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Trade Liberalization and Compensation

By C. Davidson and S.J. Matusz

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The Authors

Carl Davidson and Steve Matusz are External Research Fellows in the Leverhulme Centre for Research on Globalisation and Economic Policy in the School of Economics, University of Nottingham and Professors of Economics at Michigan State University, USA.

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Abstract

Trade liberalization harms some groups while generating aggregate net benefits. In this paper we investigate the best way to compensate those who lose from freer trade. We consider four labor market policies: wage subsidies, employment subsidies, trade adjustment assistance (i.e., unemployment insurance) and training subsidies. Our goal is to find the policy that fully compensates each group of losers at the lowest cost to the economy (in terms of deadweight loss). We argue that the best way to compensate those who bear the adjustment costs triggered by liberalization is with a temporary targeted wage subsidy while the best way to compensate those who remain trapped in the previously protected sector is with temporary targeted employment subsidies. Our analysis also indicates that the cost of achieving full compensation is relatively low.

Outline

1 Introduction

Two of the most generally accepted propositions in economics are that trade liberalization harms some groups but that it also generates aggregate net benefits. In fact, there are large literatures devoted to identifying the winners and losers from freer trade and measuring their gains and losses. Yet, there has been surprisingly little research aimed at investigating the best way to go about compensating those who lose. Using a traditional, full employment model of trade Dixit and Norman (1980, 1986) have argued that it is possible to use commodity taxes to compensate the losers without exhausting the benefits from freer trade. This is an important finding since it indicates that with such a compensation scheme in place, trade liberalization would always lead to a Pareto improvement. Brecher and Choudhri (1994) have raised concerns about this result by showing that in the presence of unemployment this scheme may not work. They show that in such a setting, under reasonable conditions, fully compensating the losers may eat away all of the gains from trade. Feenstra and Lewis (1994) have shown that similar problems arise when factors of production are imperfectly mobile. However, they demonstrate that the situation can be remedied by augmenting the Dixit-Norman scheme with policies aimed at enhancing factor mobility. In particular, they show that the use of commodity taxes ***coupled*** with trade adjustment assistance may be adequate to achieve true Pareto gains from liberalization. Freenstra and Lewis do not ask whether there is a superior way to achieve this goal. In fact, we know of no paper that tries to determine the best way to compensate those who are harmed by liberalization.

In contrast, the policy community has been interested in this question for quite some time. Much of the recent policy debate may have been triggered by findings that the ***personal*** cost of worker dislocation may be quite high. For example, Jacobson, LaLonde, and Sullivan (1993a, b) find that the average dislocated worker suffers a loss in lifetime earnings of $80,000! Keltzer (2001) also finds that the losses are non-trivial, but her estimates are less dramatic. Focusing on the reduction in wages that these workers eventually accept in order to find new jobs, she finds that the average dislocated worker accepts a 12% pay cut. The policy debate has centered on labor market policies that could be used to alleviate the burden placed on such workers.[1] Among the policies that have been considered are wage subsidies, employment subsidies (sometimes referred to as "reemployment bonuses"), trade adjustment assistance (usually in the guise of unemployment insurance) and training subsidies.[2] Many of the recent contributors to this debate have focused attention on wage subsidies largely because of their incentive effects – wage subsidies reward work and encourage dislocated workers to return to work quickly. In contrast, trade adjustment assistance lowers the opportunity cost of unemployment, resulting in longer spells of unemployment.

In this paper we compare a variety of labor market policies to determine the best way to compensate the groups that are harmed by liberalization.[3] We consider this to be an

[1] For other contributions to the debate, see Baily, Burtless and Litan (1993), Burtless, Lawrence, Litan, and Shapiro (1998), Parsons (2000), Kletzer and Litan (2001), and Hufbauer and Goodrich (2001).

[2] In a recent policy brief that has generated much discussion, Kletzer and Litan (2001) argue that the best way to compensate dislocated workers is with "wage insurance" which is essentially a wage subsidy. See also Hufbauer and Goodrich (2001) who suggest a similar but more generous policy

[3] We do not allow the government to redistribute income via commodity or income taxes. Thus, we rule out the type of compensation scheme envisioned by Dixit and Norman (1980, 1986). There are at least two reasons for this. First and foremost, we know of no government that has ever considered such a scheme to compensate workers harmed by changes in trade pattern. In contrast, the labor market policies that we

important question. The objections of those who will be harmed if trade barriers are removed create roadblocks that make freer trade difficult to achieve. Coupling liberalization with an adequate compensation scheme is one way to secure general agreement about trade policy. However, compensating the losers distorts the economy and reduces welfare. Our goal is to find the labor market policy that fully compensates each group while imposing the smallest distortion on the economy.

To compare these policies, we develop a model of trade in which workers seeking employment must first complete costly training and search processes. The government can reduce the costs imposed on these workers by subsidizing training and/or offering unemployment benefits to searching workers. Alternatively, the government can augment the compensation received by employed workers through wage or employment subsidies.

There are two types of jobs in our economy. First, there are low-tech jobs that require few skills, are easy to find, pay low wages, and are not very durable. Second, there are high-tech jobs that require significant skills, are relatively difficult to obtain, pay high wages, and last for a long time. Workers differ in terms of ability with higher-ability workers producing more output in a given sector than their lower-ability counter-parts. In equilibrium, workers separate with low-ability workers attracted to the low-tech sector and high-ability workers attracted to the high-tech sector. If we refer to the worker who is just indifferent between training for high and low-tech jobs as the "marginal worker,"

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consider are at the center of the policy debate on dislocated workers. Second, some authors have raised concerns about the practicality of the Dixit-Norman scheme. As we mentioned above, Brecher and Choudhri (1994) argue that the scheme may not work in the presence of unemployment. Spector (2001) then this implies that the average low-tech worker has lower ability than the marginal worker while the average high-tech worker has a higher ability level than the marginal worker. This distinction plays an important role in our policy analysis.

We assume that in the initial equilibrium the low-tech sector is protected by a tariff. As a result, some workers who, in terms of economic efficiency, should be employed in the high-tech sector are attracted to the low-tech sector instead. We then assume that the tariff is removed and allow the economy to move to the new equilibrium. The model is simple enough that we are able to solve for the adjustment path across steady states. This allows us to take the transition period into account when calculating welfare. We show that there are two groups of workers who are harmed by liberalization. First, there are the "stayers" – those workers who remained trapped in the low-tech sector because it would be too costly for them to acquire the skills required for high-tech jobs. Second, there are the "movers" – those workers who switch sectors after the tariff is removed. While the movers eventually gain by securing higher wages, they bear the burden of the adjustment costs imposed on the economy by liberalization. They must go through a costly training process to acquire high-tech skills and then engage in costly search in order to find new jobs. We show that for reasonable parameter values, these costs usually outweigh the long-term gains so that, as a group, the movers lose.

Removing the tariff and allowing the economy to adjust to the free-trade equilibrium leads to the highest level of aggregate welfare. However, we assume instead that the

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argues that the scheme may not work when borders are open. See also Kemp and Wan (1986, 1995) who raise concerns about the assumptions required to prove the Dixit-Norman result.

government wants to compensate these two groups for their losses. Any attempt to do so creates a distortion, reducing welfare. We compare wage subsidies, employment subsidies, trade adjustment assistance (i.e., unemployment benefits) and training subsidies to see which policy achieves full compensation at the lowest cost to the economy. We find that there are three rules that a compensation scheme should satisfy. The first two are simple -- any policy should be temporary and targeted. For example, if a wage subsidy is to be used to compensate the movers, then it should only be offered for a limited time (e.g., for the duration of the first spell of post-liberalization employment) and it must be offered only to those who switch sectors after the tariff is removed.

The third rule is more subtle and focuses on how the policies affect the average and marginal workers in the targeted group. The policy's impact on the average targeted worker is important because it determines how big a program will be needed to compensate the group. If the average targeted worker's expected lifetime utility is highly sensitive to the policy parameter, then only a modest sized program will be required to fully compensate the group. The impact of a policy on the marginal worker determines the size of the distortion that the compensation scheme imposes on the economy. If the marginal worker's expected lifetime utility is highly sensitive to the policy parameter, then even a modest sized program may trigger a great deal of inefficient relocation by workers resulting a large distortion. It follows that the best policy will be one that has a large impact on the average mover and a small impact on the marginal worker.

Applying these rules, we find that the best way to compensate the movers is with a temporary targeted wage subsidy. The subsidy is paid only to those who switch sectors after the tariff is removed and it lasts no longer than the duration of the first-spell of post-liberalization high-tech employment. Under such a policy, high-ability movers (who earn a higher wage) collect more compensation than their low-ability counter-parts. When compensating the movers, this is a desirable feature -- since the average mover has higher ability than the marginal mover, a wage subsidy has a relatively larger impact on the welfare of the average mover. As a result, it is possible to fully compensate the movers with a modest sized program that creates only a small distortion. It is worth noting that, since unemployment benefits are tied to the worker's wage on her previous job, trade adjustment assistance has this same attractive feature. However, the disincentive effects of unemployment insurance, which have been emphasized in the policy community, make wage subsidies the more desirable policy.

In contrast, the best way to compensate the stayers is with a temporary targeted employment subsidy. This subsidy, which would be independent of the worker's wage, would be paid to workers holding low-tech jobs at the time of liberalization and to any worker who obtains a job in that sector shortly thereafter. It would last no longer than the duration of one spell of low-tech employment. This policy works better than wage subsidies because the average low-tech worker earns a lower wage than the marginal worker. Thus, while the wage subsidy would be relatively more valuable to the marginal worker, an employment subsidy affects the average and marginal stayers equally. It follows a wage subsidy would generate a larger distortions than an employment subsidy.

The paper divides into five additional sections. In Section 2, we introduce our model and characterize the initial tariff-distorted equilibrium. Section 3 is devoted to describing how the economy adjusts to the new equilibrium after liberalization under the assumption no compensation scheme is in place. We identify the groups that lose from liberalization and try to quantify their losses. In Section 4, we focus on the movers and determine which of the labor market policies allow the government to fully compensate this group while imposing the smallest distortion on the economy. In Section 5, we repeat this analysis for the stayers. One of the results that we find is that for reasonable parameter values, the cost of compensating either group is very small relative to the gains from trade, provided that the right policy is used. However, if the wrong policy is used, particularly when trying to compensate the stayers, it is possible to completely wipe out all of the benefits from freer trade. We conclude the paper in Section 6.

2 The Model

We consider a continuous time model of a small open economy with a total measure of L consumers. These consumers vary in ability with a_i denoting the ability of consumer i. For simplicity, we assume that a_i is uniformly distributed on [0,1].

The economy consists of two sectors – a low-tech sector (sector 1) and a high-tech sector (sector 2). In order to obtain a job, a worker must first acquire the appropriate skills and then search for suitable employment. Workers who are training for sector j jobs exit the training process at rate τ_j and the sector j job acquisition rate is e_j. While training, each sector j worker incurs a flow training cost of $c_j p_j$ where p_j is the price of the sector j good (so that sector j training costs are measured in terms of the sector j good). Once suitable employment is found, a sector j worker is paid a wage of w_j as long as the job lasts. Sector j jobs break up at rate b_j, and, once they do, workers must retrain if their skills are firm specific. If, however, their skills are sector specific, then the worker may immediately reenter the search process (provided that she does not switch sectors). We use ϕ_j to denote the probability that a sector j worker's skills transfer across sector j jobs after termination. It follows that in sector j the expected duration of training is $1/\tau_j$, the expected duration of unemployment is $1/e_j$, the expected duration of employment is $1/b_j$ and the probability that a worker will have to retrain after losing her job is $1-\phi_j$.

The dynamics of the labor market are summarized in Figure 1 and the following set of differential equations. We use $L_{jk}(t)$ to denote the measure of sector j workers in labor market state k at time t (where $k = T$ denotes training, $k = S$ denotes searching and $k = E$ denotes employed), $L_j(t)$ to denote the measure of workers attracted to sector j at time t and $\dot{X}(t)$ to denote the rate of change for variable $X(t)$.

(1) $$\dot{L}_{jE}(t) = e_j L_{jS}(t) - b_j L_{jE}(t)$$

(2) $$\dot{L}_{jS}(t) = \tau_j L_{jT}(t) + b_j \phi_j L_{jE}(t) - e_j L_{jS}(t)$$

(3) $$L_j(t) = L_{jE}(t) + L_{jS}(t) + L_{jT}(t)$$

In (1) and (2), the rate of change is the difference between the flows into and out of each labor market state. For example, in (1) $e_j L_{jS}(t)$ is the flow into sector j employment since this is the measure of searchers who find employment at time t while $b_jL_{jE}(t)$ is the flow out of sector j employment since this is the measure of workers who lose their jobs at time t. Similar logic explains (2) -- $\tau_jL_{jT}(t)$ is the measure of sector j trainers who complete the training process and begin searching for jobs at time t, $b_j\phi_jL_{jE}(t)$ is the measure of sector j workers who lose their job but immediately reenter the search process at time t because their skills transfer across sector j jobs and $e_jL_{jE}(t)$ is the measure of sector j searchers who find employment at time t. Finally, (3) is an accounting identity stating that workers tied to sector j must either be employed, searching or training.[4]

We can use (1) – (3) to determine the measure of workers in each labor market state once we know how many workers are attracted to each sector (L_1 and L_2). These values are determined by worker behavior. We assume that workers are free to change occupations at any point, but when they do so they must first enter the training process. It follows that, in equilibrium, searching and employed workers never switch sectors. In fact, small changes in parameters or world prices never result in searchers or employed workers changing occupations – all labor reallocation involves the trainers.

Each worker's choice of an occupation is based on the lifetime income that they expect to earn in each sector. When workers initially enter the labor market they have no skills. Thus, their initial choice depends on the values of V_{1T} and V_{2T}, which measure expected lifetime income for a worker training in sectors 1 and 2, respectively. If we define V_{jS} as the expected lifetime income for a sector j worker who is currently searching for a job,

[4] We could add another differential equation similar to (1) and (2) to describe the flows into and out of training. But, with (3) this equation would be redundant.

use V_{jE} to denote the expected lifetime income for an employed worker in sector j and use r to denote the interest rate, then we have the following asset value equations

$$rV_{jT}(t) = -c_j p_j + \tau_j [V_{jE}(t) - V_{jT}(t)] + \dot{V}_{jT}(t) \tag{4}$$

$$rV_{jS}(t) = 0 + e_j [V_{jE}(t) - V_{jS}(t)] + \dot{V}_{jS}(t) \tag{5}$$

$$rV_{jE}(t) = w_j(a_i) + b_j [\phi_j V_{jS}(t) + (1-\phi_j) V_{jT}(t) - V_{jE}(t)] + \dot{V}_{jE}(t) \tag{6}$$

In each equation, the first term on the right hand side represents current income. For employed workers, current income is equal to the wage they earn, which depends on their ability. Trainees and searching workers earn nothing while unemployed, and trainees must pay training costs while acquiring their skills. Thus, current income for searchers is equal to zero while trainees lose their training costs. The second term on the right hand side is the product of the capital gain (or loss) from changing labor market status and the rate at which such changes take place. For example, the flow rate from searching to employment in sector j is e_j while the capital gain associated with employment is $V_{jE} - V_{jS}$. Note that for employed workers there are two possibilities when they lose their job. With probability ϕ_j they retain their skills and can begin to search for a new job immediately, while with the remaining probability they must retrain before they can seek a new job. The last term on the right hand side is asset's rate of appreciation at time t.

We assume that in each sector workers are paid the value of their marginal product and that the output that they produce is proportional to their ability. Specifically, we assume that a worker with ability level a_i who is employed in sector j produces a flow of q_ja_i units of output as long as she is employed. We also assume that the low-tech sector is initially protected by a tariff denoted by γ. It follows that

$$(7) \qquad w_1(a_i) = p_1(1+\gamma)q_1a_i; \qquad\qquad w_2(a_i) = p_2q_2a_i$$

Jobless workers without skills train in the sector 1 if $V_{1T}(t) \geq \max\{V_{2T}(t),0\}$ and they choose to train in the high-tech sector if $V_{2T}(t) \geq \max\{V_{1T}(t),0\}$. Workers with a_i such that $0 \geq \max\{V_{1T}(t), V_{2T}(t)\}$ stay out of the labor market since it is too costly for them to train for any job. These workers are effectively shut out of the labor market – there are no jobs available for them since their training costs exceed any income that they could expect to earn after finding employment. A worker who is searching for a sector j job continues to do so if $V_{jS}(t) \geq V_{kT}(t)$; otherwise, she quits searching, switches sectors and starts training in sector k. Finally, a worker who holds a sector j job quits, switches sector and enters the sector k training process if $V_{kT}(t) \geq V_{jE}(t)$; otherwise, she continues to hold the job until an exogenous shock causes it to dissolve.

This completes the description of the model. To characterize equilibrium we must place restrictions on the parameters. While we will be much more precise about the values of the parameters in the next section, it is useful to sketch out the ideas that we are trying to capture in our model. What we have in mind is an economy in which higher ability workers are better suited to produce the high-tech good. We imagine that workers with high enough ability to choose between the two types of jobs know that they can find low-tech jobs without much effort and can master the skills they require rather easily.[5] However, they also know that these jobs do not pay well, do not last long and require skills that are largely job-specific.[6] In contrast, we want high-tech jobs to require significant training and be relatively hard to find (because the matching problem is harder to solve) but durable. Moreover, high-tech skills are much more likely to transfer across jobs than low-tech skills.[7] We capture these ideas assuming that τ_1 is higher than τ_2, b_1 is higher than b_2 (low-tech training is quicker than high-tech training and low-tech jobs do not last as long as high-tech jobs), and by setting $e_1 = \infty$ and $c_1 = \phi_1 = 0$. Thus, low-tech jobs are obtained immediately after training, there is no resource cost to acquiring low-tech skills and low-tech workers must always retrain after losing their jobs. The assumption that $c_1 = 0$ implies that all workers enter the labor force. These assumptions, while admittedly extreme, greatly simplify our analysis.

Our final assumption has to do with the relative values of the productivity parameters q_1 and q_2. To ensure that high ability workers are attracted to the high-tech sector, we must make sure that they expect to earn more by training for high-tech jobs. We can use (4)-

[5] Many low-ability workers face difficulties finding any job at all and therefore experience long spells of unemployment whenever they lose their job. We believe that this is largely due to their work history and overall lack of ability. By assuming that low-tech jobs are plentiful, we are trying to capture the idea that the ***marginal*** worker (who has the ability to train for a high-tech job) would be able to find menial employment easily if she chooses to do so.

[6] Consider, for example, a worker who moves from one low-tech job (working as a clerk in a department store) to a new one (working for a fast food restaurant). While training as a clerk, the worker may need to learn the layout of the store, the procedures for opening and closing the store, how to handle the cash register, and so on. However, acquiring these skills will not shorten the time it takes to learn how to prepare fast food.

[7] High-tech workers (e.g., managers, accountants, lawyers) are often required to complete college and some may have a post-graduate education. If they lose their jobs, most of these workers will be able to find reemployment without retraining in the same field. Moreover, even if these workers change occupations,

(7) to solve for the expected lifetime income that sector *j* trainers earn in a steady-state equilibrium. Setting the $\dot{V}(t)$ terms equal to zero and solving yields

(8) $$V_{1T}(a_i) = \frac{p_1(1+\gamma)\tau_1 q_1 a_i}{r\Delta_1}; \qquad V_{2T}(a_i) = \frac{e_2 p_2\{(r+\tau_2)q_2 a_i - b_2(1-\phi_2)c_2\}}{r\Delta_2}$$

with $\Delta_1 = r + b_1 + \tau_1$ and $\Delta_2 = (r+b_2)(r+\tau_2+e_2) + e_2\tau_2 - b_2\phi_2 e_2$. It is clear from (8) that expected lifetime income is increasing in *i* – in both sectors higher ability workers expect to earn more than their lower ability counterparts. We now want to require more. To be specific, we want to assume that an increase in ability adds more to expected income in the high-tech sector than it adds in the low-tech sector. From (8), this will be the case if $p_2 q_2 \tau_2 e_2 \Delta_2 > q_1 \tau_1 \Delta_1$.

We can now characterize the initial tariff distorted equilibrium with the aid of Figure 2. From (8), $V_{1T}(0) = 0 > V_{2T}(0)$. Moreover, since ability is more valuable in the sector 2, $V_{2T}(a_i)$ is steeper than $V_{1T}(a_i)$ (provided that p_1 is not too high). It follows that if we define a_H to be the ability level of the ***marginal*** worker (so that, $V_{1T}(a_H) = V_{2T}(a_H)$) then all workers with $a_i < a_H$ will be attracted to sector 1 while all other workers will train for high-tech jobs. Thus, $L_1 = a_H L$ and $L_2 = (1 - a_H)L$ where, from (8):

(9) $$a_H = \frac{p_2 c_2 \Delta_1[(r+b_2)(r+e_2) - b_2 e_2 \phi_2]}{p_2 \tau_2 e_2 q_2 \Delta_1 - p_1(1+\gamma)\tau_1 q_1 \Delta_2}$$

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they will have acquired some general skills along the way that may help them land new jobs without acquiring new skills.

The measure of workers in each labor market state in this steady-state equilibrium can be obtained from (1)-(3). Setting the $\dot{L}$ terms equal to zero and solving yields

$$(10) \qquad L_{1T} = \frac{a_H L b_1}{b_1 + \tau_1}; \qquad L_{2T} = \frac{(1-a_H)L(1-\phi_2)e_2 b_2}{(e_2+b_2)\tau_2 + (1-\phi_2)e_2 b_2}$$

$$(11) \qquad L_{1S} = 0; \qquad L_{2S} = \frac{(1-a_H)L\tau_2 b_2}{(e_2+b_2)\tau_2 + (1-\phi_2)e_2 b_2}$$

$$(12) \qquad L_{1E} = \frac{a_H L \tau_1}{b_1 + \tau_1}; \qquad L_{2E} = \frac{(1-a_H)L e_2 \tau_2}{(e_2+b_2)\tau_2 + (1-\phi_2)e_2 b_2}$$

The values in (9)-(12) can be used to calculate national income in the initial tariff distorted equilibrium. In the sector 1, L_{1E} workers are employed and the average worker produces $.5q_1a_H$ units of output. The remaining workers are training and earn nothing. In the sector 2, L_{2E} workers are employed with the average worker producing $.5q_2(1 + a_H)$ units of output. The L_{2T} trainers in this sector each pay a flow cost of p_2c_2 while the reamining L_S workers earn nothing while they search for employment. It follows that initial steady-state national income (evaluated at world prices), Y_{SS}, is given by

$$(13) \qquad Y_{SS} = .5\{p_1 q_1 a_H L_{1E} + p_2 q_2 (1 + a_H) L_{2E}\} - p_2 c_2 L_{2T}$$

National welfare in the initial steady-state is given by $W_{SS} = Y_{SS}/r$.

Before moving on, there is at least one important feature of our model that is worth noting. It is straightforward to show that the free-trade equilibrium in our model is efficient (see Appendix B of Davidson and Matusz 2001). This is unusual for search models. It is usually the case that search decisions are rife with externalities. For example, if an unemployed worker chooses to seek a job in a particular sector, this may make it more difficult for other unemployed workers to find a job. Such externalities typically distort behavior and lead to sub-optimal equilibria. This is not the case in our model. In fact, we set up our model with exogenous turnover rates specifically designed to avoid this problem. The reason that we did this is so that we can be sure that when we carry out our policy analysis our results will not depend on how different policies affect the distortions created by controversial, hard to measure search-generated externalities.

There is another benefit that comes from treating the turnover rates as exogenous. Doing so allows us to keep the model simple enough that we can solve for the transition path between steady-state equilibria. This means that we can take this path into account when carry out our welfare anaylsis. However, these benefits come at a cost. As we mentioned earlier, the policy community has emphasized that some labor market policies have unintended consequences. In particular, policies that reduce the opportunity cost of unemployment (e.g., unemployment insurance) lower the incentive to find new jobs, resulting in longer spells of unemployment. Our model cannot capture such disincentive effects since the turnover rates are exogenous. At the end of section 4 we return to this issue discuss how the inclusion of such effects would alter our results.

3 Liberalization without Compensation

Now, suppose that this country liberalizes trade by removing the tariff and that no attempt is made to compensate those who are harmed. The reduction in the domestic price of good 1 lowers both V_{1T} and V_{1E} making sector 1 less attractive to workers. From

Figure 2, a_H falls causing sector 2 to expand. We use a_H^{FT} to denote the new value for a_H (FT refers to free trade). As in our previous section, this value is determined by solving $V_{1T}(a_i) = V_{2T}(a_i)$ for a_i – thus, a_H^{FT} is given by (8) with $\gamma = 0$.[8] It follows then that after the tariff is removed, workers with $a_i \in \left[a_H^{FT}, a_H\right]$ will want to switch to sector 2. Those who were training for sector 1 jobs at the time of liberalization switch immediately while those who were employed in sector 1 will wait and switch after they lose their jobs (assuming that the tariff was relatively small so that V_{1E} does not fall below V_{2T}).

We begin our investigation of liberalization's impact by examining aggregate welfare. To do so, we must determine the measure of workers in each labor market state at each point in time. For workers with ability levels above a_H or below a_H^{FT} there is no change in their behavior – the fractions of these workers in each labor market state do not change when the tariff is reduced. It follows that for workers with $a_i > a_H$, the measures that are training, searching and employed in sector 2 are still given by (10b)-(12b). For workers $a_i < a_H^{FT}$, the measures that are training and employed in sector 1 are given by (10a) and (12a) with a_H replaced by a_H^{FT}.

Things are more complicated for the workers with $a_i \in \left[a_H^{FT}, a_H\right]$. Those training in sector 1 exit and start training in the high-tech sector as soon as the tariff is removed. Those who are employed at the time of liberalization make the switch more gradually, exiting only after they lose their jobs. It follow that the measures of these workers that

[8] Note that, with the exception of the V_{jk} terms, all of the terms on the right hand side of (4)-(6) are

are employed in sector 1 or training, searching or employed in sector 2 are governed by the following set of differential equations (we use $S_{jE}(t)$ for $j = 1,2$ to denote the measure of movers employed in sector j, $S_{2T}(t)$ to denote the measure of movers training in sector 2 and $S_S(t)$ to denote the measure of movers searching for sector 2 jobs)

(14) $$\dot{S}_{1E}(t) = -b_1 S_{1E}(t)$$

(15) $$\dot{S}_S(t) = b_2\phi S_{2E}(t) + \tau_2 S_{2T}(t) - e_2 S_S(t)$$

(16) $$\dot{S}_{2E}(t) = e_2 S_S(t) - b_2 S_{2E}(t)$$

(17) $$(a_H - a_H^{FT})L = S_{1E}(t) + S_{2T}(t) + S_S(t) + S_{2E}(t)$$

As in (1)-(2), the rate of change is equal to the difference between the flows into and out of each labor market state. The initial conditions for S_{1E} and S_{2T} are given by (12a) and (10a), respectively, with a_H replaced by $(a_H - a_H^{FT})$ while $S_{2S}(0) = S_{2E}(0) = 0$. Note that the measure of movers training in sector 2 at $t = 0$ is equal to the measure of workers who had been training in sector 1 at the time of liberalization.

In Appendix A of Davidson and Matusz (2001) we provide the solution to (14)-(17). This allows us to solve for the measure of workers in each of the labor market states during the adjustment process. If we use $L_{jk}^{FT}(t)$ for $j = 1,2$ and $k = T,E$ to denote the

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independent of time. It follows that all the V_{jk} terms jump immediately to their new steady-state values after liberalization.

measure of sector *j* workers training (for $k = T$) or employed (for $k = E$) at time *t* during the free trade adjustment process and use $L_S^{FT}(t)$ to denote the measure searching in sector 2, then we can write the value of net output along the transition path as

$$(18) \qquad Y_{FT}(t) = \int_0^{a_H^{FT}} p_1 \frac{q_1 a_i L_{1E}^{FT}(t)}{a_H^{FT} - a_L} da_i + \int_{a_H^{FT}}^{1} p_2 \frac{q_2 a_i L_{2E}^{FT}(t) - c_2 L_{2T}^{FT}(t)}{1 - a_H^{FT}} da_i$$

Welfare after liberalization, taking the adjustment path into account, is then $W_{FT} = \int e^{-rt} Y_{FT}(t)dt$.

A typical time path for $Y_{FT}(t)$ is depicted in Figure 3. Since the free trade equilibrium is efficient, liberalizing trade increases steady state net output from its initial level of Y_{SS} to a new higher value (Y^*) and increases aggregate welfare from W_{SS} to W_{FT}. However, net output initially falls as it takes time for the movers to train for and find new jobs in the high-tech sector. In Davidson and Matusz (2001) we used this model to explore the size and scope of the adjustment costs imposed on the economy as it moves to its new equilibrium. For empirically relevant values of the parameters, we found that the these costs were surprisingly high. In particular, we found that adjustment costs would eat away 35% to 90% of the potential gains from trade and that it would take the economy from 3 to 6 years before net output would return to its pre-liberalization level.

These results have important implications for the effect of liberalization on the distribution of income since these costs are all borne by a relatively small group of workers – those who switch sectors. Although these workers eventually gain by finding higher paying jobs, their gains may be wiped out entirely by training and search costs. Of course, some of these workers gain while others lose. Below we examine their aggregate gains or losses by looking at how the group as a whole is affected by liberalization.

The effects of the tariff reduction on all other groups of workers are unambiguous. All those who are initially tied to the high-tech sector benefit from the fall in the domestic price of the low-tech good while those who were initially tied to the low-tech sector and remain so (the "stayers") lose as their real incomes fall.

In order to quantify the gains and losses for the movers, we calculate the expected lifetime utilty that they earn as a group before and after liberalization. To do so, we must make two assumptions. First, we assume that when the tariff is in place, all tariff revenue is redistributed in a lump sum fashion in the same manner as earned income. While this assumption is made for simplicity and to minimize the role played by tariff revenue, it is not essentail for our analysis. Qualitatively identical results would hold if we assumed that traiff revenue is distributed evenly across consumers. Our second assumption is that all individuals have a Cobb-Douglas utility function of the form $U(C_1, C_2) = \sqrt{C_1 C_2}$ where C_j denotes consumption of the j-sector good. Again, this assumption is made for convenience -- our results do not depend on this functional form. We also assume that the world price of each good is equal to one and that there is initially a 5% tariff on the low-tech good. Setting the world prices equal to one, combined with our assumptions about tastes and parameters, ensures that the low-tech good will be imported.

Under these assumptions, aggegate expected lifetime utility for the movers after liberalization is given by (*MLU* stands for Movers Lifetime Utility)

$$(19) \qquad MLU_{FT} = \int \int_{a_H^{FT}}^{a_H} e^{-rt} \{ \frac{q_1 a_i S_{1E}^{FT}(t) + q_2 a_i S_{2E}^{FT}(t) - c_2 S_{2T}^{FT}(t)}{2(a_H - a_H^{FT})} \} da_i dt$$

where $S_{1E}^{FT}(t), S_{2E}^{FT}(t),$ and $S_{2T}^{FT}(t)$ solve the differential equations in (14)-(17).

Calculating aggregate expected lifetime utility for this group before liberalization is more complex because of the difference between domestic and world prices and the existence of tariff revenue. The aggregate expected lifetime income for the movers evaluated at world prices is given by (*MLI* stands for Movers' Lifetime Income)[9]

$$(20) \qquad MLI_{SS} = \frac{1}{r}\left[.5q_1(a_H + a_H^{FT})L_{1E}\right]$$

where L_{1E} is given by (12a) with a_H replaced by $(a_H - a_H^{FT})$. It follows that the share of national income earned by this group in the initial steady state is given by $MS = MLI_{SS}/W_{SS}$. In Appendix A we show that the mover's aggregate expected liftime utility in the initial tariff-distorted equiliubrium is given by

[9] This follows from the fact that each employed mover produces $q_1 a_i$ units of output and the ability level of the average mover is $.5(a_H + a_H^{FT})$.

(21) $$MLU_{SS} = \frac{\sqrt{1+\gamma}}{2+\gamma} MS$$

Liberalization benefits the movers as a group if (19) exceeds (21); otherwise they lose.

Comparing (19) and (21) is not straightforward. We therefore choose values for our parameters that are consistent with the empirical literature on labor market structure, solve the model and compare these terms. The parameters include those that determine the average durations of sector-j employment (b_j) and training (τ_j) and unemployment in the high-tech sector (e_2), those that measure the resource cost of high-tech training (c_2), the parameters of the sector-j production process (q_j), the discount rate (r) and the parameter which measures the durability of high-tech skills (ϕ_2).

Some parameters are fairly easy to pin down. For example, the average duration of unemployment, which is $1/e_2$ in our model, can be found in *The Economic Report of the President* (for 2001 see Table B-44). While this value fluctuates over the business cycle, it is usually close to one quarter (13 weeks), rarely straying from that value by more than two weeks. Thus, we set $e_2 = 4$.

Data on the average duration of employment in US manufacturing is also readily available and can be used to pin down b_2. Davis, Haltiwanger, and Schuh (1996) provide data on annual rates of job destruction in U.S. manufacturing industries and report that the average annual rate was roughly 10% for the period 1973-1988. This translates into an average duration of employment of 10 years. This value varies over the business cycle, reaching a peak in 1975 at 16.5% (implying an average duration of employment of 6 years).[10] Thus, we consider values for b_2, the separation rate in the high-tech sector, such that high-tech jobs last, on average, between 6 and 10 years.

Pinning down the separation rate in the low-tech sector is more complicated. We model these jobs as transitory, low-paying, undesirable jobs that require few skills. While many of these jobs may be found manufacturing, it is hard to know how to draw conclusions about the average length of the worst jobs in a sector from industry-wide data. So, we follow a different approach. We think of our low-tech jobs as the types of jobs that many workers hold when they first enter the labor force. Data on jobs held over a worker's lifetime indicate that up to the age of 24 workers start (roughly) one new job every two years.[11] Based on this evidence, we consider two cases – one in which low-tech jobs last one year ($b_1 = 1$) and one in which they last two years ($b_1 = .5$).

From previous work with this model, we know that results are fairly insensitive to changes in r and ϕ_2.[12] For all empirically relevant values for the interest rate (below 20%) and for values of ϕ_2 between .5 and .9, our estimates on adjustment costs vary only at the third decimal place. Since our results are so insensitive to changes in these parameters, the only values that we consider are $r = .03$ and $\phi_2 = .8$.

The remaining parameters are tied to the training and production processes. Unfortunately, not much is known about the size and scope of training costs. For the

[10] See Table 2.1 on p. 19 in Davis, Haltiwanger, and Schuh (1996).

low-tech sector, we want to choose a value for τ_1 that is consistent with the idea that low-tech skills are easy to master. Thus, we assume that the time costs are small by setting $\tau_1 = 52$ (so that it takes only one week to learn the skills required to perform low-tech jobs).

As for the high-tech sector, we turn to the limited information that is available on training costs. Hamermesh (1993) provides a survey of this evidence where the costs are assumed to include the costs of recruiting and training newly hired workers. He concludes that in some instances these costs may be quite high. For example, the cost of replacing a worker in a large firm in the pharmaceutical industry was pegged at roughly twice that worker's annual salary. In the trucking industry, the cost of replacing a driver was estimated to be slightly less than half the driver's annual salary.[13] Similar estimates can be found in Acemoglou and Pischke's (1999) study of the German apprenticeship training system. They report estimates of training costs that vary from 6 to 15 months of the average worker's annual income. We capture this wide range of estimates by assuming that high-tech training lasts four months ($\tau_2 = 4$) and then vary the value of c_2 so that total training costs vary from a low of 1 month's pay for an average high-tech worker to a high of 15 months pay. We also consider two intermediate values in which these costs are equal to 5 and 10 months of high-tech income.

[11] See Table 8.1 on p. 210 in Hamermesh and Rees (1998).
[12] See Davidson and Matusz (2001, 2002).
[13] Of course, there are some industries in which these costs are quite low. The lowest estimate of turnover costs reported in Hamermesh's survey appears to be about three weeks worth of salary, although such a low figure appears to be an exception rather than the norm.

This leaves only q_1 and q_2, the parameters of the production processes. Since all that matters is their relative value, we set $q_2 = 1.4$ (which makes the calculation of c_2 relatively easy) and vary q_1. As q_1 varies, the attractiveness of the sectors change. This results in changes in a_H and the equilibrium size of the sector 1. We consider three different values for q_1 for each combination of turnover rates. These values correspond to values of a_H equal to .1, .2 and .33. Thus, we consider parameter values that imply that initially 10%, 20%, or 33% of the workforce is employed in the low-tech sector.

Table 1 shows how the impact of liberalization on the movers varies with our parameters. The entry in each cell shows the percentage change in the aggregate expected lifetime utility earned by the movers as a group. In each case, the movers are harmed by the removal of the tariff. Even in the case in which high-tech training costs are extremely low and turnover is high (so that the transition to the new steady-state is relatively quick) the adjustment costs imposed on this group outweigh their long term gains. The losses vary bewteen one half of a percent to two and a half percent.

At the same time, workers in the high-tech sector are enjoying an increase in expected lifetime utility of less than .5% while the lowest income workers, those trapped in the low-tech sector, see their expected lifetime utility drop by more 4.5%. This means that liberalization leads to a less equal distributuion of income – the rich get slightly richer, the poor get poorer and those in the middle suffer moderate losses. Yet, in spite of this increase in inequality, there can be no doubt that liberalization is desireable since it generates aggregate net benefits.[14] These results underscore the importance of accompanying liberalization with programs that compensate the losers so that the benefits from freer trade can be shared by all. In the next two sections we turn our attention to exactly this issue by looking for the best way to compensate the movers and the stayers for the losses they suffer when the low-tech tariff is removed.

4 Compensating the Movers

A. Intuition

Any attempt to compensate those who are harmed by liberalization must distort the economy. Our goal is to find the policy that provides sufficient compensation at the lowest cost to the economy. We consider four policies – wage subsidies, training subsidies, employment subsidies and unemployment insurance. In each case, we solve for level of assistance required to exactly offset the losses suffered by the movers (as a group) and then calculate the deadweight loss (DWL) imposed on the economy. The best policy is the one that compensates the movers while generating the smallest DWL.

There are two distortions associated with each compensation scheme. The first comes from the policy itself since this distorts incentives. For example, a wage subsidy offered to workers who move to the high-tech sector makes sector 2 more attractive than it ought to be and results in too many workers switching sectors. The removal of the tariff causes the V_{1T} to shift down and implementing a compensation scheme for the movers causes the V_{2T} curve to shift up. As a result, a_H falls more than it should – it falls below its free

[14] See Davidson and Matusz (2001) for a detailed analysis of the size of these benefits and the adjustment costs associated with them.

trade level. The need to pay for the compensation scheme creates the second distortion. We assume that any policy is financed by taxing earned income at a constant rate of ψ.[15] The introduction of this tax distorts incentives, although in a less obvious way. In short, both the implementation of the policy and the introduction of the tax rate change the equilibrium allocation of labor across the two sectors so that the transition from the initial tariff distorted equilibrium to the new steady state is no longer efficient.

It should be clear that the policy that fully compensates the losers while having the smallest impact on the equilibrium distribution of workers will generate the smallest distortion. This leads to two immediate conclusions – ***any optimal policy must be targeted and temporary***. By targeted we mean that only those in groups that lose from liberalization must qualify for assistance. Thus, if we are considering using a wage or training subsidy to compensate the movers, then only those who were training or employed in the low-tech sector at the time of liberalization should qualify for the subsidy. Offering the subsidy to workers who were already attached to the high-tech sector would add to the program's cost and create a larger than necessary distortion. In addition, there is no reason that these workers should qualify. After all, they already benefit from the removal of the tariff – why increase their incomes even further?

The reason that the compensation program must be temporary is more subtle, but can be understood with the aid of Figure 4. Suppose that trade is liberalized and that we attempt

[15] We assume that the government chooses a tax rate that is independent of time. Thus, we require the government budget to be balanced in the only in the long-run -- the government is allowed to run a deficit during the early stages of the adjustment process. Assuming that the tax rate is independent of *t* allows us

to compensate the movers with a wage subsidy paid only to those who switch sectors. As noted above, liberalization causes the V_{1T} curve to shift down and the wage subsidy causes the V_{2T} curve to shift up. As a result, too many workers switch sectors. Now, with a permanent program, the movers would receive a wage subsidy each time they accept a high-tech job while a temporary program would pay them a subsidy only the first time they do so. As a result, these programs differ in the way that they affect the equilibrium distribution of workers. Under the permanent program the shift up in the V_{2T} curve is permanent so that any worker who switches sectors does so permanently.

This is not the case with a temporary program. Under a temporary program, there will be two V_{2T} curves – one faced by those training in the high-tech sector for the first time after liberalization (and are therefore eligible for the wage subsidy when they find a job) and one for those workers who must retrain after losing the high-tech skills they acquired while training for that first job. In Figure 4, the former curve is represented by V_{2T}^{1} while V_{2T}^{+} represents the latter curve. To see how these shifts affect the movers, let a_H^h solve $V_{1T}(a_H^h) = V_{2T}^h(a_H^h)$ for $h = 1,+$. From Figure 4, $a_H^1 < a_H^+$. Moreover, note that in the absence of the income tax, the V_{2T}^{+} curve and the free trade V_{2T} curve would be identical. Since the tax rate required to pay for the program will be small, it follows that $a_H^+ \approx a_H^{FT}$.[16] Now consider the plight of the movers after liberalization. Since workers with $a_i \in [a_H^+, a_H]$ earn relatively more training for high-tech jobs even after they are no

to solve explicitly for the transition path to the new policy induced steady-state. We show how to calculate this tax rate in Appendix C.

[16] In fact, for the parameter values that we consider below the two values differ only at the fourth decimal place.

longer eligible for the subsidy, these workers switch sectors permanently. In contrast, for workers with $a_i \in [a_H^1, a_H^+]$ training for high-tech jobs is only desirable when they are eligible to collect the subsidy. Once they lose their high-tech skills and are forced to retrain, they would rather return to sector 1.[17] It follows that these workers switch sectors temporarily. Thus, a permanent wage subsidy lowers a_H to a new value that remains ***permanently*** below a_H^{FT} (because V_{2T} reamins permanently higher), while with a temporary program a_H eventually returns almost to its efficient level, a_H^{FT} (because V_{2T} shifts back down to its old value once the worker is no longer eligible for the subsidy).

Note that under the temporary program there are two types of movers, those who switch sectors permanently (workers with $a_i \in [a_H^+, a_H]$) and those who switch only long enough to collect the subsidy (workers with $a_i \in [a_H^1, a_H^+]$), while with the permanent program all workers who switch do so permanently. Yet, in terms of efficiency, the only workers who ***should*** switch are those who would move under free trade. It follows that a temporary program generates a temporary distortion while the distortion introduced by a permanent program is permanent.

Figure 4 can also be used to examine the impact of the four labor market policies on the distribution of workers. To do so, Let w_m (t_m) denote a wage (training) subsidy paid to the movers during their first spell of employment (training) in the high-tech sector.

[17] When she loses her first high-tech job she returns to the low-tech sector ***if*** she loses her high-tech skills. But, if her skills transfer across high-tech jobs, she remains in sector 2 and searches for reemployment. It is worth noting that it may take quite some time for this worker to return to the low-tech sector. In our model, high-tech jobs last, on average, between 6 and 10 years and skills transfer across jobs 80% of the time.

Similarly, let s_m denote the replacement rate used to calculate the unemployment benefits paid to these workers during their first spell of high-tech unemployment and define e_m to be an employment subsidy paid to the movers during their first spell of low-tech employment. This employment subsidy differs from a wage subsidy in that it is independent of the worker's wage so that all movers receive the same payment regardless of ability. Thus, a mover who is collecting a wage sudsidy receives a flow of $w_m p_2 q_2 a_i (1-\psi)$ as long as she is eligible for it while an employment subsidy pays a flow of $e_m(1-\psi)$. A worker collecting a training subsidy receives a flow of $p_2 c_2 t_m$. Finally, since unemployment compensation is tied to the wage the worker earned on her *last* job, unemployment benefits would be equal to $s_m p_1 q_1 a_i$.

Since the employment and training subsies do not vary with ability, both cause the V_{2T} curve to shift up in a parallel fashion. In fact, since these two programs affect the V_{2T} curve in qualitatively identical ways, they are equivalent – for any employment subsidy there exists a training subsidy that generates the same amount of worker relocation and dead weight loss. There is a similar connection between wage subsidies and unemployment benefits. Since these two programs provide payments that are tied to ability, they both cause the V_{2T} curve to shift up in a tilted fashion with high ability workers receiving more compensation. And, since both increase linearly with ability, for every wage subsidy there exists an equivalent unemployment insurance program that generates the same amount of worker relocation and dead weight loss.

We are now in a position to describe the optimal policy. Intuitively, there are two factors that determine the efficacy of a compensation scheme. The first has to do with the sensitivity of the expected lifetime income earned by the movers as a group with respect to the policy parameter. This factor determines the size of the program needed to fully compensate the group. For example, if the mover's expected lifetime income is highly sensitive to the policy parameter, then only a modestly sized program will be required to achieve full compensation. On the other hand, if the group's expected lifetime income is insensitive to changes in the policy parameter, a large and costly program will be required. If we use the expected lifetime income of the ***average*** mover as a proxy for the group's aggregate income, then it follows that, all else equal, a compensation scheme will be relatively more atractive if it has a bigger impact on the average mover's expected lifetime income than other compensation schemes.

The second factor is tied to the manner in which changes in the policy parameter affect the ***marginal*** worker's behavior. This factor determines how each compensation scheme affects the number of temporary movers – or, alternatively, a_H^1, with smaller values of a_H^1 implying a bigger distortion. For example, if the marginal worker's expected lifetime income is relatively sensitive with respect to the policy parameter, then a given increase in that parameter will generate a relatively large response in a_H^1 and a large distortion. It follows that, all else equal, a compensation scheme will be relatively more attractive if it has a small impact on the marginal worker.

Combining these two factors, the ideal compensation scheme will be one that has a large impact on the average mover and a small impact on the marginal mover. Or alternatively, one that is more valuable to the average mover than to the marginal mover. Since an employment (or training) subsidy shifts V_{2T} up in a parallel fashion, it increases the reward to high-tech training by the same amount for the marginal and average movers. In contrast, a wage subsidy (or unemployment benefit) is relatively more valuable to the average mover because the average mover has a higher ability level than the marginal mover. This implies that it is better to compensate the movers with a wage subsidy or unemployment insurance rather than with employment or training subsidies.

These results hinge upon our assumptions that each sector's output is linear in ability and that training costs are the same for all workers. Of course, in reality, the realtionship between output and ability is probably more complex and training costs probably do vary with ability. As for training costs, we would expect that higher ability workers would face lower training costs than lower ability workers.[18] If this is the case, then training subsidies will be relatively more valuable to the marginal mover since the marginal mover has lower ability and therefore faces higher training costs! Consequently, if we were to extend our model to allow training costs to vary with ability, they would perform even worse. At the end of sub-section C below we relax the assumption that output is linear in ability and argue that under more general conditions, wage subsidies emerge as the optimal policy. But, before we do so, in sub-section B we show how to derive the wage subsidy or unemployment benefit that fully compensates the movers as a group and

[18] Smarter students can achieve the same grades as other students with less study time. Similarly, high ability workers will pick up new skills quicker than low ability workers.

the deadweight loss that each policy generates. At the beginning of sub-section C, we present these values for the parameters we introduced at the end of Section 3. We note that sub-section B is fairly technical and can be skipped by readers who are not particularly interested in the technical details of our analysis.

B. The Details

Any temporary targeted policy aimed at compensating the movers creates four classes of workers. Two of these groups do not alter their labor market behavior – workers with $a_i \in [a_H, 1]$ are attached to the sector 2 before liberalization and reamin so afterwards and workers with $a_i \in [0, a_H^1]$ are attached to sector 1 before liberalization and remain trapped there. The only difference is that these workers must now pay taxes while employed to cover the cost of the compensation scheme. It follows that the labor market dynamics for these two groups are still governed by (1)-(3) and (10)-(12) (although a_H must be replaced by a_H^1 in (10a)-(12a)). In addition, their expected lifetime income are still governed by (4)-(6) although the wage in (6) must now be multiplied by *(1 - ψ)*.

The other two groups are the temporary and permanent movers. We begin with the permanent movers -- workers with $a_i \in [a_H^+, a_H]$. Their labor market behavior is no different than it would be under free trade; they move immediately to sector 2 if training and make the move after losing their sector 1 job if employed when the tariff is removed. In either case, the move is permanent – they never return to the low-tech sector. It follows that their labor market dynamics are still governed by (14)-(17). However, there is one new wrinkle. In order to determine the equilibrium tax rate we must keep track of government outlays. Therefore, we now need to distinguish between the movers who are in the high-tech sector for the first time (and are eligible for compensation) and those who are in that sector subsequently (and receive no extra compensation). We therefore introduce some new notation that allows us to make such distinctions. We use $PM_{2k}^{h}(t)$ to denote the measure of permanent movers who are in labor market state *k* (for *k* = *E, T, S*) for the first time after liberalization (if *h* = *1*) or subsequently if (*h* = +) at time *t*. Finally, we use $PM_{1E}(t)$ to denote the measure of permanent movers still employed in the low-tech sector at time *t*. In Appendix B we provide the differential equations that govern the movements into and out of these labor market states along with their solutions. These equations are based on the same logic as (1)-(3) and (14)-(17) in that the difference between the flow into and out of a particular labor market state defines the state's growth rate. We also provide the asset value equations that define expected lifetime income for each possible labor market state for the permanent movers and show how to solve for a_H^{+}. These equations are based on the same logic as (4)-(6).

Turn next to the temporary movers, workers with $a_i \in [a_H^1, a_H^+]$. These workers switch over to the high-tech sector in the same manner that they would under free trade. However, once they lose the high-tech skills they acquire while training for their first post-liberalization high-tech job, they return to the low-tech sector and remain there forever after. We use $TM_{2k}^{h}(t)$ to denote the measure of temporary movers who are in labor market state *k* (for *k* = *E, T, S*) for the first time after liberalization (if *h* = *1*) or subsequently if (*h* = +) at time *t*. Note that since these workers do not retrain in the high-tech sector, $TM_{2T}^{+}(t)=0$. Finally, we use $TM_{1E}(t)$ to denote the measure of temporary movers still employed in the low-tech job they held at the time of liberalization and $TM_{1k}^{R}(t)$ to denote the measure of temporary movers training (for *k* = *T*) or employed (for *k* = *E*) in the low-tech sector after their return. In the latter half of Appendix B we provide the differentail equations that govern their movements into and out of these various labor market states along with the solutions. We also provide the asset value equations that define expected lifetime income for each possible labor market state for the temporary movers and show how to solve for a_H^1.

We are now in position to describe how to solve for the optimal compensation scheme. Our goal is to find the scheme that exactly offests the losses suffered by the permanent movers while generating the smallest deadweight loss for the economy. The solutions to the differential equations provided in Appendix B allow us to solve for the permanent mover's utility at time *t, PMI(t)*. We obtain

(22)
$$PMU(t)=\int_{a_H^+}^{a_H}\frac{(1-\psi)a_i\{q_1PM_{1E}(t)+q_2[PM_{2E}^{1}(t)(1+\omega_m)+PM_{2E}^{+}(t)]\}}{2(a_H-a_H^+)}da_i+\int_{a_H^+}^{a_H}\frac{s_mq_1a_iPM_{2S}^{1}(t)-c_2[(1-t_m)PM_{2T}^{1}(t)+PM_{2T}^{+}(t)}{2(a_H-a_H^+)}da_i$$

The first term on the right hand side, $(1-\psi)q_1a_iPM_{1E}(t)$, is the income earned at time *t* by those still employed in sector 1. The next two terms capture the income earned by those who have their first high-tech job, $(1-\psi)q_2a_i(1+\omega_m)PM_{2E}^{1}(t)$, and those who are employed in that sector subsequently, $(1-\psi)q_2 a_i PM_{2E}^{+}(t)$. The fourth term represents the unemployment benefits paid to the movers who are searching in the high-tech sector for the first time, $s_m q_1 a_i PM_S^1(t)$. Finally, the last two terms are the training costs imposed on these workers when training in the high-tech sector the first time, $c_2(1-t_m)PM_{2T}^1(t)$, and subsequently, $c_2 PM_{2T}^{+}(t)$. It follows that the permanent mover's expected lifetime utility (*PMEU*) is given by

$$(23) \qquad PMEU = \int e^{-rt} PMU(t)dt$$

The permanent movers are fully compensated if the policy parameters are chosen such that (23) equals (21), their expected lifetime income as a group before liberalization.

The deadweight loss imposed on the economy is the difference in the value of the net output that would have been produced under free trade and what is actually produced in the policy distorted equilibrium. The free trade value of net output is given by Y_{FT}(t) in (18) and free trade welfare is therefore given by $W_{FT} = \int e^{-rt} Y_{FT}(t)dt$.

To calculate the value of net output in the policy distorted equilibrium, we focus on the value of the net output produced in each sector. We begin with the low-tech sector where, at time *t*, total employment is made up of four different types of workers. First, there are $\dfrac{\tau_1 a_H^1 L}{b_1+\tau_1}$ employed workers who remain trapped in that sector (see eq. 12a). Second, there are $PM_{1E}(t)$ permanent movers who are still employed in that sector.

Finally, there are two types of temporary movers – those who are still employed in sector 1 and have yet to switch over to sector 2, and those who have made the switch, returned and are now reemployed in that sector. The measure of the former group is $TM_{1E}(t)$ while the measure of the latter group is $TM_{1E}^{R}(t)$. It follows that in the policy distorted equilibrium the value of net output in the low-tech sector at time *t* is given by:

$$(24) \qquad Y_1^P(t) = \frac{\tau_1 q_1 (a_H^1)^2 L}{2(b_1+\tau_1)} + \int_{a_H^1}^{a_H^+} q_1 a_i \frac{TM_{1E}(t) + TM_{1E}^R(t)}{a_H^+ - a_H^1} da_i + \int_{a_H^+}^{a_H} q_1 a_i \frac{PM_{1E}(t)}{a_H - a_H^+} da_i$$

Now turn to the high-tech sector where there are five groups of workers producing output. First, from (12b) there are $\frac{\tau_2 e_2 (1-a_H)L}{(e_2+b_2)\tau_2 + (1-\phi_2)e_2 b_2}$ employed workers who were attached to sector 2 before liberalization. Next, there are two groups of permanent movers – those employed in the high-tech sector for the first time and those employed there subsequently. The measure of the former group is $PM_{2E}^1(t)$ and the measure of the latter group is $PM_{2E}^+(t)$. Finally, there are two groups of temporary movers – those holding high-tech jobs for the first time and those who are employed in sector 2 subsequently (because they have not yet lost their high-tech skills). The measure of the former group is $TM_{2E}^1(t)$ and the measure of the latter group is $TM_{2E}^+(t)$. As for training costs, there are four groups training in the high-tech sector at any point in time. From (10b) the measure of trainers who were attached to this sector before liberalization is given by $\frac{(1-\phi_2)e_2 b_2 (1-a_H)L}{(e_2+b_2)\tau_2 + (1-\phi_2)e_2 b_2}$. Among the permanent movers there are two groups

– those training for the first time and those training subsequently. The measure of the former group is given by $PM_{2T}^{1}(t)$ while the measure of the latter group is given by $PM_{2T}^{+}(t)$. Finally, among the temporary movers there are $TM_{2T}^{1}(t)$ workers training in the high-tech sector for the first time.[19] It follows that the value of net output produced at time t in the policy distorted equilibrium is given by:

$$(25)\qquad Y_2^P(t) = \frac{\tau_2 e_2 q_2[1-(a_H)^2]L}{2[\tau_2(e_2+b_2)+(1-\phi_2)e_2 b_2]} + \int_{a_H^1}^{a_H^+} q_2 a_i \frac{TM_{2E}^1(t)+TM_{2E}^+(t)}{a_H^+ - a_H^1} da_i + \int_{a_H^+}^{a_H} q_2 a_i \frac{PM_{2E}^1(t)+PM_{2E}^+(t)}{a_H - a_H^+} da_i - \frac{c_2(1-\phi_2)e_2 b_2(1-a_H)L}{\tau_2(e_2+b_2)+(1-\phi_2)e_2 b_2} - \int_{a_H^1}^{a_H^+} c_2 \frac{TM_{2T}^1(t)}{a_H^+ - a_H^1} da_i - \int_{a_H^+}^{a_H} c_2 \frac{PM_{2T}^1(t)+PM_{2T}^+(t)}{a_H - a_H^+} da_i$$

National welfare in the policy distorted equilibrium can now be written as $W_P = \int e^{-rt}[Y_1^P(t)+Y_2^P(t)]dt.$ The deadweight loss imposed on the economy by the compensation scheme is the difference between W_{FT} and W_P.

C. Results and Extensions

For each of the parameters listed in Table 1, we solve for the policy variables that fully compenaste the permanent movers and compare the size of the deadweight losses. As expected, we find that wage subsidies and unemployment insurance are equivalent,

[19] No temporary movers train in the sector a second time. Instead they return to the low-tech sector.

training and employment subsidies are equivalent, and the former policies are superior to the latter policies.

The wage subsidy that is required to fully compensate the movers is reported in Table 2 and the equivalent replacement rate that is used to calculate unemployment benefits is reported in Table 3. The dead weight loss imposed on the economy by these programs as a fraction of the net gains from liberalization are reported in Table 4 (measured by $\frac{W_{FT} - W_P}{W_{FT} - W_{SS}}$). Since these values are largely insensitive to the turnover rates, we report them for only the two extreme cases – one in which the average high-tech job lasts ten years while the average low-tech job lasts one year and one in which the average high-tech job lasts six years while the average low-tech job lasts two years. In all cases, the wage subsidy is modest – generally less than one percent – but this is misleading.[20] Since high-tech jobs are very durable (lasting 6-10 years), the movers receive this wage subsidy for a subtantial length of time. In addition, when they lose their high-tech job their skills transfer 80% of the time. This means that most movers will obtain additional high-tech jobs without having to reenter the costly, lengthy high-tech training process. Thus, it should not be surprising that such a small subsidy is sufficient to compensate the movers for their losses.

Table 3 reveals that the replacement rate used to calculate the movers' unemployment benefit leads to a much higher flow payment than the wage subsidy. This should not be surprising since the average spell of unemployment is considerably shorter than the average spell of high-tech employment. The one curious result in Tables 2 and 3 is that the size of the payment required to compensate the movers is decreasing in the size of high-tech training costs. This counter-intuitive outcome emerges because of the manner in which we calibrate the model. Low high-tech training costs make sector 2 appear more appealing. Thus, to get the right fraction of the work force to search in sector 1, q_1, the sector 1 productivity parameter, must increase when training costs fall. This means that when workers move to sector 2, the sector 1 output that they are forgoing is larger when sector 2 training costs are low. Thus, when training costs are low the movers require more compensation than when the training costs are high.

The results in Table 4 are striking. Regardless of the turnover rates, these compensation schemes do not impose a large cost on the remainder of the economy. Deadweight loss is consistently below two tenths of one percent of the net gains from trade. There are two factors that contribute to this outcome. First, as Table 1 indictates, the movers in our model do not suffer huge losses from liberalization. Second, liberalization does not trigger that much movement in our model. In the case in which 20% of the labor force is initially employed in the low-tech sector, only 4% of the labor force switches to the high-tech sector when the tariff is removed.[21] The fact that the cost imposed on the rest of the economy is so small makes these redistributional policies considerably attractive – it is almost costless to compensate the movers for their losses.

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[20] Of course it would be possible to achieve the same objective by offering a higher subsidy that would not last for the full duration of the job. For example, an alternative (and equivalent) program might pay the worker a subsidy only during the first year of high-tech employment.

Up to this point we have argued that both wage subsidies and unemployment benefits are superior to training and employment subsidies when it come to compenasting the movers. It is natural to ask, how much better are these programs? In other words, if we were to use training subsidies instead, how much higher would the dead weight loss be? The answer to this question depends on the initial size of the low-tech sector and the extent of training costs. At one extreme, when training costs are equal to 15 months of high-tech wages and $a_H = .33$, the difference is very small – dead weight loss would be 2% higher with training subsidies. At the other extreme, when training costs are equal to just one month of high-tech wages and $a_H = .1$, the difference is dramatic with training subsidies increasing the dead weight loss by over 21%.

We close this section by arguing that two simple, natural extensions of our model would lead to the conclusion that it is more efficient to compensate the movers with wage subsidies than unemployment benefits. We begin by reminding the reader that the turnover rates in our model are all exogenous. As we pointed out at the end of section 2, we choose to set the model up this way in order to keep it tractable and to insure that our free trade equilibrium would be efficient. However, in reality, workers can alter their job acquisition rates by varying their intensity of job search. Our model would therefore be more realistic if e_2, the rate at which workers return to work, was endogenously determined by worker behavior. In such a model, wage subsidies would be superior to uemployment benefits becasuse of their impact on e_2.. Wage subsidies, by increasing the

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[21] This fraction grows to 10% for the case in which 33% of the labor force starts out attached to sector 1 and shrinks to less than one half of a percent for the case in which $a_H = .1$.

opportunity cost of remaining unemployed, would encourage the movers to search hard and return to work quickly. In contrast, unemployment benefits would lower the opportunity cost of unemployment, lower e_2, and slow down the transition to the new steady state. Thus, if we were to extend our model to allow the turnover rates to be endogenous, wage subsidies and unemployment benefits would no longer be equivalent – wage subsidies would be a superior way to compensate the movers.

The other assumption that would be worthwhile to relax has to do with the manner in which ability affects the wages earned by workers. In our model, the wage in each sector increases linearly with ability. In reality, since ability is more valuable in complex settings, it is probably the case that high-tech wages are more sensitive to ability than low-tech wages. One way to capture this notion would be to assume that low-tech wages are concave in ability while high-tech wages are convex in ability.[22] The implication of this assumption is that there will be a larger spread between what the average and marginal worker will earn in the high-tech sector than there is in the low-tech sector. And, since wage subsidies are tied to the wage earned on mover's new job (in sector 2), while unemployment benefits are tied to the wage earned on the worker's previous job (in sector 1), such an assumption would have important policy implications. In particular, wage subsidies would have a larger differential impact on the average and marginal mover's expected lifetime incomes than would unemployment benefits. It follows that

[22] Of course, such an extreme assumption is not required. If we were to write the sector j wage as a function of ability, $w_j(a_i)$, then it would be sufficient to assume that $w_1(a_i)$ is more concave than $w_2(a_i)$ in the usual Arrow-Pratt sense.

wage subsidies and unemployment benefits would no longer be equivalent ways to compensate the movers – wage subsidies would be superior.[23]

In conclusion, our results strongly suggest that it would be relatively cheap (in efficiency terms) to compensate those who change jobs as a result of trade liberalization. The optimal way to do so is to offer temporary wage subsidies targeted only at those workers who were tied to the low-tech sector at the time of liberalization.

5 Compensating the Stayers

The group that is harmed the most by liberalization is the stayers – the workers who cannot produce enough in the high-tech sector to make training for such jobs worthwhile. These workers have lower incomes than the movers and suffer bigger losses from liberalization. In this section, we compare compensation schemes for this this class of workers. Since we carefully described the technical details of the process used to solve for the optimal compensation scheme for the movers and since the processes are extremely similar, we do not go into the same level of detail in this section. Instead, we provide a heuristic description of the solution and discuss some new complications that arise when trying to find the best way to compensate the stayers. The detalied analysis of this case is available from the authors upon request.

As before, liberalization causes the V_{IT} curve to pivot down. Any policy designed to compensate the stayers increases the relative attractiveness of the low-tech sector,

[23] We verified this assertion by solving the model under the assumption that the low-tech wage is independent of ability. In this alternative model training subsidies and unemployment benefits are

causing this curve to shift back up. This creates a problem, some workers who should be attracted to the high-tech sector may wind up in the low-tech sector. As with the movers, one way to minimize the distortions created by such inefficient labor market behavior is to make the compensation scheme temporary and targeted. For example, wage subsidies should be offered only to those workers who were either employed in sector 1 at the time of liberalization, or are in their first spell of low-tech employment following the removal of the tariff. Doing so reduces the flow of inefficient labor market reallocation from sector 2 to sector 1. Making the policy temporary guarantees that the distortions created by the program will be temporary in nature. High-tech workers who move to the low-tech sector to take advantage of the policy will return to sector 2 as soon as they complete a spell of low-tech employment and collect whatever subsidies that are offered.

We consider three programs. First, there is a temporary training subsidy that is paid to all workers who are engaged in low-tech training immediately after the tariff is removed. This subsidy is paid only as long as the training process lasts and is not paid for subsequent periods of low-tech training. Second, there is a temporary wage subsidy which can be collected in one of two ways. Workers who hold low-tech jobs at the time of liberalization collect it immedaitely and continue to collect it until they lose their jobs. Those who are engaged in low-tech training can also collect the subsidy, but only after completing the training process and finding a low-tech job. Thus, to be eligible for the wage subsidy sector 2 workers must relocate to sector 1 and start training for a low-tech job as soon as the tariff is removed. Of course, since this is a temporary program, the wage subsidy can only be collected during one spell of employment. Finally, there is a

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equivalent and both are dominated by wage subsidies.

temporary employment subsidy that works in exactly the same manner as the wage subsidy except that the payment is independent of the worker's wage. Thus, all low-tech workers are offered the same employment subsidy regardless of their ability levels.

Suppose then that liberalization takes place and that a temporary compensation scheme targeted at the stayers is implemented at the same time. As in the previous section, there will be some low-tech workers who will choose to relocate to the high-tech sector. If the compensation offered is low, then some workers may choose to move to sector 2 immediately, some others may wait until they lose their low-tech jobs before switching and some others may delay movement until after they have taken full advantage of the compensation scheme. However, the compensation that must be offered to the stayers is ***not*** low. As we saw earlier in section 3, liberalization leads to large permanent losses for these workers – roughly 4.5% of their expected lifetime utility. It takes a large temporary payment to make up for such a loss. For example, if a wage subsidy is used, it will generally exceed 1.5 if the average low-tech jobs lasts one year and .75 if the average low-tech job lasts two years. This means that during the first spell of employment following liberalization the stayers income will have to be increased by somewhere between 75% to 150%![24]

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[24] To get an idea where these values come from, consider the following back-of the envelope calculation. Let x denote the flow of expected lifetime utility for the stayers in the initial, tariff-distorted steady state equilibrium. Then, after liberalization, if no compensation scheme is implemented the flow of expected lifetime income for these workers would drop to (roughly) .965x. Suppose instead that a wage subsidy of w_s is instituted and that low-tech jobs last exactly $1/b_1$ periods (i.e., there is no randomness). Then, if the wage subsidy is set to fully compensate the worker it must be the case that

$$\frac{x}{r} = \int_0^{\frac{1}{b_1}} e^{-rt}(.965x)(1+\omega_s)dt + \int_{\frac{1}{b_1}}^{\infty} e^{-rt}(.965x)dt$$

If $r = .03$, then if low-tech jobs last for 1 year ($b_1 = 1$) the wage subsidy must be set at (roughly) 1.75 while if low-tech jobs last 2 years ($b_1 = .5$) the wage subsidy must be set at .8.

With such a generous policy in place, no one moves to sector 2 immediately. In fact, some of the workers who are training in sector 2 at the time of liberalization switch and start training in sector 1 to take advantage of the compensation scheme. Of course, after these workers complete their sector 1 training and hold one low-tech job, they head right back to the high-tech sector. However, their decision to switch sectors temporarily creates a distortion, since they are better suited for high-tech employment.

We can make this precise by introducing new notation similar to that used in the previous section. Since the compensation scheme is temporary, we must distinguish between workers training or employed in sector 1 for the first time after liberalization and all others. Thus, let $V_{1k}^{h}(a_i)$ denote the expected lifetime income for a low-tech worker with ability a_i who is employed (if $k = E$) or training (if $k = T$) in sector 1 for the first time (if $h = 1$) or subsequently (if $h = +$) following liberalization. Now, suppose that a worker is attached to sector 1 at the time of liberalization. Then this worker will remain attached to this sector if, after losing her next low-tech job, retraining in sector 1 is still more attractive then switching to sector 2 – that is, if $V_{2T}(a_i) < V_{1T}^{+}(a_i)$, or $a_i < a_H^{+}$. All other low-tech workers (those with $a_i > a_H^{+}$) move to sector 2 but only after remaining in sector 1 long enough to take advantage of the compensation scheme. Since none of these workers move to sector 2 immediately, we refer to them as ***delayed movers***.

Turn next to those who are attached to the high-tech sector at the time of liberalization. Most of these workers will remain permanently attached to this sector. But, some may decide to move ***temporarily*** to the low-tech sector to take advantage of the compensation scheme and then move back to sector 2 afterward. High-tech trainers switch to sector 1 if $V_{2T}(a_i) < V_{1T}^1(a_i)$, high-tech searchers switch if $V_S(a_i) < V_{1T}^1(a_i)$, and sector 2 workers quit their high-tech job and move sector 1 if $V_{2E}(a_i) < V_{1T}^1(a_i)$.

For the most part, it is these ***temporary movers*** who relocate to the low-tech sector in order to take advantage of the compensation scheme that cause the distortion.[25] Just as in our previous section, the key to fining the optimal compensation scheme is to find a policy that is valued greatly by the average stayer (so that full compensation can be achieved with a modest sized program) but affects the marginal stayer only slightly (so that there is a minimal amount of temporary relocation). When our goal is to compensate the stayers, it would appear, at first blush, that training and employment subsidies should be equivalent and that both should dominate the wage subsidy. The reason is that among this class of workers the average stayer has a lower ability level than the marginal stayer. Thus, a wage subsidy is valued more by the marginal worker than the average worker because the marginal worker earns the higher wage.[26] In contrast, training and employment subsidies affect the marginal and average satyers in exactly the same manner since training costs are independent of ability and the employment subsidy is independent

[25] Note that all workers with ability levels such that $V_{2T}(a_i) > V_{1T}^+(a_i)$ eventually switch to sector 2. In the absence of income taxes, this would lead to the efficient amount of labor reallocation. However, the income tax is needed to fund the program and this creates another source of distortion. This issue was discussed on pages 26-27 and in footnote 16 in the previous section.

[26] If we were to allow for low-tech unemployment, the same argument would apply to unemployment benefits.

of the worker's wage.[27] Thus, it is tempting to conclude that the optimal way to compensate the stayers is with either a training subsidy or an employment subsidy.

However, there is a new complication that arises when trying to use a training subsidy to compensate the stayers. Since the subsidy must be large and since only those who are training for low-tech jobs immediately after the tariff is removed are eligible to receive it, workers employed in low-tech jobs will quit in order to collect the subsidy (because $V_{1T}^{1}(a_i) > V_{1E}^{+}(a_i) \forall a_i < a_H$). They do so knowing that low-tech training can be completed quickly so that it will not take them long to find new low-tech jobs. However, the fact that they quit implies that sector 1 output will fall making training subsidies less attractive. In fact, the reduction is low-tech output is large enough that in some cases, training subsidies are worse than wage subsidies (where this issue of quitting does not arise). Since low-tech workers have no reason to quit with an employment subsidy, the optimal way to compensate the stayers is with a temporary employment subsidy.

The employment subsidies that fully compensate the stayers as a group (measured as a fraction of the average stayer's wage) are given in Table 5 for each of the cases we consider. As discussed above, these subsidies are quite large ranging from 79% to 165% of the average stayer's wage. Society's cost of providing this compensation is reported in Table 6. The cost is measured as the percentage of the net gains from liberalization that

[27] If we were to extend the model to allow for training costs that vary with ability, the natural extension would have lower-ability workers facing higher training costs. The implication would then be that the average mover would value training subsidies more than the marginal mover. This would make training subsidies more attractive than employment subsidies. However, as we discuss above, the fact that a training subsidy causes low-tech workers to quit (while an employment subsidy does not) is a more

are lost due to the deadweight loss associated with the compensation scheme. Comparing Tables 4 and 6 we see that the cost of compensating the stayers is much higher than the cost of compensating the movers. There are two reasons for this – there are more stayers than movers and the stayers suffer larger losses than the movers. The most important feature of Table 6 is that, although it is more costly to compensate this group, the total cost is still quite modest – it never rises above 5% of the net benefit from liberalization. This makes for a compelling argument in favor of providing such compensation.

In the previous section we noted that attempts to compensate the movers with the wrong policy could increase dead weight loss by as much as 20%. Mistakes are even more costly when attempting to compensate the stayers. Since training subsidies encourage low-tech workers to quit their jobs, they result in a large reduction of low-tech output immediately following liberalization. In addition, since wage subsidies are more valuable to high-ability workers than they are to low-ability workers, they encourage considerably more temporary reallocation to the low-tech sector by high-tech tech workers. In fact, for the cases that we consider, employment subsidies result in only a small measure of high-tech trainers switching sectors to take advantage of the program. In contrast, wage subsidies result in much more reallocation by trainers and, in some cases, result in high-tech searchers switching sectors as well. As a result, using training or wage subsidies instead of employment subsidies can result in a dramatic increase in dead weight loss. In most cases, deadweight loss is more than 10 times greater under

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important consideration and this leads us to conclude that the optimal way to compensate the stayers is to use an employment subsidy.

these alternative policies. In some cases, these alternative policies eat away all of the gains from trade, making liberalization with compensation undesireable!

6 Conclusion

This paper has been devoted to an important issue – what is the best way to compensate those who are harmed by trade liberalization? To answer this question one must use a model takes into account the training and search processes that workers must go through in order to find jobs. We have provided such a model and have derived some preliminary results. In the context of our model, we have argued that the optimal way to compensate the movers (who bear the adjustment costs imposed on the economy by liberalization) is with a targeted, temporary wage subsidy. We have also argued that the optimal way to compensate the stayers (those who remain trapped in the low-tech sector because they find it too difficult to acquire the skills required for high-tech jobs) is with a targeted, temporary employment subisdy.

In order to keep our model tractable, we were required to make a number of simplifying assumptions. For example, we have treated the labor market turnover rates as exogenous, we have assumed that these turnover rates do not vary with ability, and we have assumed that additional training does not increase productivity. In the future it will be important to relax these assumptions to see how our results must be modified. Our results should therefore be viewed as the first step in a long process of investigating optimal compensation schemes when labor markets are imperfect.

We close by pointing out that we take some comfort in our belief that our results should survive when the turnover rates are endogenized. The reason for this is that our optimal policies, wage and employment subisidies, should be even more appealing in such a setting. After all, they encourage workers to search harder for employment, resulting in lower average spells of unemployment. In contrast, if we compensate the losers by increasing unemployment benefits or by offering training subsidies, we would expect to see an increase in the average length of jobless spells. This follows from the fact that theser two policies decrease the opportunity cost of unemployment.

Appendix A

In this Appendix our goal is to show that the mover's expected lifetime utility in the initial tariff-distorted equilibrium is given by (21). Since we have assumed that tariff revenue is redistributed in a manner that does not alter the distribution of income, the ratio of the mover's expected lifetime utility to the aggregate expected lifetime utility is equal to their share of income (*MS*). To find aggregate expected lifetime utility, note that with our utility function, the aggregate consumption bundle is given by $C_1 = \frac{I}{2(1+\gamma)}$ and $C_2 = \frac{I}{2}$ where *I* is a measure of aggregate income. It follows that $C_2 = (1+\gamma)C_1$. Now, at the tariff-distorted equilibrium, it must be the case that the value of output equals the value of the consumption bundle when both are evaluated at world price ($p_1 = p_2 = 1$). If we use X_j to denote the production of good *j,* then the value of output evaluated at world prices is $I_W = X_1 + X_2$. It follows that $C_1 + C_2 = I_W$. We can now substitute for C_2 from above to obtain $C_1 = \frac{I_W}{2+\gamma}$. This implies that $C_2 = \frac{(1+\gamma)I_W}{2+\gamma}$. Plugging these consumption bundles into the indirect utility function for the Cobb-Douglas utility function yields (21).

Appendix B

In this Appendix we provide the differential equations that determine the measures of permanent movers (workers with $a_i \in [a_H^+, a_H]$) and temporary movers (workers with $a_i \in [a_H^1, a_H^+]$) in each possible labor market state, the solution to these equations and the asset value equations that can be used to solve for a_H^+ and a_H^1. We start with the permanent movers. Their labor market dynamics are governed by

$$(B.1) \qquad P\dot{M}_{1E}(t) = -b_1 PM_{1E}(t)$$

$$(B.2) \qquad P\dot{M}_{2T}^1(t) = b_1 PM_{1E}(t) - \tau_2 PM_{2T}^1(t)$$

$$(B.3) \qquad P\dot{M}_{2S}^1(t) = \tau_2 PM_{2T}^1(t) - e_2 PM_{2S}^1(t)$$

$$(B.4) \qquad P\dot{M}_{2E}^1(t) = e_2 PM_{2S}^1(t) - b_2 PM_{2E}^1(t)$$

$$(B.5) \qquad P\dot{M}_{2S}^+(t) = b_2\phi_2[PM_{2E}^1(t) + PM_{2E}^+(t)] + \tau_2 PM_{2T}^+(t) - e_2 PM_{2S}^+(t)$$

$$(B.6) \qquad P\dot{M}_{2E}^+(t) = e_2 PM_{2S}^+(t) - b_2 PM_{2E}^+(t)$$

$$(B.7) \qquad (a_H - a_H^+)L = PM_{1E}(t) + PM_{2T}^1(t) + PM_{2T}^+(t) + PM_{2S}^1(t) + PM_{2S}^+(t) + PM_{2E}^1(t) + PM_{2E}^+(t)$$

Equations (B.1) and (B.5)-(B.7) are analogous to (14)-(17) and are based on the same logic. Equations (B.2)-(B.4) describe the labor market flows for permanent movers who are training, searching or employed in the high-tech sector for the first time. As before, the growth rate is defined as the difference between the flow into and out of each state. For example, in (B.2) workers enter high-tech training for the first time as they lose their low-tech jobs (which happens at rate b_1) and they exit this state at rate τ_2.

We solve these equations recursively, starting with (B.1). This differential equation allows us to solve for the measure of permanent movers who are still employed in their low-tech jobs at time *t*. This is a simple differential equation with a solution of the form $PM_{1E}(t) = ce^{-b_1 t}$ where *c* is a constant. We can solve for *c* using the initial condition (adapted from eq. 12a) $PM_{1E}(0) = \frac{\tau_1(a_H - a_H^+)L}{b_1 + \tau_1}$. Thus, we have

$$(B.8) \qquad PM_{1E}(t) = \frac{\tau_1(a_H - a_H^+)L}{b_1 + \tau_1} e^{-b_1 t}$$

Turn next to (B.2) which allows us to solve for the measure of permanent movers training in sector 2 for the first time. We can use (B.8) to substitute for $PM_{1E}(t)$ and then use the solution method described in Chiang (1984, p. 480-481) to solve for the general solution. We obtain $PM_{2T}^1(t) = Ae^{-\tau_2 t} + \frac{b_1\tau_1(a_H - a_H^+)L}{(b_1 + \tau_1)(\tau_2 - b_1)} e^{-b_1 t}$, where *A* is a constant. Finally, since it is the trainers who make the switch immediately, we know from (10a) that $PM_{2T}^1(0) = \frac{b_1(a_H - a_H^+)L}{b_1 + \tau_1}$. Using this allows us to solve for A, yielding our solution

$$(B.9) \qquad PM^1_{2T}(t) = \frac{b_1(a_H - \overset{+}{a}_H)L}{(b_1+\tau_1)(\tau_2-b_1)}[\tau_1 e^{-b_1 t} - (\tau_2 - b_1 - \tau_1)e^{-\tau_2 t}].$$

Turn next to (B.3), which allows us to solve for the measure of permanent movers searching for a sector 2 jobs for the first time. We can use $(B.9)$ to substitute for $PM^1_{2T}(t)$ and then use the method from Chiang used above to solve for the general solution. We obtain $PM^1_{2S}(t) = Be^{-e_2 t} + z\{\frac{\tau_1}{e_2 - b_1}e^{-b_1 t} + \frac{\tau_2 - \tau_1 - b_1}{e_2 - \tau_2}e^{-\tau_2 t}\}$, where B is a constant and $z = \frac{\tau_2 b_1(a_H - \overset{+}{a}_H)L}{(b_1+\tau_1)(\tau_2-b_1)}$. Since workers must train before they can search, no permanent movers are searching for sector 2 jobs at t = 0. We can use this initial condition to solve for B, which gives us our solution

$$(B.10) \qquad PM^1_{2S}(t) = \beta_P(t) - \beta_P(0)e^{-e_2 t}$$

where $\beta_P(t) = \frac{\tau_1 b_1(a_H - \overset{+}{a}_H)L}{(b_1+\tau_1)(\tau_2-b_1)}\{\frac{\tau_1}{e_2 - b_1}e^{-b_1 t} + \frac{\tau_2 - \tau_1 - b_1}{e_2 - \tau_2}e^{-\tau_2 t}\}$.

Equation (B.4) can be solved in the same manner and yields the measure of permanent movers employed in sector 2 for the first time. We use $(B.10)$ to substitute for $PM^1_{2S}(t)$ in (B.4) and then solve for the general solution. We then use the initial condition $PM^1_{2E}(0) = 0$ to solve for the constant term. This yields the following solution

$$(B.11) \qquad PM^1_{2E}(t) = \alpha_P(t) - \alpha_P(0)e^{-b_2 t}$$

where

$$\alpha_P(t) = \frac{e_2\tau_2 b_1(a_H - \overset{+}{a}_H)L}{(b_1-\tau_1)(\tau_2-b_1)}\{\frac{\tau_1}{e_2 - b_1}[\frac{e^{-b_1 t}}{b_2 - b_1} - \frac{e^{-e_2 t}}{b_2 - e_2}] + \frac{\tau_2 - \tau_1 - b_1}{e_2 - \tau_2}[\frac{e^{-\tau_2 t}}{b_2 - \tau_2} - \frac{e^{-e_2 t}}{b_2 - e_2}]\}.$$

This leaves (B.5)-(B.7) which can be solved for $PM_{2S}^{+}(t)$, $PM_{2E}^{+}(t)$ and $PM_{2T}^{+}(t)$ -- the measure of permanent movers searching, employed and training in sector 2 (but ***not*** for the first time). To solve these equations, we begin by solving (B.7) for $PM_{2T}^{+}(t)$ and then substitute the resulting expression into (B.5). We are then left with the following two differential equations

$$(B.12) \qquad P\dot{M}_{2S}^{+}(t) = -(e_2 + \tau_2)PM_{2S}^{+}(t) + (b_2\phi_2 - \tau_2)PM_{2E}^{+}(t) + g(t)$$

$$(B.13) \qquad P\dot{M}_{2E}^{+}(t) = e_2 PM_{2S}^{+}(t) - b_2 PM_{2E}^{+}(t)$$

where $g(t) \equiv \tau_2(a_H - a_H^{+})L + (b_2\phi_2 - \tau_2)PM_{2E}^{1}(t) - \tau_2[PM_{2T}^{1}(t) + PM_{2S}^{1}(t) + PM_{1E}(t)]$;

with $PM_{2E}^{1}(t)$, $PM_{2T}^{1}(t)$, $PM_{2S}^{1}(t)$ and $PM_{1E}(t)$ given above. To solve this system of equations we follow Boyce and DiPrima (1977, p. 329-331). If we use the initial conditions that $PM_{2E}^{+}(0) = PM_{2S}^{+}(0) = PM_{2T}^{+}(0) = 0$ we obtain the following solutions:

$$(B.14) \qquad PM_{2S}^{+}(t) = \frac{b_2 + \lambda_1}{\lambda_2 - \lambda_1}[\theta_1(0) - e^{\lambda_1 t}\theta_1(t)] - \frac{b_2 + \lambda_2}{\lambda_2 - \lambda_1}[\theta_2(0) - e^{\lambda_2 t}\theta_2(t)]$$

$$(B.15) \qquad PM_{2E}^{+}(t) = \frac{e_2}{\lambda_2 - \lambda_1}\{\theta_1(0) - e^{\lambda_1 t}\theta_1(t) - \theta_2(0) + e^{\lambda_2 t}\theta_2(t)\}$$

where $\theta_j(t) \equiv \int g(t)e^{-\lambda_j t}dt$ with $\lambda_1 \equiv -.5\{b_2 + e_2 + \tau_2 + \sqrt{(b_2 + e_2 + \tau_2)^2 - 4b_2 e_2(1 - \phi_2)}\}$

and $\lambda_2 \equiv -.5\{b_2 + e_2 + \tau_2 - \sqrt{(b_2 + e_2 + \tau_2)^2 - 4b_2 e_2(1 - \phi_2)}\}$.

Finally, $PM_{2T}^{+}(t)$ can be obtained as a residual. That is,

$$(B.16) \qquad PM_{2T}^{+}(t) = (a_H - a_H^{+})L - PM_{1E}(t) - PM_{1T}^{1}(t) - PM_{2S}^{1}(t) - PM_{2E}^{1}(t) - PM_{2S}^{+}(t) - PM_{2E}^{+}(t).$$

We now turn to the asset value equations that define expected lifetime income for permanent movers in each possible labor market state. Define V_{2k}^{h} to be the expected lifetime income for each mover who is training (if k = T), employed (if k = E) or searching (if k = S) in the high-tech sector for the first time after liberalization (if h = 1) or subsequently (if h = +). Then we have

$$(B.17)\qquad rV_{1E} = q_1 p_1 a_i (1-\psi) + b_1[V_{2T}^{1} - V_{1E}]$$

$$(B.18)\qquad rV_{2T}^{1} = -c_2 p_2 (1-t_m) + \tau_2[V_{2S}^{1} - V_{2T}^{1}]$$

$$(B.19)\qquad rV_{2S}^{1} = s_m q_1 p_1 a_i + e_2[V_{2E}^{1} - V_{2S}^{1}]$$

$$(B.20)\qquad rV_{2E}^{1} = e_m + q_2 p_2 a_i (1-\psi)(1+\omega_m) + b_2[\phi_2 V_{2S}^{+} + (1-\phi_2)V_{2T}^{+} - V_{2E}^{1}]$$

$$(B.21)\qquad rV_{2T}^{+} = -c_2 p_2 + \tau_2[V_{2S}^{+} - V_{2T}^{+}]$$

$$(B.22)\qquad rV_{2S}^{+} = e_2[V_{2E}^{+} - V_{2S}^{+}]$$

$$(B.23)\qquad rV_{2E}^{+} = q_2 p_2 a_i (1-\psi) + b_2[\phi_2 V_{2S}^{+} + (1-\phi_2)V_{2T}^{+} - V_{2E}^{+}]$$

As in our earlier sections, (B.17)-(B.23) follow from the fundamental equation of dynamic programming which states that the product of the discount rate and the asset value equals the sum of the current flow of income and the expected capital gain or loss from switching labor market states. Note that in (B.20) the current flow-income of a mover who is employed in the high-tech sector for the first time includes a wage subsidy and/or an employment subsidy. Similarly, the flow-income for movers who are training or searching in the high-tech sector for the first time include a training subsidy (in B.18) and unemployment benefits (in B.19). The temporary nature of these programs is reflected in the fact that the workers receive no additional assistance during subsequent spells of training, search and employment (the subsidies are not included in B.21-B.23).

The expected capital gain in (B.17)-(B.23) is given by the product of the rate at which the workers switch states and the capital gain from doing so. Note that in (B.17) a mover who is initially employed in the low-tech sector switchers to the high-tech sector after losing her job. The only other feature worth pointing out is that movers who complete their first spell of high-tech employment move to new labor market states in which they no longer receive government assistance (see eq. B.20).

These seven equations can be solved for the seven V terms, one of which is $V_{2T}^{+}(a_i)$. To find a_H^{+} we then solve $V_{2T}^{+}(a_i) = V_{1T}(a_i)$ for a_i.

Similar terms define expected lifetime income for the temporary movers. There are only two differences. First, (B.20) and (B.23) are no longer valid because these workers return to the low-tech sector if, after losing their high-tech job, they also lose their high-tech skills.[28] Thus, if we define V_{1T}^{R} (V_{1E}^{R}) to be the expected lifetime income for a temporary mover who has returned to and is training (employed) in the low-tech sector, then (B.20) and (B.23) must be replaced by

$$(B.24) \qquad rV_{2E}^{1} = e_m + q_2 p_2 a_i (1-\psi)(1+\omega_m) + b_2[\phi_2 V_{2S}^{+} + (1-\phi_2)V_{1T}^{R} - V_{2E}^{1}]$$

$$(B.25) \qquad rV_{2E}^{+} = q_2 p_2 a_i (1-\psi) + b_2[\phi_2 V_{2S}^{+} + (1-\phi_2)V_{1T}^{R} - V_{2E}^{+}]$$

[28] Note these workers do not return to the low-tech sector until they lose their high-tech skills. A worker who retains her high-tech skills when she loses her job earns V_{2S}^{+} if she remains in sector 2 and V_{1T} if she returns to sector 1. However, we know that $V_{2S}^{+}(a_i) > V_{2T}^{1}(a_i)$ and, by the definition of a_H^{1} we know that $V_{2T}^{1}(a_H^{1}) = V_{1T}(a_H^{1})$. Thus, each temporary mover is better off remaining in the high-tech sector as long as her skills transfer across high-tech jobs.

with

$$(B.26) \qquad rV_{1T}^{R} = \tau_1[V_{1E}^{R} - V_{1T}^{R}]$$

$$(B.27) \qquad rV_{1E}^{R} = q_1 p_1 a_i (1-\psi) + b_1[V_{1T}^{R} - V_{1E}^{R}]$$

These equations can be solved for the V terms, one of which is V_{2T}^{1}. To find a_H^1 we then solve $V_{2T}^{1}(a_i) = V_{1T}(a_i)$ for a_i.

The labor market dynamics for the temporary movers are similar to those for the permanent movers. However, as with expected lifetime income, there is one major difference -- after losing their high-tech skills the temporary movers return to the low-tech sector rather than retrain in sector 2. The labor market dynamics of the temporary movers are then governed by (B.1)-(B.4) and (B.6) with "PM" replaced by "TM" and the following set of additional differential equations:

$$(B.28) \qquad T\dot{M}_{2S}^{+}(t) = b_2\phi_2[TM_{2E}^{1}(t) + TM_{2E}^{+}(t)] - e_2 TM_{2S}^{+}(t)$$

$$(B.29) \qquad TM_{1E}^{R}(t) = \tau_1 TM_{1T}^{R}(t) - b_1 TM_{1E}^{R}(t)$$

$$(B.30) \qquad (a_H^{+} - a_H^{1})L = TM_{1E}(t) + TM_{2T}^{1}(t) + TM_{2S}^{1}(t) + TM_{2S}^{+}(t) + TM_{2E}^{1}(t) + TM_{2E}^{+}(t) + TM_{1T}^{R}(t) + TM_{1E}^{R}(t)$$

Note that (B.28) differs from (B.5) in that there are no temporary movers who train in the high-tech sector a second time. Workers who lose their high-tech skills return to the low-tech sector, retrain and accept low-wage jobs instead.

The solutions to (B.1)-(B.4) are given above. The only difference here is that the term $(a_H - a_H^{+})$ must now be replaced by $(a_H^{+} - a_H^{1})$ because the temporary movers have different ability levels then the permanent movers and because the measures of these two classes of workers differ. Thus, we have

$$(B.31) \qquad TM_{1E}(t) = \frac{\tau_1(a_H^+ - a_H^1)L}{b_1 + \tau_1} e^{-b_1 t}$$

$$(B.32) \qquad TM_{2T}^1(t) = \frac{b_1(a_H^+ - a_H^1)L}{(b_1 + \tau_1)(\tau_2 - b_1)}[\tau_1 e^{-b_1 t} - (\tau_2 - b_1 - \tau_1)e^{-\tau_2 t}]$$

$$(B.33) \qquad TM_{2S}^1(t) = \beta_T(t) - \beta_T(0)e^{-e_2 t}$$

$$(B.34) \qquad TM_{2E}^1(t) = \alpha_T(t) - \alpha_T(0)e^{-b_2 t}$$

with $\beta_T(t) = \frac{\tau_1 b_1(a_H^+ - a_H^1)L}{(b_1 + \tau_1)(\tau_2 - b_1)}\{\frac{\tau_1}{e_2 - b_1}e^{-b_1 t} + \frac{\tau_2 - \tau_1 - b_1}{e_2 - \tau_2}e^{-\tau_2 t}\}$ and

$$\alpha_T(t) = \frac{e_2\tau_2 b_1(a_H^+ - a_H^1)L}{(b_1 - \tau_1)(\tau_2 - b_1)}\{\frac{\tau_1}{e_2 - b_1}[\frac{e^{-b_1 t}}{b_2 - b_1} - \frac{e^{-e_2 t}}{b_2 - e_2}] + \frac{\tau_2 - \tau_1 - b_1}{e_2 - \tau_2}[\frac{e^{-\tau_2 t}}{b_2 - \tau_2} - \frac{e^{-e_2 t}}{b_2 - e_2}]\}.$$

Turn next to (B.28) and (B.6) which describe the measures of temporary movers searching and employed in the high-tech sector (but ***not*** for the first time). We begin by using (B.34) to substitute into (B.28) for $TM_{2E}^1(t)$. This leaves us with a system of two equations that can be solved as in Boyce and DiPrima (1977, p. 329-331). If we use the initial conditions that $TM_{2E}^+(0) = TM_{2S}^+(0) = 0$ we obtain the following solutions:

$$(B.35) \qquad TM_{2S}^+(t) = \frac{b_2 + \gamma_1}{\gamma_2 - \gamma_1}[H_1(0) - e^{\gamma_1 t}H_1(t)] - \frac{b_2 + \gamma_2}{\gamma_2 - \gamma_1}[H_2(0) - e^{\gamma_2 t}]$$

$$(B.36) \qquad TM_{2E}^+(t) = \frac{e_2}{\gamma_2 - \gamma_1}\{H_1(0) - e^{\gamma_1 t}H_1(t) - H_2(0) + e^{\gamma_2 t}H_2(t)\}$$

where

$H_j(t) \equiv b_2\phi_2 \int TM_{2E}^{1}(t)e^{-\gamma_j t}dt$; $\gamma_1 \equiv -.5\{b_2 + e_2 + \sqrt{(b_2+e_2)^2 - 4b_2e_2(1-\phi_2)}\}$ and

$\gamma_2 \equiv -.5\{b_2 + e_2 - \sqrt{(b_2+e_2)^2 - 4b_2e_2(1-\phi_2)}\}$.

The measures of temporary movers training and employed in the low-tech sector (after their return) are described by (B.29) and (B.30). We can solve (B.30) for $TM_{1T}^{R}(t)$ and then substitute this expression into (B.29). We can then rewrite (B.29) as

$$(B.37) \qquad T\dot{M}_{1E}^{R}(t) = \tau_1 M(t) - (b_1 + \tau_1)TM_{1E}^{R}(t)$$

with

$$M(t) \equiv (a_H^{+} - a_H^{1})L - TM_{1E}(t) - TM_{2T}^{1}(t) - TM_{2S}^{1}(t) - TM_{2S}^{+}(t) - TM_{2E}^{1}(t) - TM_{2E}^{+}(t)\}.$$

This equation can be solved using the method described in Chiang (1984, p. 480-481) and the initial condition $TM_{1E}^{R}(0) = 0$ to obtain

$$(B.38) \qquad TM_{1E}^{R}(t) = R(t) - e^{-(b_1+\tau_1)t}R(0)$$

where $R(t) \equiv e^{-(b_1+\tau_1)t}\int \tau_1 M(t)e^{(b_1+\tau_1)t}dt.$ Finally, $TM_{1T}^{R}(t)$ is the residual. That is,

$$(B.39) \qquad TM_{1T}^{R}(t) = M(t) - TM_{1E}^{R}(t).$$

Appendix C

In this appendix we show how to solve for the balanced-budget marginal tax rate on income when the government fully compensates the movers. To do so, we must calculate total government spending and the size of the government's tax base.

We begin with government spending. There are four sources of government spending (wages subsidies, employment subsidies, training subsidies and unemployment compensation) and two types of movers that collect these payments (permanent and temporary). A mover with ability level a_i who is collecting a wage subsidy gets $p_2 q_2 \omega_m a_i$ each period of employment. Thus, total wage subsidy payments are given by

$$(C.1) \qquad TPWS = p_2 q_2 \omega_m \int e^{-rt} \left[\int_{a_H^1}^{a_H^+} \frac{TM_{2E}^1(t)}{a_H^+ - a_H^1} a_i da_i + \int_{a_H^+}^{a_H} \frac{PM_{2E}^1(t)}{a_H - a_H^+} a_i da_i \right] dt$$

Each mover collecting an employment subsidy is paid e_m each period of employment. Thus, total employment subsidy payments are given by

$$(C.2) \qquad TPES = e_m \int e^{-rt} \left[\int_{a_H^1}^{a_H^+} \frac{TM_{2E}^1(t)}{a_H^+ - a_H^1} da_i + \int_{a_H^+}^{a_H} \frac{PM_{2E}^1(t)}{a_H - a_H^+} da_i \right] dt$$

Each mover with ability level a_i who is searching for high-tech employment for the first term collects unemployment benefits of $s_m p_1 \beta q_1 a_i$ as long as they remain unemployed. Thus, total unemployment benefits paid out are given by

$$(C.3) \qquad TPUB = s_m p_1 \beta q_1 \int e^{-rt} \left[\int_{a_H^1}^{a_H^+} \frac{TM_{2S}^1(t)}{a_H^+ - a_H^1} a_i da_i + \int_{a_H^+}^{a_H} \frac{PM_{2S}^1(t)}{a_H - a_H^+} a_i da_i \right] dt$$

Finally, all movers who are training for their first high-tech job after liberalization collect $t_m p_2 c_2$ in training subsidies for as long as they train. Thus, total training subsidy payments are given by

$$(C.4) \qquad TPTS = t_m p_2 c_2 \int e^{-rt} \left[\int_{a_H^1}^{a_H^+} \frac{TM_{2T}^1(t)}{a_H^+ - a_H^1} da_i + \int_{a_H^+}^{a_H} \frac{PM_{2T}^1(t)}{a_H - a_H^+} da_i \right] dt$$

It follows that total payments are equal to $TP = TPWS + TPES + TPUB + TPTS$.

Turn next to tax revenue. We have assumed that only employed workers pay taxes (that is, unemployment benefits and training subsidies are not taxed). The tax base can be calculated as follows. First, there are those workers who begin in sector 1 and remain there after liberalization. The tax base for this group of sector-1 stayers is given by

$$(C.5) \qquad TBS1 = p_1 \beta q_1 \left[\frac{\tau_1 (a_H^1)^2 L}{2r(b_1 + \tau_1)} \right]$$

Next, we have the movers who are employed in the low-tech sector. The tax base from this group is given by

$$(C.6) \qquad TBM1 = p_2 \beta q_2 \int e^{-rt} \left[\int_{a_H^1}^{a_H^+} \frac{TM_{1E}(t) + TM_{1E}^R(t)}{a_H^+ - a_H^1} a_i da_i + \int_{a_H^+}^{a_H} \frac{PM_{1E}(t)}{a_H - a_H^+} a_i da_i \right] dt$$

Next, we have the movers who are employed in the high-tech sector. It is convenient to divide this group into those who are moving temporarily and those who move permanently. The tax base from the temporary movers is given by (C.7) while the tax base from the permanent movers is given by (C.8).

$$(C.7) \qquad TBTM2 = p_2 q_2 \int e^{-rt} \left[\int_{a_H^1}^{a_H^+} \frac{(1+\omega_m) TM_{2E}^1(t) + TM_{2E}^+(t)}{a_H^+ - a_H^1} a_i da_i \right] dt$$

$$(C.8) \qquad TBPM2 = p_2 q_2 \int e^{-rt} \left[\int_{a_H^+}^{a_H} \frac{(1+\omega_m) PM_{2E}^1(t) + PM_{2E}^+(t)}{a_H - a_H^+} a_i da_i \right] dt \, .$$

Finally, we have those workers who are originally attached to the high-tech sector and remain so after liberalization. The tax base from this group of sector-2 stayers is equal to

$TBS2 = p_2 q_2 L_{2E} \left[\frac{1 + a_H}{2r} \right]$ where L_{2E} is given in (12b). It follows that the total tax base can be written as $TB = TBS1 + TBM1 + TBTM2 + TBPM2 + TBS2.$

Since the marginal tax rate is chosen to balance the budget, we have $\psi \equiv \frac{TP}{TB}$.

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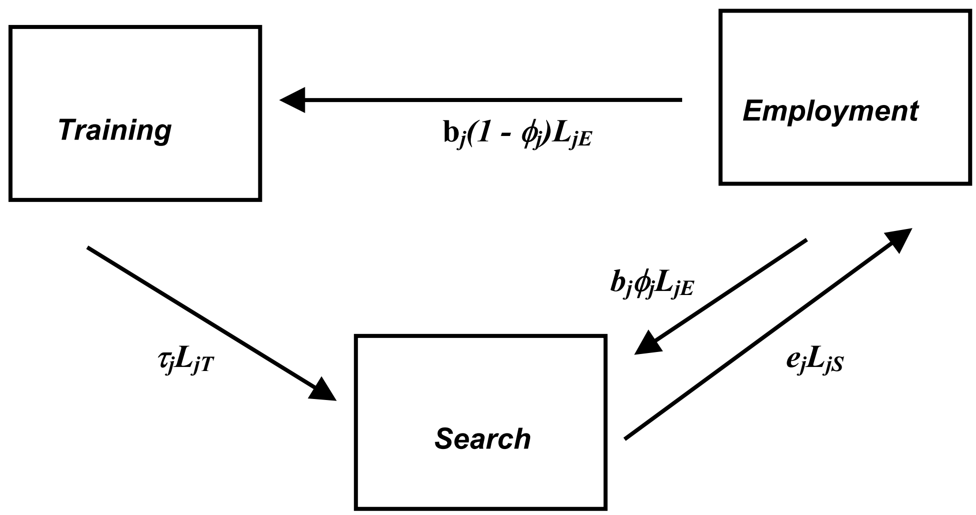

Figure 1: Labor Market Dynamics in Sector *j*

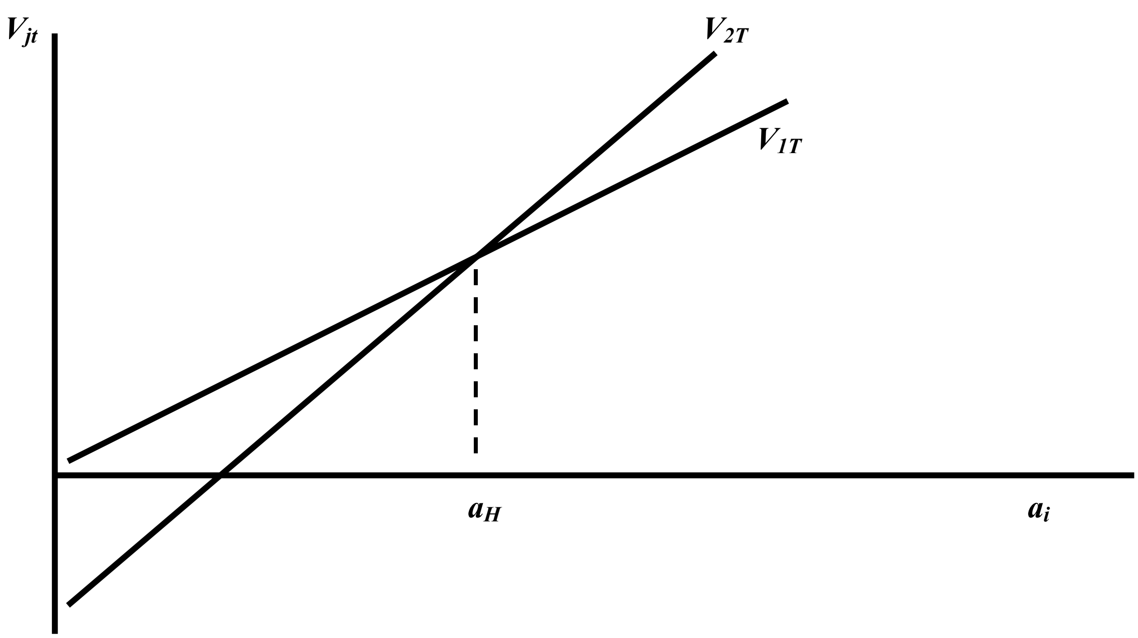

Figure 2: The Equilibrium Allocation of Workers

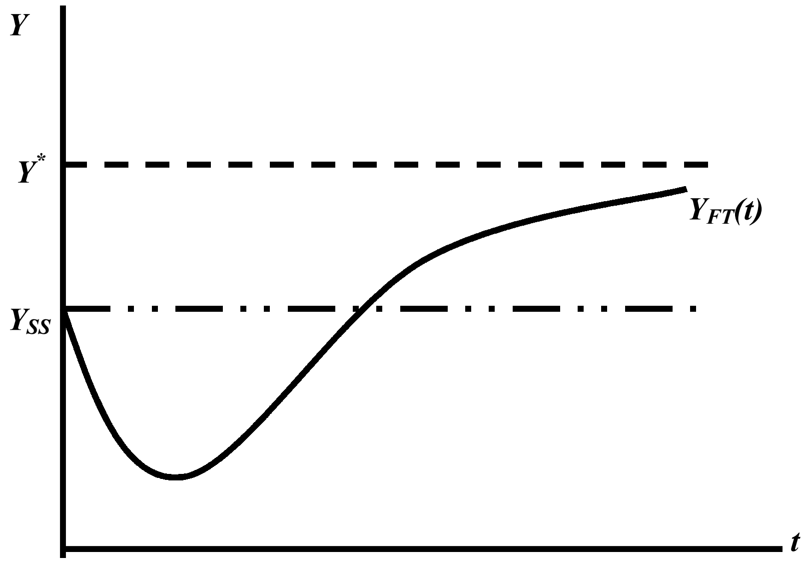

Figure 3: The Value of Output Net of Training Costs over Time

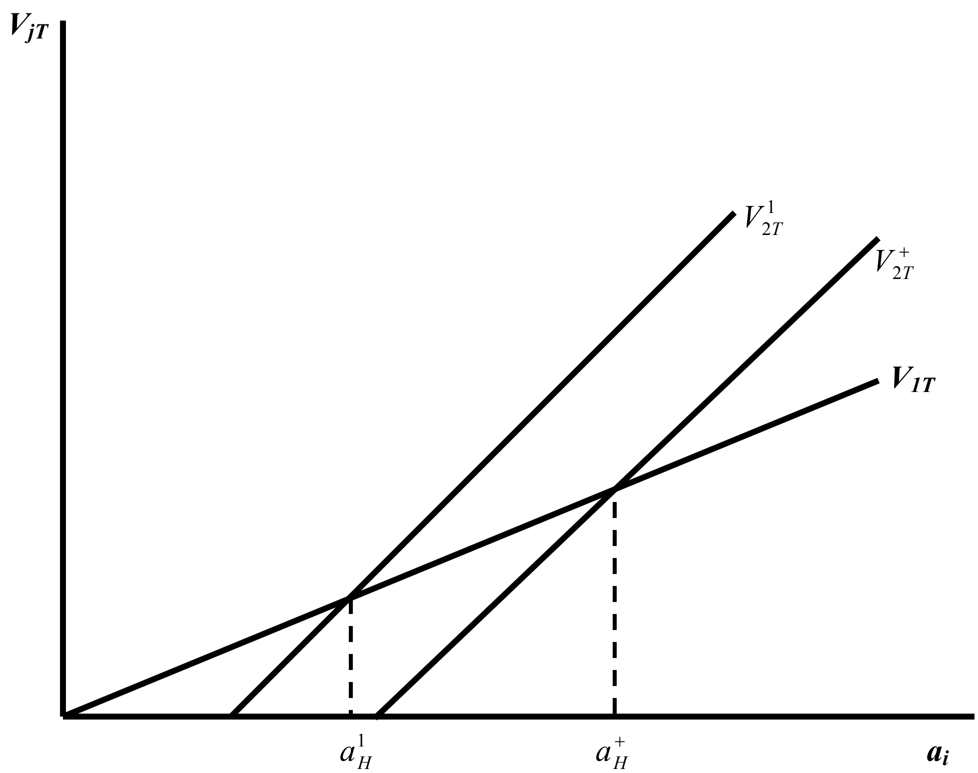

Figure 4: A Temporary Program to Compensate the Movers

a_H Training Costs	.10	.20	.33
b_1=.5 b_2=.1			
1 month	-1.50	-0.96	-0.37
5 months	-2.20	-1.83	-1.27
10 months	-2.35	-2.08	-1.60
15 months	-2.40	-2.18	-1.75
b_1=.5 b_2=.167			
1 month	-1.63	-1.10	-0.49
5 months	-2.26	-1.93	-1.39
10 months	-2.38	-2.15	-1.69
15 months	-2.42	-2.23	-1.83
b_1=1 b_2=.1			
1 month	-1.40	-0.86	-0.26
5 months	-2.12	-1.75	-1.20
10 months	-2.28	-2.00	-1.52
15 months	-2.34	-2.11	-1.67
b_1=1 b_2=.167			
1 month	-1.54	-1.00	-0.38
5 months	-2.19	-1.83	-1.31
10 months	-2.31	-2.07	-1.61
15 months	-2.36	-2.17	-1.75

Table 1

The Percentage Change in the Movers Expected Lifetime Utility Due to Liberalization

a_H Training Costs	.10	.20	.33
b_1=.5 b_2=.167			
1 month	.0146	.0190	.0140
5 months	.0069	.0087	.0089
10 months	.0047	.0066	.0069
15 months	.0030	.0054	.0059
b_1=1 b_2=.1			
1 month	.0104	.0125	.0060
5 months	.0050	.0062	.0062
10 months	.0036	.0047	.0048
15 months	.0026	.0040	.0042

Table 2

The Wage Subsidy that Fully Compensates the Movers

a_H Training Costs	.10	.20	.33
b_1=.5 b_2=.167			
1 month	.343	.438	.320
5 months	.196	.220	.215
10 months	.177	.186	.177
15 months	.170	.175	.164
b_1=1 b_2=.1			
1 month	.358	.421	.201
5 months	.197	.225	.216
10 months	.175	.186	.177
15 months	.168	.173	.162

Table 3

The Replacement Rate that Fully Compensates the Movers

a_H Training Costs	.10	.20	.33
b_1=.5 b_2=.167			
1 month	.132	.085	.020
5 months	.151	.131	.081
10 months	.154	.137	.095
15 months	.154	.140	.101
b_1=1 b_2=.1			
1 month	.090	.045	.005
5 months	.108	.093	.053
10 months	.112	.098	.065
15 months	.140	.102	.071

Table 4

Dead Weight Loss as a Percentage of the Net Gains from Liberalization When Fully Compensating the Movers

a_H Training Costs	.10	.20	.33
b_1=.5 b_2=.167			
1 month	.860	.835	.774
5 months	.862	.837	.777
10 months	.863	.840	.781
15 months	.865	.843	.786
b_1=1 b_2=.1			
1 month	1.656	1.607	1.489
5 months	1.658	1.611	1.495
10 months	1.660	1.615	1.503
15 months	1.663	1.620	1.509

Table 5

The Employment Subsidy Rate that Fully Compensates the Stayers

a_H Training Costs	.10	.20	.33
b_1=.5 b_2=.167			
1 month	1.04	0.40	0.16
5 months	3.36	2.21	1.28
10 months	4.15	3.20	2.16
15 months	4.49	3.69	2.68
b_1=1 b_2=.1			
1 month	0.94	0.37	0.16
5 months	3.51	2.19	0.55
10 months	4.50	3.30	1.10
15 months	4.96	3.95	2.04

Table 6

Dead Weight Loss as a Percentage of the Net Gains from Liberalization When Fully Compensating the Stayers