# Modeling, Measuring, and Compensating the Adjustment Costs Associated with Trade Reforms

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## 1. Introduction.

One of the most deeply-rooted tenets in neoclassical economics is that movement toward freer international trade increases aggregate economic welfare. While it is generally understood that there are costs associated with the reallocation of resources induced by trade reforms, there has been surprisingly little research focused on modeling, characterizing, measuring, and analyzing these costs in the aggregate.[1] Matusz and Tarr (2000) provide a reasonably comprehensive survey of the state of the literature as it existed in the late 1990s. Even a cursory reading of that paper reveals that there were only a small handful of studies aimed explicitly at furthering our understanding of these costs. In the absence of more concrete research, the authors of that study pieced together bits and pieces of several dozen studies that were tangentially related to adjustment in order to argue that adjustment costs are likely small relative to the overall gains from liberalization.

The work by Matusz and Tarr piqued our interest in the topic of adjustment costs, and much of our research since 2000 has been aimed at this topic.[2] This note is intended as a brief summary of our methodology and findings. Our approach is to first sketch a slightly simplified version of the model that we have found useful in our study of adjustment costs and then follow with a discussion of a variety of results that we have been able to tease from this model.

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[1] There are several prominent studies that have measured the personal costs of worker dislocation. For example Jacobsen, LaLonde, and Sullivan (1993), Kletzer (2001), and Hijzen, Upward, and Wright (2008).
[2] We have not been alone in noting this gap in the literature, as evidenced by the other research notes commissioned for this project. Two notable pieces that were published in recent years and that complement our work are Treffler (2004) and Artuç, Chaudhuri, and McLaren (2008).

## 2. A Basic Model.[3]

### *A. Labor Dynamics*

We assume that there are two sectors and labor is the only factor of production. Define *L* as the total (time-invariant) endowment of labor with $L_s(t)$ being the mass of workers associated with sector *s* at time *t*, so that $L_1(t)+L_2(t)=L$. We eventually explain how $L_s(t)$ is exogenously determined. For now, however, we take the distribution of workers across sectors as a given.

We assume that jobs in sector 1 are always available instantly to anyone who wishes to work in this sector, and that jobs in this sector are never subject to involuntary separation. In contrast, workers who wish to obtain jobs in sector 2 must first invest time and resources in training, then search for those jobs, with the search process taking further time. Moreover, jobs in sector 2 are subject to involuntary separation. Some workers who lose their jobs may be fortunate and retain their skills, thereby being able to immediately re-enter the search process. However, others are less fortunate and must again start at the bottom.

Clearly, time is an essential ingredient in this (or any) model of adjustment costs. The arithmetic used in analyzing continuous-time models tends to be neater and cleaner than the arithmetic used for discrete-time analysis. As such, we set our model in continuous time.

[3] This model is a slightly simplified version of the model that we develop in Davidson and Matusz (2000, 2004b, 2004c, and 2006). The main simplification is to strip one sector of all job turnover and assume that the marginal product of labor in that sector is independent of worker ability.

We think of transitions between states as following a Poisson process. Figure 1 illustrates the dynamics in sector 2 and sets out the notation. The rates of transition out of training, unemployment, and employment are represented by the exogenous parameters $\tau$ , *e*, and *b*, all of which are positive.[4] Given the Poisson process, the expected duration of training and unemployment, as well as the expected duration of a job are given by $1/\tau, 1/e$ and $1/b$ .

Define $\phi$ as the share of sector-2 workers who retain their skills after losing their job, and let $L_T(t)$, $L_U(t)$, and $L_E(t)$ be the mass of sector-2 workers training, unemployed, and employed at time *t*. Finally, let $L_2(t)$ be the (endogenously-determined) mass of workers associated with sector 2 at time *t*.

The labor market dynamics of sector 2 are represented by the following set of differential equations, where a dot over a variable signifies a derivative with respect to time:

(1) $\dot{L}_E(t) = eL_U(t) - bL_E(t)$

(2) $\dot{L}_U(t) = \phi b L_E(t) + \tau L_T(t) - eL_U(t)$

(3) $\dot{L}_T = (1-\phi) b L_E(t) - \tau L_T(t)$

Each of the above equations indicates that the change in the mass of workers in a given state equals the difference between the flow into that state and the flow out of that state. For example, $eL_U(t)$ is the flow from unemployment to employment, while $bL_E(t)$ is the flow out of employment.

[4] In other work, we have investigated congestion externalities and their implication for gradual adjustment to trade shocks. In order to do so, we endogenize the transition out of unemployment, making it a function of the number of workers searching for jobs. See for example Davidson and Matusz (2004a).

Let $L_E(\infty)$ represent the steady state mass of employed workers, with analogous notation defining other steady-state variables. For now, take $L_2(\infty)$ as given. We can then solve (1) – (3) to obtain

$$(4) \quad L_E(\infty) = \left( \frac{e\tau}{(1-\phi)eb + (e+b)\tau} \right) L_2(\infty)$$

$$(5) \quad L_U(\infty) = \left( \frac{b\tau}{(1-\phi)eb + (e+b)\tau} \right) L_2(\infty)$$

$$(6) \quad L_T(\infty) = \left( \frac{(1-\phi)eb}{(1-\phi)eb + (e+b)\tau} \right) L_2(\infty)$$

As we show below, the steady-state distribution of labor across sectors will depend, in part, upon trade policy. Imagine, for example, that trade liberalization results in workers moving from sector 1 (where they were fully employed) to sector 2 (where they must begin at the bottom, by training for new work). The immediate impact is that total output falls because of the reduction in sector 1 output that is not instantly compensated by greater sector 2 production. Moreover, there may be real resource costs involved in the training of sector 2 workers, as well as in the search process. As time goes on, those workers who moved to sector 2 eventually finish training and move through the search process to obtain employment. Adjustment costs in this context are measured by the lost output and resources spent in training and search along the adjustment path to the new steady state. Because of the simplicity of (1) – (3), closed-form solutions for the adjustment path are easily derivable.[5]

[5] See Davidson and Matusz (2002, 2004c) for explicit closed-form solutions to this system of equations.

*B. General Equilibrium*

To close out the model, we need to endogenize $L_2(t)$. To do so, we assume that workers are heterogeneous in ability, indexed by $a \in [0,1]$. We assume that ability only matters for the production of good 2. In particular, each worker in sector 1 can produce $q_1$ units of output, whereas a worker in sector 2 produces $q_2 a$ units of output. We assume that output markets are perfectly competitive. Combined with the assumption that labor is the only input, all revenue reverts to the worker so that wages are $w_1 = q_1$ and $w_2 = pq_2 a$ where *p* is the price of good 2 and good 1 is numeraire.

The basic decision that each worker faces is whether to take a job in sector 1 or start the training process in sector 2. Once this decision is made, the worker is carried along by the dynamics of the model (either remaining employed in sector 1 or moving through the training-search-employment process in sector 2) unless some exogenous change causes the worker to re-evaluate his choice of activity.

In order to decide the appropriate course of action, each worker has to calculate the present discounted value of the expected utility that would result from each activity. Let $V_1$ represent this value for workers employed in sector 1, while $V_T$, $V_U$, and $V_E$ represent the same terms for workers training, seeking employment, or employed in sector 2. Letting $v(w_i, p)$ represent indirect utility and $\rho$ represent the discount rate, the present discounted values for each type of worker can be found by solving the following Bellman equations:

$$(7) \quad \rho V_1 = v(w_1, p) + \dot{V}_1$$

$$(8) \quad \rho V_E(a) = v(w_2(a), p) - b\left[V_E(a) - \left(\phi V_U(a) + (1-\phi)V_T(a)\right)\right] + \dot{V}_E(a)$$

$$(9) \quad \rho V_U(a) = 0 + e\left[V_E(a) - V_U(a)\right] + \dot{V}_U(a)$$

$$(10) \quad \rho V_T(a) = -v(c,p) + \tau\left[V_U(a) - V_T(a)\right] + \dot{V}_T(a)$$

In (9), we assume that unemployed workers earn no income. The real resource cost of training is represented by *c* in (10).

Because transition rates and wages are both time invariant (except for the possibility of discrete jumps in response to changes in policy), these discounted values are also time invariant so the time derivatives in (7) – (10) are zero.

Substituting for wages, equations (7) – (10) can be solved for discounted incomes in terms of parameter values.[6] Doing so results in an expression for $V_T$ that is a (linearly) increasing function of ability, whereas $V_1$ is independent of ability. For a wide range of relative price, there exists a critical cutoff ability $\bar{a}$ such that $V_T(\bar{a}) = V_1$. Workers indexed by $a < \bar{a}$ maximize expected lifetime utility by working in sector 1, those with $a > \bar{a}$ do so by first training in sector 2, then moving up the ladder to employment. Of course, the marginal worker with ability index $\bar{a}$ is just indifferent between sectors. The determination of $\bar{a}$ is illustrated in Figure 2.

Let $F(a)$ be the distribution function for ability. Then we have:

$$(11) \quad L_1(t) = F(\bar{a})L$$

$$(12) \quad L_2(t) = \left(1 - F(\bar{a})\right)L$$

*C. Welfare*

We measure social welfare by adding up expected lifetime utilities for all individuals in the economy. Welfare at time *t* is then:

[6] For solutions, see Davidson and Matusz (2004c).

(13) $W(t) = L_1(t)V_1 + L_E(t)V_E + L_U(t)V_U + L_T(t)V_T$

This is equivalent to the present discounted value of utility net of training costs if we were to freeze the allocation of labor as it appears at time *t*. By replacing the time-t allocations of labor with their steady-state values, we obtain the steady-state value of welfare.

Let $W_{FT}(\infty)$ represent the steady-state level of welfare with free trade and $W_{TD}(\infty)$ the steady-state level of welfare in an initially trade-distorted equilibrium. If we were able to jump from one steady state to another, the present discounted value of the gain from trade would be $W_{FT} - W_{TD}$. We can refer to this difference as the *potential* gain from trade reform. However, the adjustment to the new steady state is time consuming. Let $W_A$ represent the present discounted value of utility along the economy's adjustment path moving toward free trade. That is:

(14) $W_A = \int_t^{\infty} e^{-\rho t} v\big(Y(t) - C(t), p\big)$

where $Y(t)$ is the aggregate value of gross output at time *t* and $C(t)$ is aggregate training cost.

Equation (14) takes a different form than (13) because we are allowing the distribution of employment to change along the adjustment path in (14), but not in (13). Note that the relative simplicity of the model permits us to trace out the entire adjustment path and calculate (14).

The actual gain from trade reform is $W_A - W_{TD}(\infty)$. Adjustment costs $(AC)$ represent the gap between the potential gain and the actual gain:

$$(15) \quad AC = W_{FT}(\infty) - W_A .$$

*D. Numeric Implementation*

We need a few key parameters to use this model to numerically evaluate the adjustment costs of reform. One key parameter is *b*, the job breakup rate. The theoretical interpretation of this parameter matches up well with the measures of job destruction originally conceived and calculated by Davis, Haltiwanger, and Schuh (1996) for the United States. Moreover, since their seminal work, many researchers have followed suit and calculated job destruction rates for many countries, including the United Kingdom (Konings 1995) Poland (Konings, Lehmann, and Schaffer 1996), Norway, (Klette and Mathiassen 1996), Canada (Baldwin, Dunne, and Haltiwanger 1998), Bulgaria, Hungary and Romania (Bilsen and Konings, 1998), Slovenia (Bojnec and Konings 1999), Russia (Brown and Earle 2002), Estonia (Haltiwanger and Vodopivec 2002), and Ukraine (Konings, Kupets, and Lehmann 2003).

The other key parameter, the job acquisition rate (*e*) is more difficult to pin down. This is not closely related to the job creation measures of Davis, Haltiwanger, and Schuh. The basic difference is that their measure is a rate based on firm-level employment, whereas the theory calls for a rate based on sector-specific unemployment. One way around this is to note that the inverse of this measure is the average duration of a spell of unemployment, which is clearly observable at the level of the economy. However, we need this measure to be sector specific, and that might be problematic.

Other parameters include the time and resource costs of training, as well as the probability that a worker needs to re-train after losing his job. There exists at least some research touching on these issues.

The final set of parameters includes preference parameters, the discount rate, and the parameters of the technology (determining the equilibrium wage rates). All of these can be set so that the resulting equilibrium matches up well with what a real economy might look like.

Using parameter estimates from the literature (where available) and choosing other values that seemed sensible when they were not available from the literature, we undertook a thought experiment where a "low-tech" sector where workers could train very quickly without any resource costs and move right from training into a job was initially protected by a 5 percent import tariff. We then removed the tariff, causing some workers to shift into a "high-tech sector" where training was both time-consuming used real resources. Moreover, job search subsequent to training was non trivial. But jobs in the high-tech sector were more durable and paid better wages than those in the low-tech sector.[7] We found the following[8]:

- Adjustment costs accounted for at least one third of the gross benefits from trade reform under the most optimistic scenario where training costs were low, the

[7] See Davidson and Matusz (2000, 2002, 2004c). In this exercise, we had job turnover in both sectors, but the breakup rate for jobs was higher in sector 1 (the low-tech sector) was higher than in sector 2 (the high-tech sector). In particular, we assumed that the breakup rate in sector 2 varied from $b_2 = 0.1$ (implying that the average duration of a job is 10 years) to $b_2 = 0.167$ (so that the average duration of a job in this sector is approximately 6 years. For sector 1, we assumed that either $b_1 = 1.0$ or $b_2 = 0.5$ (the average duration of a job varied between 1 year and 2 years). We maintained the assumption that training was only required in sector 2 (justifying our reference to this as the "high-tech" sector) and calibrated the model so that $\tau = 3$ (the average duration of training is 4 months) and we varied the real resource cost of training between a minimum of 1 month of the average sector-2 worker's wage to a maximum of 15 months of the average sector-2 workers wage. We assumed that $\phi = 0.8$, though our sensitivity analysis showed that the results were almost completely insensitive to the value of this parameter. We set $e = 4$ so that the average duration of unemployment was 13 weeks, consistent with U.S. experience over the long run. We assumed Cobb-Douglass preferences with consumers evenly splitting their income between the two goods. Again, sensitivity analysis showed that the preference parameter had virtually no impact on the magnitude of the results. Finally, we chose productivity and price parameters so that the initial equilibrium was characterized by a certain fraction of the labor force in the high-tech sector, with that fraction ranging from 0.20 to 0.66.

[8] These results are summarized in Table 1, which is adapted from Table 1 in Davidson and Matusz (2004c).

protected sector was large, and the discrepancy in job durability between the two sectors was minimized.

- Adjustment costs ate up as much as 80 percent of the gross benefits from trade when training costs averaged 15 months of the average high-tech worker's wage and when the protected sector was relatively small.
- Ignoring the resource costs of training reduced the adjustment costs considerably, though these costs could still be as high as 25 percent of the gross gains from trade. On the low end, however, adjustment costs were much smaller, accounting for only 5 percent of the gross gains from trade.
- As expected, net output dips right after liberalization as workers shift into a sector that requires significant training and search. Net output did not return to its pre-liberalization level for more than a year, and in some scenarios it took as long as two and one half years before net output reached its pre-liberalization level. These figures were roughly halved when we looked only at gross output, not adjusting for the real resource costs of training.[9]

3. Other Issues.

We have studied various features of this model in our exploration of adjustment costs. We note some of our findings in this section.

[9] Using a different model of adjustment (where workers are always fully employed, but incur non-pecuniary idiosyncratic moving costs in switching sectors), Artuç, Chaudhuri, and McLaren (2008) find that approximately 8 years are required before adjustment is 95 percent complete. This metric is somewhat different than the one we used, but a casual glance at Figures 4 and 5 in Davidson and Matusz (2000) would suggest that in our framework adjustment would be 95 percent complete somewhere in the range of 5 years.

Despite the fact that labor is the only input, there are winners and losers from trade liberalization. This follows from the fact that labor is heterogeneous in ability. Workers who are in the export oriented sector prior to liberalization (the "incumbents") gain unambiguously. Those who remain in the import-competing sector subsequent to liberalization (the "stayers") are unambiguously harmed. Those who switch sectors (the "movers") bear the entire adjustment cost. The lower-ability workers in this segment are harmed by liberalization, while the higher ability workers benefit. This is consistent with the empirical evidence on the experience of displaced workers.[10]

Any labor-market policy (short of lump-sum transfers) aimed at compensating those harmed by trade reform effectively results in the replacement of one distortion with another. Our research in this area shows that the least distorting policies are those that are tied to the ex post wage (e.g., wage subsidies) if the target group involves the movers, whereas the least distorting policies are independent of the wage (e.g., employment subsidies) if the target group centers on those trapped in the import-competing sector. In the first instance, the subsidy encourages excessive movement, but a wage subsidy minimizes this effect because the marginal mover has a relatively low wage compared with the average mover, so the subsidy that fully compensates the group of movers is relatively small for the marginal mover. In contrast, policies softening the blow to the stayers discourage movement. Since the marginal stayer in this case has higher ability than the average stayer, policies that are independent of the wage (ability) will minimize the resulting distortion.

[10] Kletzer (2001, Table 3.1) finds that more than one third of displaced workers find re-employment at wages equal to or higher than their pre-displacement wage.

We work out the full analysis of compensation in Davidson and Matusz (2006b). In that paper, we apply numeric techniques similar to those we used in getting a handle on the magnitude of adjustment costs to get some sense of the costs of compensation (measured as the size of the resulting distortion relative to the gain from trade). We find that using the correct policy creates very little deadweight loss, ranging from well under 1 percent of the gains from trade to approximately 30 percent of the gains from trade, depending upon parameter assumptions and the particular scenario studied. However, using the wrong policy causes these costs to balloon, in some cases more than doubling for the same set of parameter values and the same scenario.

One might think that even the free-trade equilibrium of our model is distorted since wages differ by sector. Indeed, the marginal worker is indifferent between the low-wage and the high-wage sector. Since the wage reflects productivity, it would seem sensible to induce at least some workers near the margin to move to the high-wage sector. But the laissez faire equilibrium in this model is not distorted. Workers make the right choices by maximizing the discounted value of expected lifetime utility. What the above story misses is that it is not possible to move a worker employed in the low-wage sector directly into employment in the high-wage sector. While the value of output may ultimately increase by moving in this direction, there are initial losses that more than offset any future gain. We analyze this issue in detail in Davidson and Matusz (2006a).

One of the key assumptions that leads to efficiency of the laissez faire equilibrium is the assumption that the job acquisition rate is exogenous. We pursue a different route in Davidson and Matusz (2006b) where the acquisition rate is subject to congestion externalities. In that framework, escape-clause policies that are explicitly temporary trade limitations in response to unexpected global shocks can increase social welfare by slowing the adjustment process and partially offsetting the externality.

## 4. Strengths and Weaknesses

We clearly think that our approach to modeling adjustment has much to offer. The analysis is framed within an internally-consistent general-equilibrium model that is squarely in the tradition of the simple general equilibrium models often used to explore trade and policy issues. The arithmetic for undertaking comparative steady-state analysis is clean and (while somewhat messy) it is possible to explicitly derive closed form solutions for the adjustment path. The key parameters are small in number and (with perhaps one key exception to be noted below) empirically observable. The model allows for heterogeneous outcomes among workers and permits calculation of an explicit, well defined measure of adjustment costs as well as an explicit, well defined measure of the gains from liberalization. The numeric results are plausible.

Some of the benefits of our approach can be seen by a comparison with Trefler's (2004) excellent empirical study of the short-run costs and long-run benefits of the Canada-U.S. free trade agreement (CUSTA). As in our methodology, Trefler is able to examine the effects of the creation of trade preferences on a variety of outcomes (including employment and productivity) within the context of a coherent framework. Despite his examination of 213 industries, however, his is not a true general-equilibrium analysis. Moreover, he is able to conclude that CUSTA reduced Canadian manufacturing employment by 12 percent (an adjustment cost) while creating large increases in industry-wide productivity. However, he is only able to suggest that the employment effect was transitory (amounting to an adjustment cost) while the productivity effect was permanent (translating into the benefit of liberalization). In any event, the magnitudes of the employment effect and productivity effect cannot be meaningfully aggregated to draw any conclusions about the magnitude of the adjustment cost relative to the benefits of trade.

On the flip side, Trefler's analysis also has strengths that shine a light on some of the weaknesses of our model. Trefler's work is, after all, an econometric undertaking. As such, he is able to talk about issues such as statistical significance and so on, whereas our model is not able to draw those sorts of conclusions. In addition, by ignoring the general-equilibrium effects, Trefler is able to examine many sectors simultaneously. While it is possible to add sectors to our model, the results become muddied. For example, imagine just three sectors such that workers with the lowest ability self-select into sector 1, those with intermediate ability self-select into sector 2, and those with the highest ability go to sector 3. Suppose now that liberalization results in a simple change in the price of good 2. For example, suppose that the price of good 2 falls relative to the prices of goods 1 and 3. This will cause exit from sector 2, with lower-ability workers in this sector moving to sector 1, and higher ability workers in this sector moving to sector 3. This is only one possible scenario, but already it is possible to see how the complications can mushroom.[11]

Another weakness of our model is that the numeric results depend upon the magnitude of the job acquisition rate ($e$ in equation 1). As we noted earlier, empirical

[11] This does not even take into account the standard issues regarding the difficulty of determining trade patterns and resource allocation when the number of sectors exceeds 2.

measures of job destruction are conceptually close to our job breakup rate (*b* in equation 1), but the same cannot be said for empirical measures of job creation.

Finally, our model cannot get at the within-sector changes in productivity identified by Melitz (2003) resulting from the expansion of high-productivity firms as low-productivity firms are eliminated by trade reform.[12]

While not an inherent weakness of our model, we should note that our frame of reference is an industrialized economy that is generally free from distortions other than those pertaining to trade. Application to developing countries might require suitable modifications to account for an informal sector, substantial state-owned enterprises, and other characteristics of such economies.

[12] We touch on this issue in Davidson, Matusz, and Shevchenko (2008), though we only explore comparative steady-states in that model.

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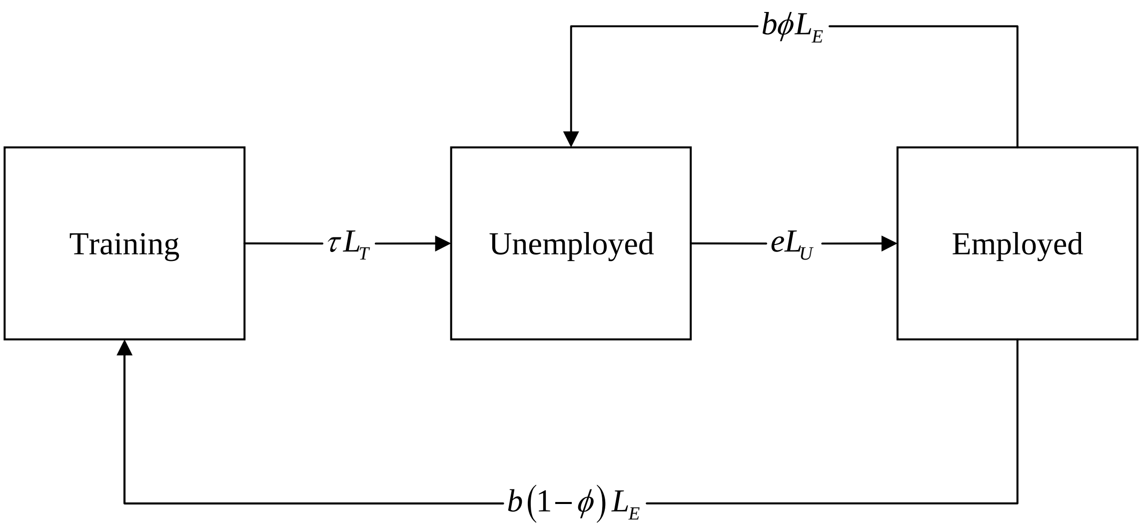


Figure 1

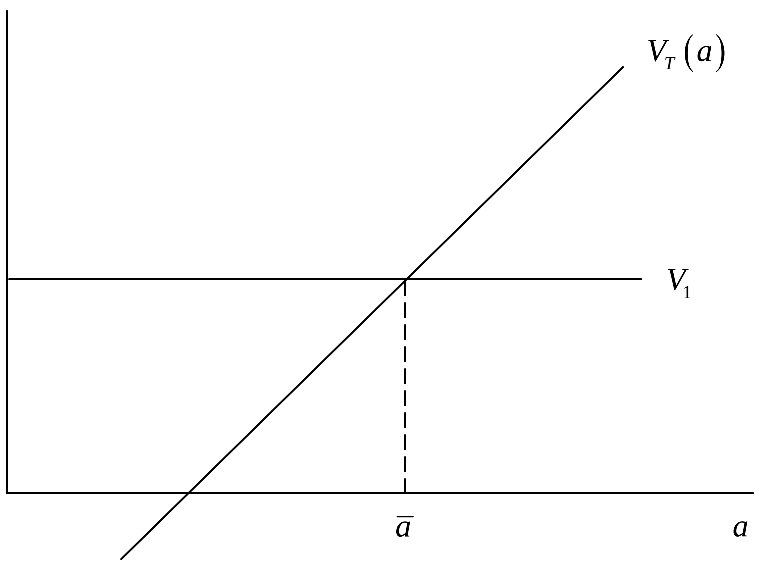


Figure 2

Table 1

One third of labor force in the initially-protected sector

| Training Cost | Adjustment cost as a share of gross benefit of trade reform |
|---|---|
| 1 month | 0.39 |
| 15 months | 0.80 |

Two thirds of labor force in the initially-protected sector

| Training Cost | Adjustment cost as a share of gross benefit of trade reform |
|---|---|
| 1 month | 0.34 |
| 15 months | 0.72 |

| Training Cost | Years before output returns to its pre-liberalization level |
|---|---|
| 1 month | 1.3 |
| 15 months | 1.5 |

Notes: Training cost is measured as the number of months worth of wages for the average high-tech worker. The number of years before output returns to its pre-liberalization level is insensitive to the initial share of the workforce in the protected sector. These examples were calculated assuming that the average duration of a job in the low-tech sector is 2 years, while the average duration of a job in the high-tech sector is 10 years.