certain number of Y workers out of the Y sector and into the X sector over time, pushing X wages down. If labor demand in X is sufficiently inelastic, the X wage will be lower in the long run than it was under autarchy. Thus, in this example, for an X worker, the benefit from free trade is short-lived, and must be weighed against a long-run cost. On the other hand, if the trade opening is announced in advance, Y workers begin moving into X right away, pushing X wages down *even before output prices change*. Thus, X workers lose the benefit of the short-run wage increase that they would have enjoyed under unanticipated trade, and jump immediately to the long-run cost of increased competition from former Y workers.

These examples serve to illustrate the range of possible outcomes. Except in the knife-edge case with $B_\infty = D_\infty = 0$, delay tends to make workers unanimous in their stance toward trade, but whether it is a positive or negative stance depends on the relative responsiveness of labor demand in the two sectors. Of course, whether delay in any given real world liberalization event is likely to turn workers into beneficiaries or victims of trade is an empirical matter. Artuç, Chaudhuri and McLaren (2008) simulate equilibria of this model for a range of parameters in order to illustrate these points and to explore the magnitudes of delay required to achieve unanimity of workers. For middling values of the elasticity of substitution, unanimity can require decades of delay.

6 Some Evidence on Anticipatory Effects

Some of the more surprising results of the model concern the economy's response to an anticipated future trade shock. The model predicts that after announcement of a future negative trade shock to a given sector, workers begin to move out of the sector right away, resulting in both an anticipatory movement in trade flows and anticipatory movements in wages, the latter favoring workers in the shrinking sector. We note here that these features are consistent with empirical evidence in quite a number of cases.[12] Note that the present paper is an attempt to clarify the theory, not an empirical study. Our aim in this section is to provide examples of phenomena that plausibly could be explained by anticipatory movements such as in the model. We do not claim to have a *proof* that any one episode is caused by the underlying mechanism, which is a difficult enquiry for another day. But it is instructive to observe that a number of cases seem to fit the story of the model quite well.

One place to look for evidence of anticipatory effects is in accession of a country to a trade block such as the European Union (EU), since the process of accession tends to take several years even when the outcome is not seriously in doubt. Freund and McLaren (1999) demonstrated that trade flows in European countries joining the European Union began to reorient themselves toward the EU on average four years before the date of accession, suggesting reallocation of resources in anticipation of the new trade regime. This is consistent with the behavior of our model, even though the data in that study show only trade flows and do not isolate movements of labor *per se*.

Another type of example is a change in trade policy uncertainty. Often economic agents expect a future change in policy with a positive probability, and an agreement between countries can prevent those future policy changes, thus causing anticipatory reallocation

[12] The anticipation rents that go to the workers in the sector that receives the adverse shock result from our assumption of immobile capital. If capital was perfectly mobile, both intersectorally and internationally, then the marginal value product of capital would be fixed by the required world rate of return, and so before the tariff change, the wage in each sector would also be fixed. With the removal of the tariff, the import-competing sector wage would jump to its new permanent level and stay there. Thus, with perfect capital mobility, there would be no anticipatory movement of wages, but only of workers. An extension of interest would be to include quasi-fixed capital, which would allow for the possibility of an anticipatory movement of capital, and and even anticipatory movement of wages in the opposite direction from our model. That would be a far more complicated model, of course.

of resources. Handley and Limão (2012) examine the 1986 accession of Portugal to the European Community (EC), and show that much entry of firms into EC export markets can be explained by the fact that it eliminated uncertainty about future policy changes.[13] Handley and Limão (2013) similarly show that the entry of Chinese firms into the US export market following the accession of China to the WTO is largely explained by the fact that it eliminated uncertainty about future US trade policy toward China. Handley (2014) finds similar effects on exports to Australia, measuring policy uncertainty by the gap between WTO tariff bindings and applied tariffs. These are examples that show a large reallocation of resources due to a change in the probability distribution of future policy, but these studies do not look at workers or wages, since the focus is on firm behavior and in particular the extensive margin. Pierce and Schott (2012) do look at workers, showing that the reduction of trade policy uncertainty following China's entry into the WTO explains a large movement of workers out of US manufacturing. But the paper does not look at the behavior of workers' wages, or at workers' welfare.

One paper that looks at wages and movement of workers in the context of anticipated policy changes is Hakobyan and McLaren (2010), who study the North American Free Trade Agreement (NAFTA). NAFTA included schedules for the elimination of all tariffs between signatories, with much variation across industries in the speed of elimination. An industry with a 10% initial tariff but only a 2% reduction over the data period is an industry with an anticipated further reduction of 8%; while an industry with a 2% initial tariff and a 2% reduction over the data period is an industry with no further anticipated reduction. It turns out that industries with a larger anticipated future tariff reduction saw *reductions* in blue-collar employment but *increases* in wages relative to industries with smaller anticipated future reductions, controlling for a range of personal characteristics including age and human capital. Although there may be other explanations, this finding is directly interpretable as an anticipation rent as described in our model.

The end of the Multifiber Arrangement provides a final example. The system of quotas

[13] For example, Portugal had a preferential agreement with Spain, which was understood to be temporary but it was not clear where it would lead. Joining the EC together eliminated any uncertainty about tariffs between the two countries.

protecting industrial-country textile and apparel industries from low-income country imports was dismantled under an agreement worked out as part of the Uruguay Round of the GATT that entered into force in January 1995. Relaxation of the quota was to be phased in over 10 years, with the last quotas eliminated completely in January 2005, but most of the liberalization was deferred until the end of the period. Thus, the period 1995 to 2005 was largely a period of *anticipation* of a trade liberalization.[14]

We examine this episode with data on US manufacturing workers who were between 22 and 64 years old from the IPUMS-CPS database between 1981 and 2010. (See King et al. (2010)). The sample size is 267,281 workers over all years. We observe workers' wage, industry, occupation, age, gender, education, and relation to the head of household. Figure 6 shows the evolution of textile and apparel wages relative to other manufacturing wages (in other words, the average textile-and-apparel sector wage divided by the average non-textile-and-apparel manufacturing wage). The vertical lines in the figure mark the anticipation period. Clearly, wages in the sector increased sharply during the anticipation period and fell sharply afterward, as predicted by the model. Figure 7 shows the evolution of the share of textile and apparel employment within manufacturing. Clearly, the anticipation period saw a rapid movement of workers out of textiles and apparel, from around 8% to below 4%, and this movement was not simply the continuation of a pre-existing trend.

A natural question is whether or not these trends are driven by compositional effects. For example, it could be that the least-educated workers leave the sector first, driving up average wages without raising the wage for any one worker. This would be quite different from the anticipation rent we have discussed. To answer this question, we purge the compositional effects from wages and labor allocations using the following Mincer wage and logit regressions:

$$\log w_t^n = \beta_{i,t} D_t^{i,n} + X_t^n B_t + \epsilon_{1,t}^n, \tag{16}$$

$$y_t^n = \gamma_{0,t} + X_t^n \Gamma_t + \epsilon_{2,t}^n, \tag{17}$$

[14] Considerable background on the end of the Multifiber Arrangement together with some empirical analysis can be found in Evans and Harrigan (2005) and Harrigan and Barrows (2009).

where w_t^n is the wage of individual n at time t and y_t^n is the dependent variable for the logit regression implying $y_t^n > 0$ if the individual is employed in textiles or apparel; $D_t^{i,n}$ is the dummy for the sector fixed effect;[15] X_t^n is the vector of individual characteristics such as blue collar, female, household-head, age, age squared and education level (secondary school, high school or college); $\beta_{i,t}$, $\gamma_{0,t}$, Γ_t and B_t are regression coefficients, and $\epsilon_{1,t}^n$ and $\epsilon_{2,t}^n$ are error terms.

We first run these regressions separately for each year, and plot $\beta_{textile,t}$ to show the evolution of wages and plot $\gamma_{0,t}$ to show the evolution of the ratio of textile workers, net of any effect caused by composition of individual characteristics or general manufacturing trends. Figures 8 and 9 show that after purging the data of composition effects in this way, we can still see the negative trend in textile and apparel employment and the positive trend in the sector's wages during the period 1995-2004 as predicted by the model.

Finally, we pool the data across all years to test the significance of within-period time trends using the following regressions:

$$\log w_t^n = \beta_0 D_t + \beta_j \Delta^j D^{textile,n} + t\alpha_j \Delta^j D^{textile,n} + X_t^n B + \epsilon_{3,t}^n, \tag{18}$$

$$y_t^n = \gamma_j \Delta^j + t\theta_j \Delta^j + X_t^n \Gamma + \epsilon_{4,t}^n, \tag{19}$$

where w_t^n is the wage of individual n at time t; y_t^n is the dependent variable for the logistic regression implying $y_t^n > 0$ if the individual is employed in textiles or apparel; D_t is the dummy for time fixed effect; $D^{textile,n}$ is the textile dummy which is equal to one if the individual is employed in the textile/apparel sector; Δ^j is the dummy for period fixed effect: $\Delta^1 = 1$ if $1981 \leq t \leq 1994$, $\Delta^2 = 1$ if $1995 \leq t \leq 2004$, and $\Delta^3 = 1$ if $2005 \leq t \leq 2010$; X_t^n is the vector of individual characteristics (such as blue collar, female, household-head, age, age squared and education level, i.e. secondary school, high school or college); β_0, β_j, α_j, γ_j, θ_j, Γ and B are regression coefficients, and $\epsilon_{3,t}^n$ and $\epsilon_{3,t}^n$ are error terms.

[15] The ten manufacturing sectors are: 1. Furniture and wood; 2. Metals and minerals; 3. Machinery; 4. Vehicles, etc.; 5. Miscellaneous Durables; 6. Food; 7. Textiles and apparel; 8. Paper; 9. Chemicals, and 10. Miscellaneous non-durables.

We are seeking a trend rather than a one-time change, so we use intercept and slope variables and test if the changes in wages and labor allocation are statistically significant. Since we have time dummies for each year of the data, the time trends we estimate are trends relative to other manufacturing industries. We also cluster the errors by 1-digit manufacturing sector to allow for correlated shocks within each sector. In the wage regression, β_j is the intercept and α_j is the slope coefficient for the time-trend for period j. In the logit regression, γ_j is the intercept and θ_j is the slope coefficient. In particular, we expect α_2 to be positive and significant, indicated a rise in wages between the announcement and shock, and θ_2 to be negative, indicating an exodus of workers between the announcement and the shock.

Table 1: Mincer and Logit Regression Results

	Wage Regression		Logit Regression	
D_80_94	-0.293	*(-39.03)*	-2.879	*(-38.96)*
D_95_04	-0.329	*(-31.59)*	-2.806	*(-37.98)*
D_05_09	-0.280	*(-23.86)*	-3.493	*(-47.88)*
D_80_94*(t-1980)	0.004	*(3.81)*	0.006	*(2.07)*
D_95_04*(t-1995)	0.015	*(5.29)*	-0.077	*(-13.12)*
D_05_09*(t-2005)	0.004	*(0.57)*	-0.039	*(-4.43)*
Blue_col	0.347	*(47.34)*	-0.449	*(-21.49)*
Female	-0.359	*(-58.54)*	1.203	*(41.74)*
Not_head	-0.113	*(-9.54)*	0.271	*(11.84)*
Max_high	0.174	*(30.17)*	-0.800	*(-34.88)*
Max_college	0.429	*(26.81)*	-0.637	*(-20.33)*
Age	0.036	*(46.92)*	-0.008	*(-1.39)*
Age Squared	-0.001	*(-46.67)*	0.000	*(3.39)*

(t-statistics are in parentheses)

The results are shown in Table 1. The slope coefficient of the wage regression during the anticipation period, α_2, is equal to 0.015 with a t-statistic of 5.39. This shows that there was a strong positive trend in wages between 1995 and 2004. We also find some evidence of a mild increase in wages in the previous years but the slope is much smaller, 0.004, and statistically weaker. Additionally, we find that the slope coefficient of the logit regression during the same period, θ_2, is equal to -0.077 with a t-statistic equal to -13.12, consistent with the predictions of the model. We find that the slope coefficients before the announcement and after the shock are also statistically significant but they have much smaller magnitude and t-statistics. Therefore the trends in wages and labor allocations in textiles are much stronger (both statistically and in terms of magnitude) between the announcement and the shock as predicted by the theoretical model, consistent with the visual evidence we provided via figures.

7 Conclusion

We have studied a simple trade model with costly labor mobilty and idiosyncratic moving-cost shocks. The model is shown to have non-trivial dynamics, including gradual adjustment and anticipatory effects, resulting solely from fixed moving costs plus time-varying idiosyncratic moving cost shocks to individual workers. A key conclusion is that the steady state does not resemble a model with frictionless labor mobility. Specifically, intersectoral wage differentials persist permanently, making workers more expensive in larger sectors. In addition, trade liberalization lowers the long-run wage in the import-competing sector relative to the export sector, and delaying liberalization reduces the difference between the effect of liberalization on export-sector and on import-competing workers.

Thus, the trade economist's habit of assuming that a frictionless model will be a good predictor of long-run trade effects is called into question.

Appendix

Lemma 2. Assume that the value function is twice continuously differentiable in (L_t^X, L_t^Y). Then:

(i) The functions L_t^X and L_t^Y are differentiable in (L_0^X, L_0^Y).

(ii) The derivatives $L_{t1}^X \equiv \partial L_t^X(L_0^X, L_0^Y)/\partial L_0^X$ and $L_{t1}^Y \equiv \partial L_t^Y(L_0^X, L_0^Y)/\partial L_0^X$ are all non-negative, and $L_{t1}^X + L_{t1}^Y = 1 \forall t > 0$. Further, L_{t1}^X is decreasing in t.

(iii) The derivatives L_{t2}^X and L_{t2}^Y are all non-negative, and $L_{t2}^Y + L_{t2}^X = 1 \forall t > 0$. Further, $L_{t2}^X$is increasing in t.

(iv) $L_{t1}^i \to L_{\infty 1}^i$ as $t \to \infty$, for $i = X, Y$.

Proof. First, note that since $\overline{\mu}_t^X = -\overline{\mu}_t^Y - 2C$, once $\overline{\mu}_t^X$ has been specified, $\overline{\mu}_t^Y$ can be computed from it, and then L_{t+1}^X and L_{t+1}^Y can be computed from $\overline{\mu}_t^X$, L_t^X and L_t^Y by (7). We can thus write L_{t+1}^X as a function of $\overline{\mu}_t^X$, conditional on L_t^X and L_t^Y. Note that it is a strictly decreasing function, allowing us to define its inverse: $\overline{\mu}^X(L_{t+1}^X; L_t^X, L_t^Y)$, which is clearly differentiable.

Part (i) can be seen as follows. We can write the planner's first-order condition (13) in this form:.

$$\overline{\mu}^X(L_{t+1}^X; L_t^X, L_t^Y) + C = \beta[V_1(L_{t+1}^X, L_{t+1}^Y) - V_2(L_{t+1}^X, L_{t+1}^Y)], \text{ or}$$

$$\begin{aligned} &\overline{\mu}^X(L_{t+1}^X; L_t^X, L_0^X + L_0^Y - L_t^X) + C \\ &= \beta[V_1(L_{t+1}^X, L_0^X + L_0^Y - L_{t+1}^X) - V_2(L_{t+1}^X, L_0^X + L_0^Y - L_{t+1}^X)]. \end{aligned}$$

The differentiability of L_1^X can be inferred by applying the Implicit Function Theorem to this equation for $t = 0$. Given the differentiability of $L_{t'}^X$, the differentiability of $L_{t'+1}^X$ can be inferred by applying the same logic to the equation for $t = t'$. Thus, the result follows by induction.

Parts (ii) and (iii) simply follow from our results on the dynamics of adjustment, plus the requirement that $L_t^X + L_t^Y = L_0^X + L_0^Y \forall t$.

To see (iv), differentiate the planner's first-order condition with respect to L_0^X to get:

$$\overline{\mu}_1^X L_{t+1,1}^X + \overline{\mu}_2^X L_{t1}^X + \overline{\mu}_3^X L_{t1}^Y = \beta[V_{11} L_{t+1,1}^X + V_{12} L_{t+1,1}^Y - V_{21} L_{t+1,1}^X - V_{22} L_{t+1,1}^Y], \text{ or}$$

$$(\overline{\mu}_2^X - \overline{\mu}_3^X) L_{t1}^X = (\beta[(V_{11} - V_{12} - V_{21} + V_{22})] - \overline{\mu}_1^X) L_{t+1,1}^X + \beta(V_{12} - V_{22}) - \overline{\mu}_3^X,$$

where the derivatives of $\overline{\mu}_1^X$ are evaluated at $(L_{t+1}^X; L_t^X, L_t^Y)$ and the derivatives of the value function are evaluated at (L_{t+1}^X, L_{t+1}^Y). Now, since L_{t1}^X is positive but decreasing in t, it must take a limit, say, η. Taking limits of this equation as $t \to \infty$, we find:

$$\eta = \frac{\beta(V_{12} - V_{22}) + \overline{\mu}_3^X}{\overline{\mu}_2^X - \overline{\mu}_3^X - \beta[(V_{11} - V_{12} - V_{21} + V_{22})},$$

where the derivatives of $\overline{\mu}^X$ are evaluated at $(L_\infty^X; L_\infty^X, L_\infty^Y)$ and the derivatives of the value function are evaluated at (L_∞^X, L_∞^Y). Now, noting that the steady-state values must satisfy

$$\overline{\mu}^X(L_\infty^X; L_\infty^X, L_\infty^Y) + C = \beta[V_1(L_\infty^X, L_\infty^Y) - V_2(L_\infty^X, L_\infty^Y)],$$

we can differentiate this, and, using $L_\infty^X + L_\infty^Y = L_0^X + L_0^Y$ (and thus $L_{\infty 1}^X + L_{\infty 1}^Y = 1$), solve for $L_{\infty 1}^X$. But this then yields $L_{\infty 1}^X = \eta$.

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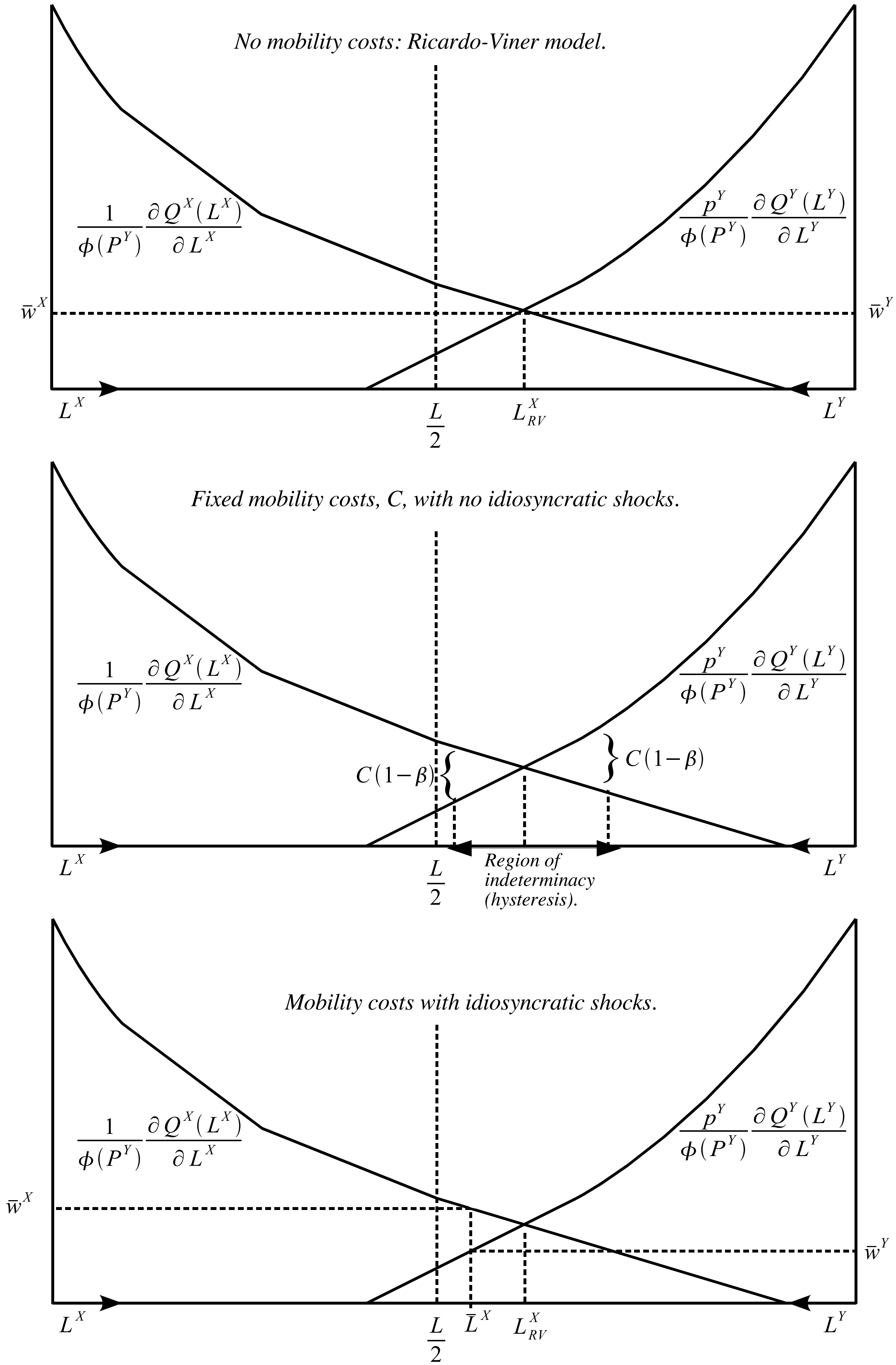

Figure 1: Steady-state allocations under different assumptions about mobility costs.

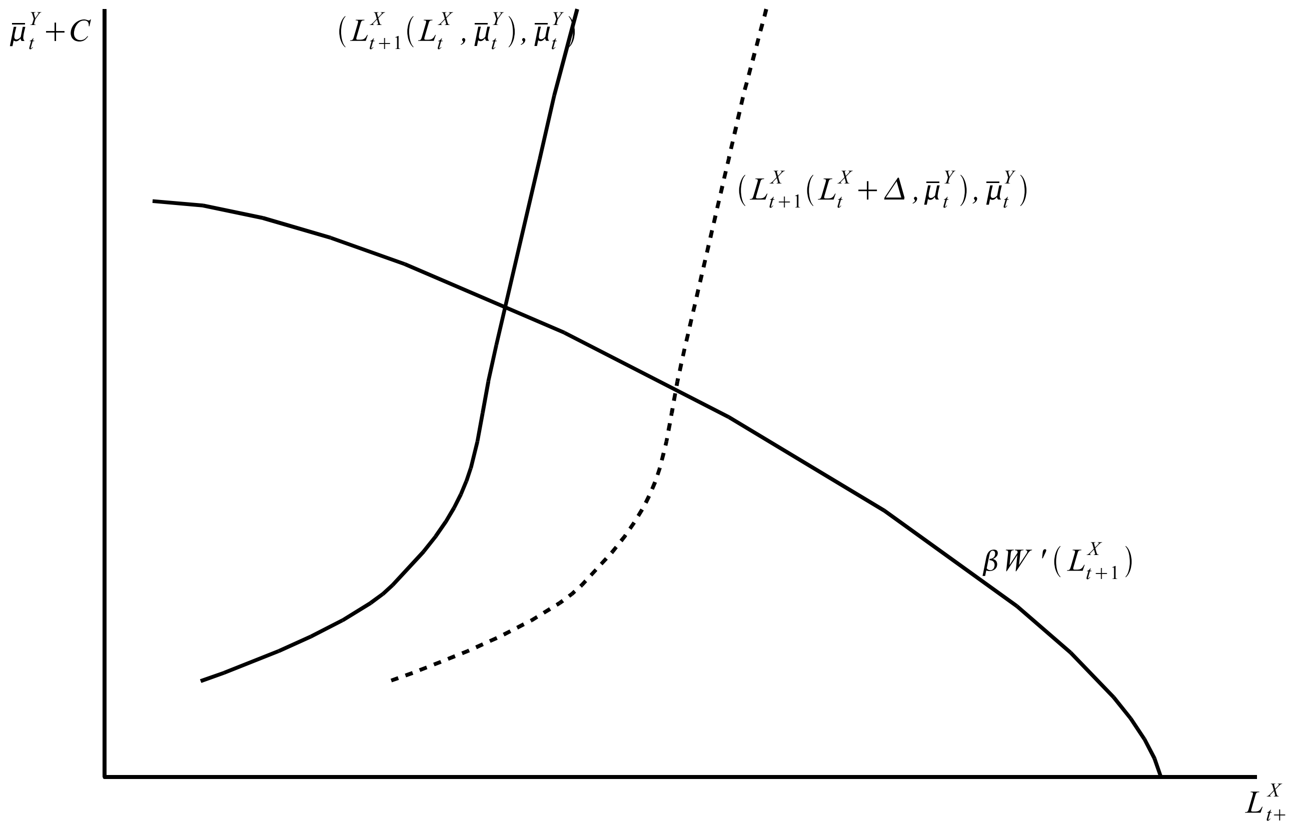

Figure 2: Determination of next-period labor allocation.

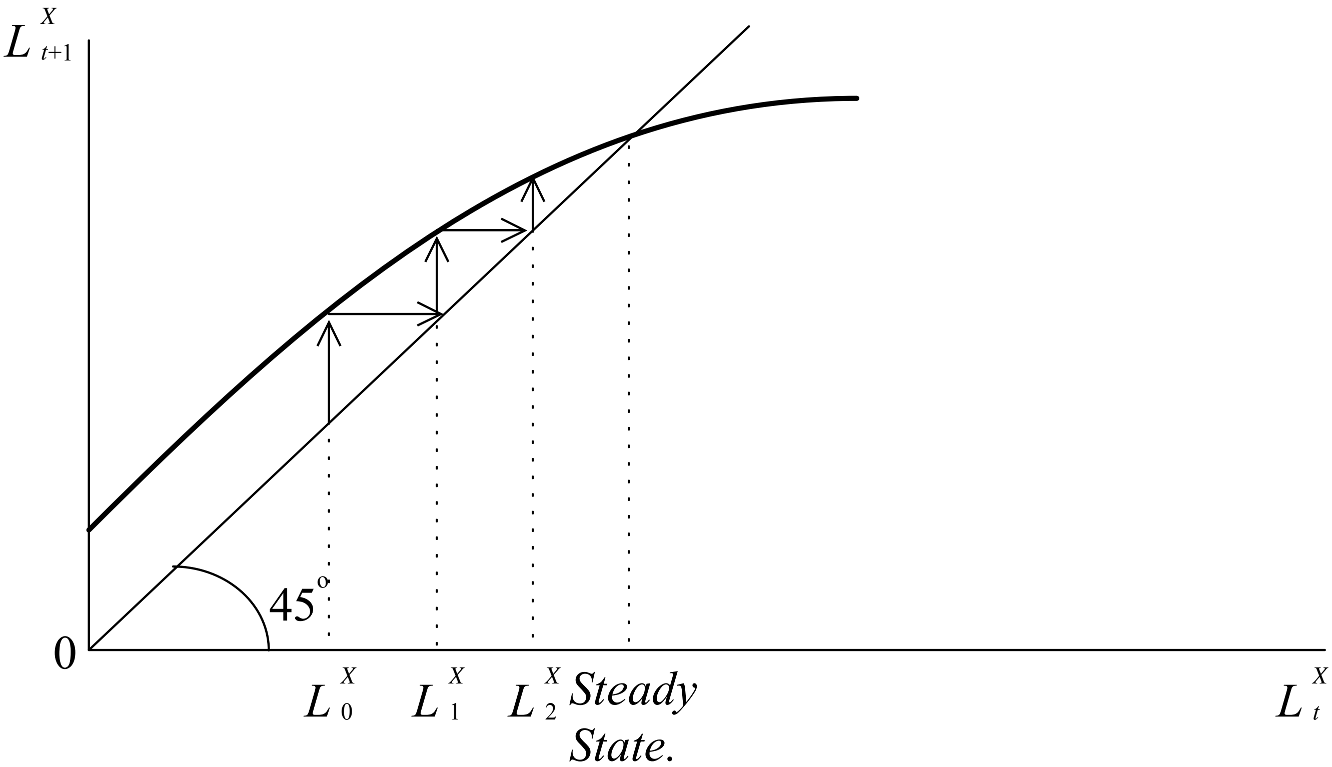

Figure 3: The Transition Function.

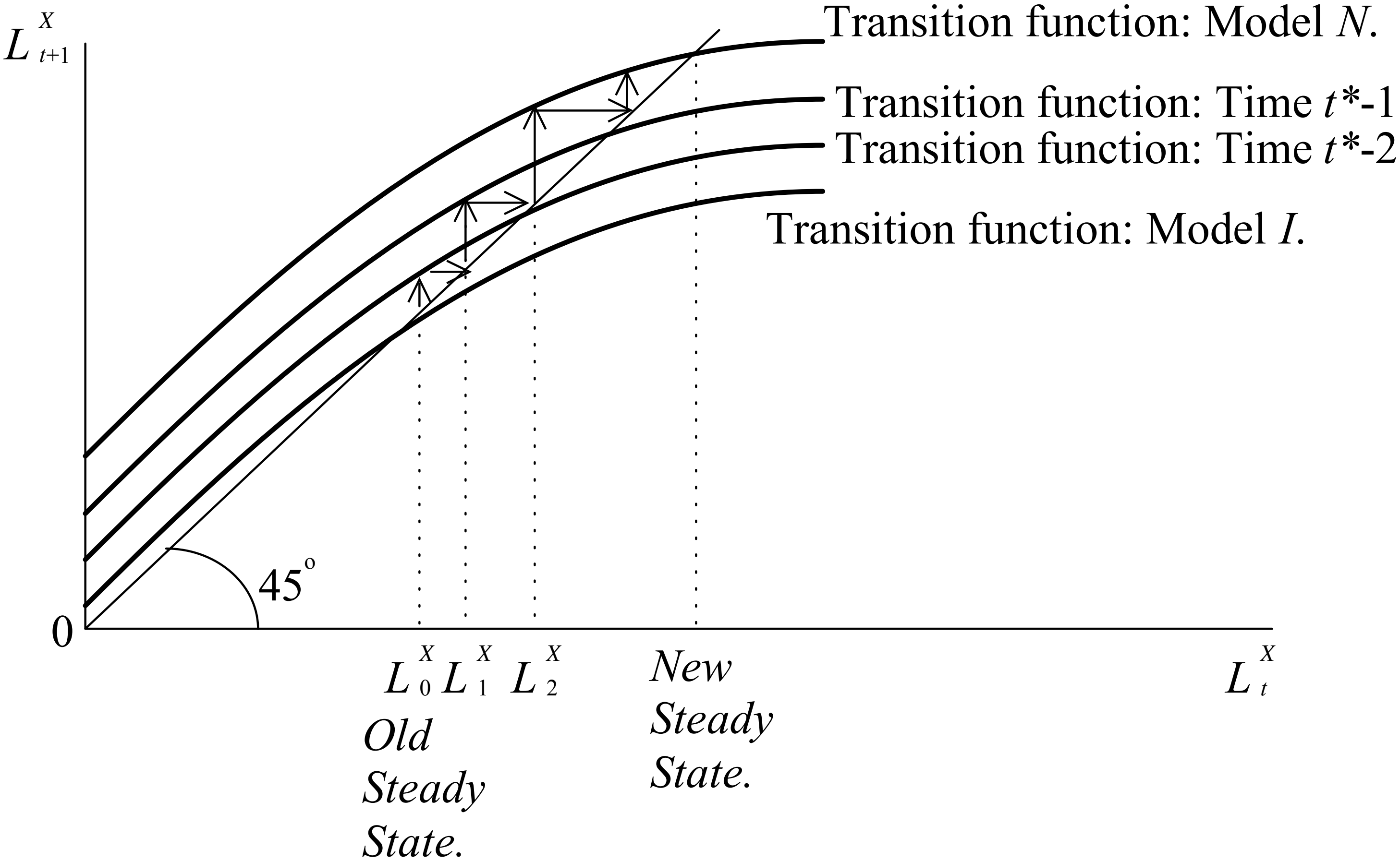

Figure 4: Anticipated Trade Liberalization..

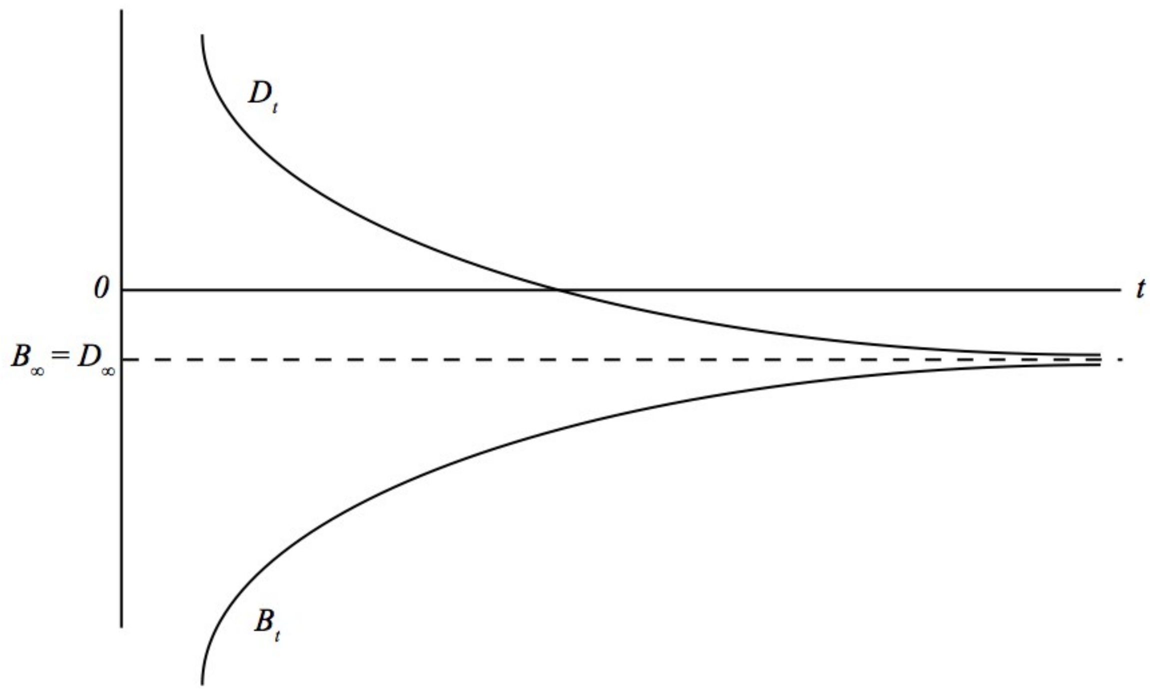

Figure 5: Derivation of the effect of delay.

Figure 6: Textile-and-Apparel Wage, Relative to Other Manufacturing.

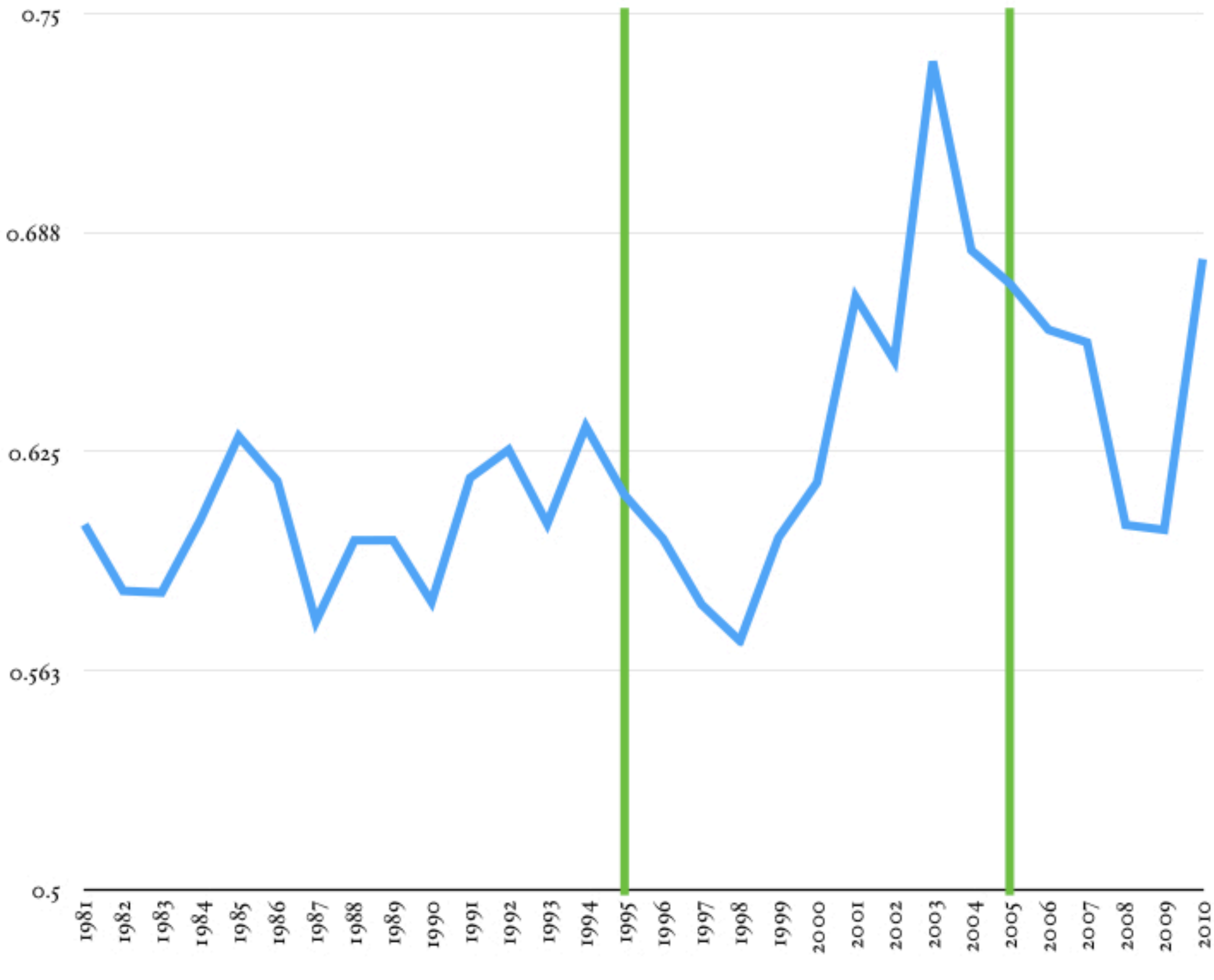

Figure 7: Employment in Textiles and Apparel as a Fraction of Total Manufacturing Employment.

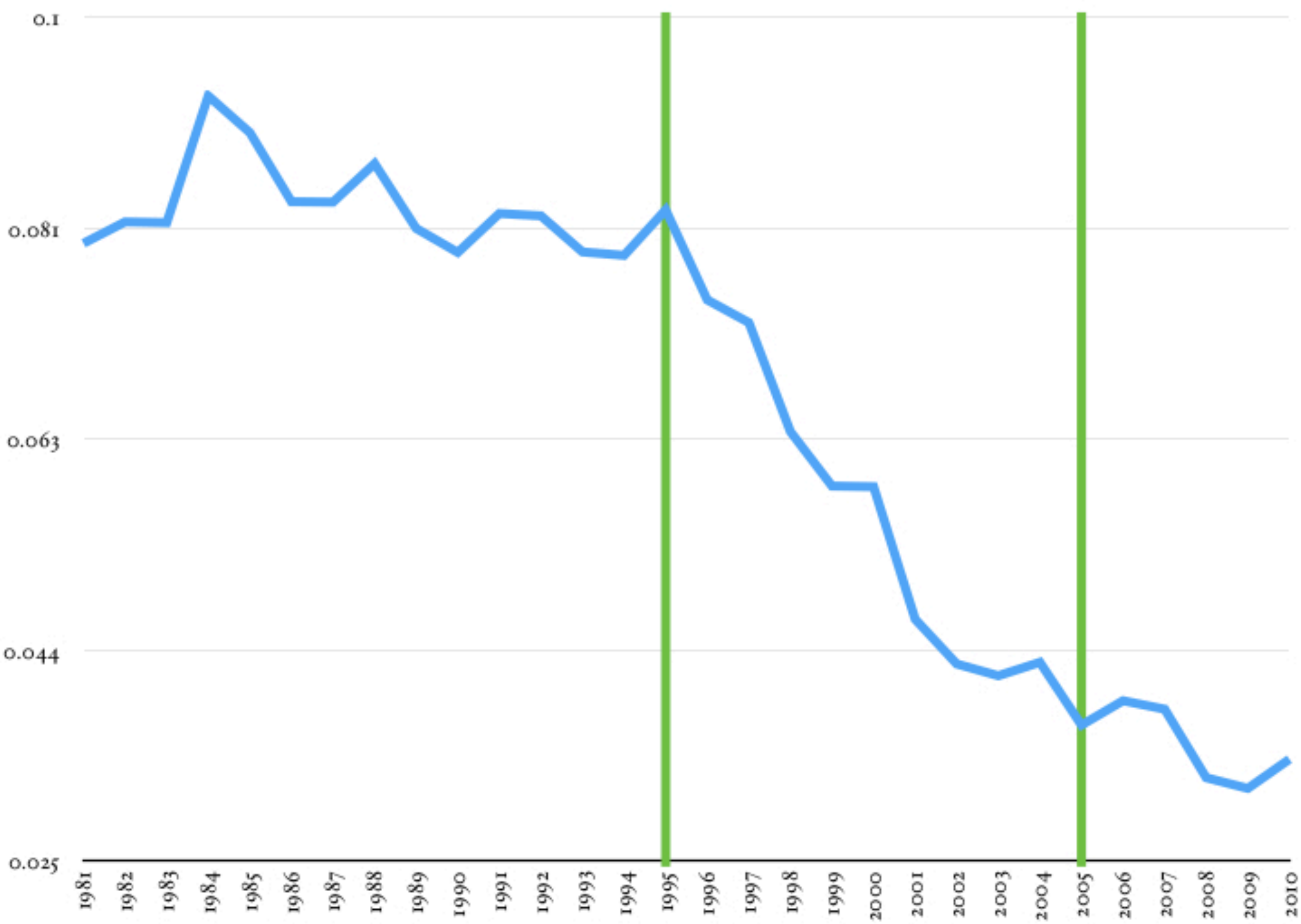

Figure 8: Relative Textile and Apparel Wage, Purged of Compositional Effects.

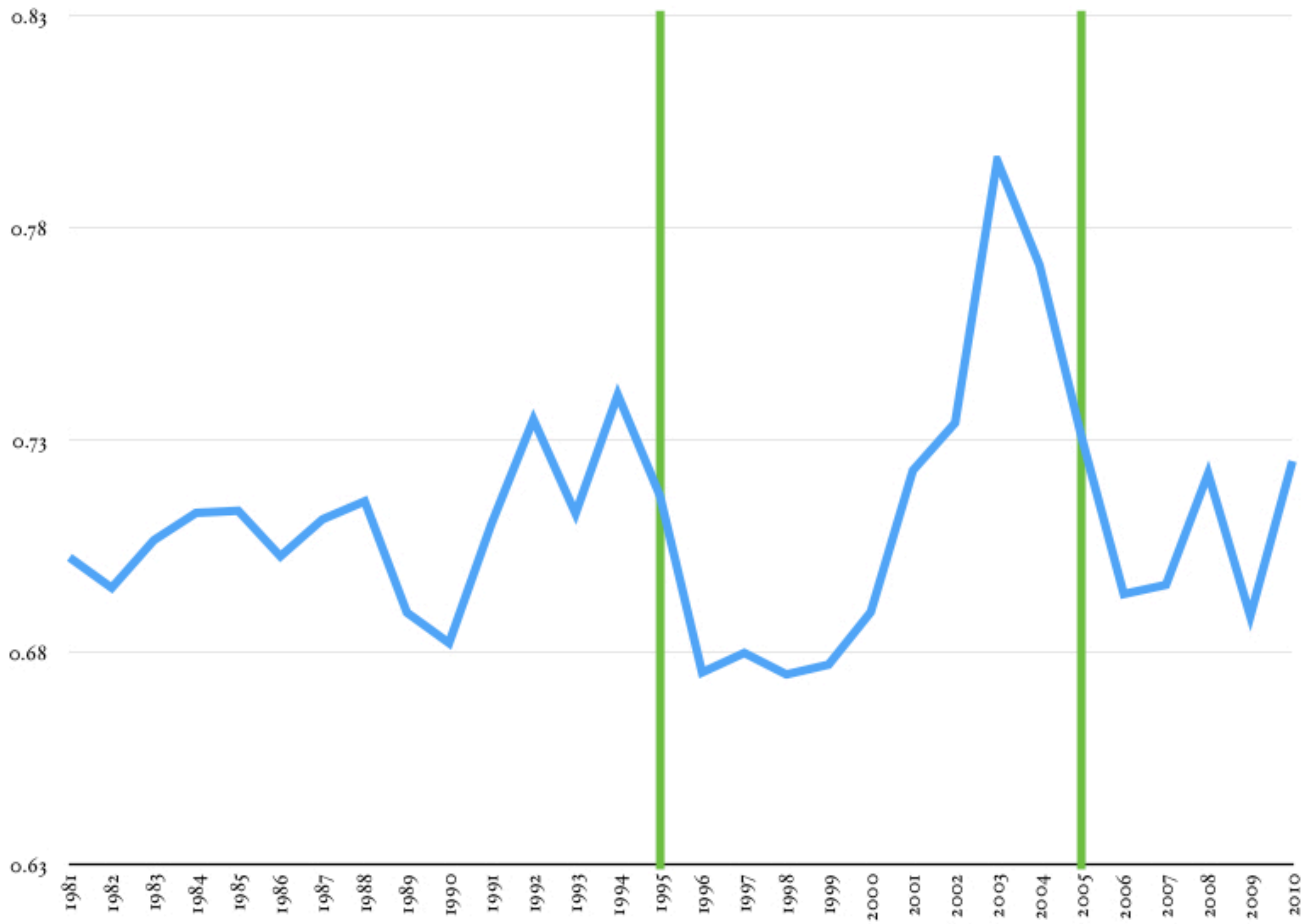

Figure 9: Fraction of Manufacturing Workers in Textiles and Apparel, Purged of Compositional Effects.