

# Trade Liberalization, Unemployment, and Inequality with Endogenous Job Destruction

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## **Abstract**

In a two sector extension of the Mortensen-Pissarides model of endogenous job destruction, it is shown that trade liberalization increases both job creation and job destruction in the import competing sector and reduces them in the export sector. Since trade liberalization increases unemployment in the import competing sector and reduces it in the export sector, the impact on economywide unemployment is ambiguous. While job destruction increases upon impact in the import competing sector, there is no immediate decrease in job destruction in the export sector leading to short term spikes in the net job destruction and unemployment rates in response to trade liberalization. Trade liberalization increases intersectoral wage inequality, however, intra-sectoral wage inequality increases in the export sector but decreases in the import competing sector. Finally, a more generous unemployment benefit increases the responsiveness of job destruction to trade liberalization.

Key words: trade liberalization, job destruction, unemployment, wage inequality

JEL Classification Codes: F16

# 1 Introduction

The main worry of people concerned with the adverse effect of trade liberalization on jobs is that it leads to job destruction. However, much theoretical work in the literature on trade and unemployment uses models where job destruction is exogenous. In these models trade liberalization changes the incentives for job creation leaving the incentive for job destruction unaffected. Therefore, the rate of job destruction is unchanged. This is contrary to not only popular perception, but empirical work on job flows as well. This paper aims to fill this gap in the literature by analyzing the impact of trade liberalization on unemployment and job flows in a model where job destruction is endogenous a la Mortensen and Pissarides (1994).

It constructs a two sector general equilibrium model with search generated unemployment and endogenous job destruction. All new jobs are created at maximum productivity but the job specific productivity is subject to an idiosyncratic shock which can lower job productivity. If the productivity falls below a cutoff then the job is destroyed. Trade liberalization reduces the relative price of the import competing good and increases the relative price of the export good. This leads to a decrease in the value of a job in the import competing sector and an increase in the value of a job in the export sector. This in turn increases the cutoff level of productivity below which jobs are destroyed in the import competing sector and decreases the cutoff in the export sector. The result is an increase in the rate of job destruction in the import competing sector and a decrease in the rate of job destruction in the export sector. Since the rates of job creation and destruction are equalized in steady state, the rate of job creation increases in the import competing sector and decreases in the export sector. Even though the steady state results are symmetrically opposite in the two sectors, the impact effects are asymmetric. A lot of jobs in the import competing sector become unviable and are destroyed immediately. The opposite happens in the export sector. That is, a lot of lower productivity jobs which were not viable to begin with survive now. However, since these lower productivity jobs were not viable earlier, they do not exist at the time of trade liberalization. These jobs appear and survive in the  $X$  sector only in the medium run. This asymmetry can lead

to short term spikes in job destruction and unemployment in response to trade liberalization.

Next, the paper looks at the impact of trade liberalization on wage inequality. Since wages are determined through Nash bargaining and there is renegotiation of wages following changes in job productivity, the model exhibits intra and intersectoral wage inequality. It is shown that the intersectoral wage inequality increases upon trade liberalization. As far as intra-sectoral wage inequality is concerned, it increases in the export sector and decreases in the import competing sector. The paper also studies how generous unemployment benefits affect job flows and unemployment in the open economy. It finds that generous unemployment benefits increase the responsiveness of the rate of job destruction and unemployment to trade liberalization. The results of the model are consistent with the empirical work described below.

In a recent paper studying the relationship between job flows and trade costs, Groizard et al. (2011) find that a reduction in the industry trade cost significantly reduces job creation and significantly increases job destruction. Moreover, the effect on job destruction is larger than the effect on job creation. Dutt, Mitra and Ranjan (2009), using cross-country data on trade policy and unemployment, find that unemployment and trade openness are negatively related. Using panel data, they find an unemployment-increasing short-run impact of trade liberalization, followed by an unemployment-reducing effect leading to the new steady state. Even though this paper does not look at job creation and job destruction separately, the result on the differential responses of trade liberalization in the short and long runs can be explained using our endogenous job destruction framework. Our results are also consistent with the results in Hasan et al. (forthcoming), which, using state level variation in the exposure to trade liberalization across Indian states, finds some weak evidence that the immediate short-run effect of a tariff reduction is to increase unemployment prior to reduction to a lower steady-state unemployment rate.

While our model studies the effect of trade liberalization on job flows, one could use the two sector set up to study the impact of real exchange rate changes on job flows in the traded and non-traded sectors. Since exchange rate appreciations increase the relative price of non-traded goods, the impact on the traded sector would be similar to the impact on the import competing sector

in our framework. Since manufacturing produces traded goods, one would expect the impact of exchange rate appreciation on manufacturing to be similar to that on the import competing sector in our theoretical framework. Klein, Schuh, and Triest (2003) study the impact of real exchange rate changes on job flows in the U.S. manufacturing industries from 1974 to 1993. Their key finding is that movements in trend real exchange rates significantly affect both job creation and destruction in the same direction and by similar magnitudes, thus they have large allocation effects but no effect on net employment growth. In contrast, an appreciation of the cyclical component of real exchange rates increases job destruction but has little effect on job creation, thus it reduces net employment growth but has no other allocation effects. Also related is a recent paper by Moser, Urban, and diMauro (2010) which studies the impact of real exchange rate changes on job flows using a sample of establishment-level data from Germany. They find evidence of net job losses in response to a real exchange rate appreciation. Their most interesting finding is that the bulk of adjustment in response to a real exchange rate appreciation occurs through less job creation than increased job destruction. They attribute this to rigid labor regulations that make job destruction costly for firms.

The paper is also related to the burgeoning theoretical literature on search generated unemployment in open economies. In a series of papers spanning over two decades Carl Davidson and Steven Matusz have studied the implications of introducing unemployment arising from labor market frictions in trade models. The main focus of their work, as discussed in Davidson and Matusz (2004), has been the role of efficiency in job search, the rate of job destruction and the rate of job turnover in the determination of comparative advantage. Among more recent works, Moore and Ranjan (2005) show how trade liberalization in a skill-abundant country can reduce the unemployment of skilled workers and increase the unemployment of unskilled workers. Skill-biased technological change on the other hand, can reduce the unemployment of unskilled workers. Helpman and Itshhoki (2010) use an imperfectly competitive set up with heterogeneous firms to look at how gains from trade and comparative advantage depend on labor market rigidities, and how labor-market policies in a country affect its trading partner. Felbermayr, Prat and Schmerer (2011) incorporate

search unemployment in a one sector model with firm heterogeneity to study the implications of a bilateral reduction in trade cost on unemployment. Mitra and Ranjan (2010) study the impact of offshoring in a two sector model where some jobs in one of the two sectors can be offshored while all the jobs in the other sector must remain onshore. In all these papers the rate of job destruction is exogenous, however. Therefore, trade liberalization affects unemployment through changes in job creation only.

The plan of the rest of the paper as follows. The next section describes the two sector search model with endogenous job destruction. Section 3 studies the implications of trade liberalization and also studies how unemployment benefits affect the responsiveness of job flows and unemployment to trade liberalization. Section 4 concludes.

## 2 The Model

### 2.1 Product Market

There is a single non-tradable final good  $Z$  which is produced using two potentially tradable inputs  $X$  and  $Y$ . The production function for  $Z$  is given below.

$$Z = \frac{AX^{1-\alpha}Y^\alpha}{\alpha^\alpha(1-\alpha)^{1-\alpha}} \quad (1)$$

Given the prices  $p_x$ , and  $p_y$ , of inputs, the unit cost for producing  $Z$  is given as follows.

$$c(p_x, p_y) = \frac{1}{A} (p_x)^{1-\alpha} (p_y)^\alpha \quad (2)$$

The market for good  $Z$  as well as the inputs  $X$  and  $Y$  is perfectly competitive. Since  $Z$  is chosen as the numeraire,  $p_z = 1$ , and therefore,  $c(p_x, p_y) = 1$ , or

$$\frac{1}{A} (p_x)^{1-\alpha} (p_y)^\alpha = 1 \quad (3)$$

The relative demand for the two inputs can be written as a function of the relative price as

follows.

$$\frac{X^d}{Y^d} = \frac{(1 - \alpha)p_y}{\alpha p_x} \quad (4)$$

## 2.2 Labor Market

Our description of labor market adapts the endogenous job destruction model of Mortensen and Pissarides (1994) to a two sector setting. To produce either  $X$  or  $Y$ , a firm needs to open job vacancies and hire workers. Let  $L_i$  be the total number of workers who look for a job in sector  $i$ . We are implicitly assuming that workers are not mobile across sectors. This may be a good description of the labor market in the presence of high mobility cost<sup>1</sup>. Allowing the workers to move costlessly across sectors will convert it into a Ricardian model because then effectively there will be a single factor of production. In this case, trade liberalization will wipe out the sector with comparative disadvantage. Since we want to capture the impact of trade liberalization on job creation and job destruction in the import competing sector, we make the assumption of no worker mobility. Also, we think that in the short to medium run, workers face high mobility costs which is the appropriate time frame for this kind of model and therefore, there is no loss of generality in assuming no worker mobility across sectors. In the long run, workers are likely to be mobile across sectors, therefore, the model and the results in the paper should be considered to be valid in a "medium run" scenario. Alternatively, the workers in the two sectors can be thought of as different types of labor such as skilled labor and unskilled labor.

Define  $\theta_i = \frac{v_i}{u_i}$  as the measure of market tightness in sector  $i$ , where  $v_i L_i$  is the total number of vacancies in sector  $i$  and  $u_i L_i$  is the number of unemployed workers searching for jobs in sector  $i$ . The probability of a vacancy filled is  $q(\theta_i) = \frac{m(v_i, u_i)}{v_i}$  where  $m(v_i, u_i)$  is a constant returns to scale matching function. Since  $m(v_i, u_i)$  is constant returns to scale,  $q'(\theta_i) < 0$ . The probability of an unemployed worker finding a job is  $\frac{m(v_i, u_i)}{u_i} = \theta_i q(\theta_i)$  which is increasing in  $\theta_i$ . The productivity of a job is denoted by  $t$  with support  $[0, 1]$  and a distribution function denoted by  $G(t)$ . All jobs are

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<sup>1</sup>See Mitra and Ranjan (2010) for a search and offshoring model with varying degrees of mobility costs.

created at the full productivity of 1. That is, a new job in either sector produces one unit of output. A job in sector- $i$  is hit with an idiosyncratic shock that leads to a change in the job productivity.  $\lambda_i$  is the Poisson arrival rate of the shock. If the job productivity falls below a reservation productivity  $R_i$  (to be determined endogenously) the job is destroyed immediately.

Denote the asset values of an occupied job in sector- $i$  with productivity  $t$  for a firm and for a worker by  $J_i(t)$  and  $W_i(t)$ , respectively. Denote the wage for a job in sector  $i$  with productivity  $t$  by  $w_i(t)$ . Denoting the rate of discount by  $r$ , the expression for  $J_i(t)$  is given by

$$rJ_i(t) = p_it - w_i(t) + \lambda_i \int_{R_i}^1 J_i(s) dG(s) - \lambda_i J_i(t) \quad (5)$$

Denoting the asset value of an unemployed worker in sector- $i$  by  $U_i$ , the expression for  $W_i(t)$  is given by

$$rW_i(t) = w_i(t) + \lambda_i \int_{R_i}^1 W_i(s) dG(s) + \lambda_i G(R_i) U_i - \lambda_i W_i(t) \quad (6)$$

Denoting the unemployment benefit including the value of leisure by  $b$ , the asset value of an unemployed worker in sector- $i$  is

$$rU_i = b + \theta_i q(\theta_i) [W_i(1) - U_i] \quad (7)$$

Note that since all jobs are created at the full productivity of 1,  $W_i(1)$  is the value of a new job for a worker.

The wage rate,  $w_i(t)$ , is such that the surplus from the job is divided according to the bargaining shares. Assume that the bargaining weight of workers is  $\beta$ . Denote the asset value of a vacant job in sector- $i$  by  $V_i$ . Now, the total surplus from a job is  $J_i(t) - V_i + W_i(t) - U_i$ . Generalized Nash bargaining implies that the worker gets a fraction  $\beta$  of the surplus.

$$W_i(t) - U_i = \beta [J_i(t) + W_i(t) - V_i - U_i] \quad (8)$$

Denote the cost of posting a vacancy in sector- $i$  in terms of good- $i$  by  $c_i$ . In a two sector model it is not obvious whether the cost of posting a vacancy should be in terms of the sectoral output

or the numeraire good. In fact, one can make an argument that modeling the recruitment cost in terms of the numeraire is more realistic. For example, if you want to post job vacancies to hire workers for a textile mill, you are more likely to pay the vacancy costs (recruitment or hiring cost) such as cost of job advertisement, paying a recruiter/head-hunter in terms of the final good rather than in terms of the textiles that your mill will produce. In the present model it turns out that modeling the recruitment cost in terms of the sectoral output makes the model slightly more tractable. Therefore, we decide to make this assumption in the paper. In an optional appendix available upon request it is shown that the qualitative results are unchanged when the recruitment cost is in terms of the numeraire.

Since all jobs are created at the maximum productivity  $t_i = 1$ , the expected profit from a vacancy in sector- $i$  is

$$rV_i = -p_i c_i + q(\theta_i)[J_i(1) - V_i] \quad (9)$$

Assuming no entry barrier in the posting of vacancy implies all rent from vacancies is dissipated:  $V_i = 0$ . Therefore, the above implies that the value of a new job satisfies

$$J_i(1) = \frac{p_i c_i}{q(\theta_i)} \quad (10)$$

The expression for wage can be derived as follows. Use (8) and (10) to re-write (7) above as

$$rU_i = b + \frac{\beta}{1 - \beta} p_i c_i \theta_i \quad (11)$$

To derive an expression for wage, multiply (6) by  $(1 - \beta)$  and (5) by  $\beta$  and subtract the latter from the former and use (8) and (11) to get

$$w_i(t) = (1 - \beta)b + \beta p_i(t + c_i \theta_i) \quad (12)$$

That is, the wage is increasing in the productivity of a job in addition to being increasing in the market tightness parameter,  $\theta_i$ , and the unemployment benefit,  $b$ . The latter two improve the bargaining position of the worker and hence his wage. A change in the productivity, on the other hand, affects the rent available from the job and hence the wage. Therefore, the model

exhibits heterogeneity in wages among identical workers. It is worth contrasting this result with those obtained in models with heterogeneous firms (e.g. Felbermayr et al. (2011)) where identical wage is paid by heterogeneous firms. In those models, firms hire many workers and the value of the marginal worker for the firm is equal to the expected recruitment cost for the worker. Since the recruitment cost is identical for all firms, the value of a marginal worker is equalized among heterogeneous firms. An implication of Nash bargaining over wages is that the surplus of worker is a scalar multiple of the surplus of firms from the marginal worker. Therefore, the equality of the surplus from the marginal worker across firms implies the equality of wages as well. In our set up with single worker firms, all firms within a sector pay identical wages to a worker when the worker is hired. This is because the value of a new job is equated to the expected recruitment cost as can be seen clearly from (10). However, for existing workers (10) does not apply and the wages are renegotiated to reflect the current productivity which determines the rent to be shared between the worker and the firm.

Next, we derive job creation and job destruction equations so that we can solve for  $R_i$  and  $\theta_i$  as functions of  $p_i$ . Note that in order for a job to be destroyed, the firm's surplus from the job must be zero. Since the firm's share of the surplus is a fraction  $(1 - \beta)$ , the overall surplus must be zero as well. That is,  $J_i(R_i) = (1 - \beta)(J_i(R) + W_i(R_i) - U_i) = 0$ . Therefore,  $W_i(R_i) - U_i = 0$  as well or  $W_i(R_i) = U_i$ . For  $t > R_i$ ,  $W_i(t) > U_i$ , and hence the worker is better off staying employed, while for  $t < R_i$ ,  $W_i(t) < U_i$ , and hence the worker would want to quit as well.

To derive the job creation curve, substitute the expression for wage given in (12) into (5) to get

$$(r + \lambda)J_i(t) = (1 - \beta)(p_i t - b) - \beta p_i c_i \theta_i + \lambda_i \int_{R_i}^1 J_i(s) dG(s) \quad (13)$$

Since  $J_i(R_i) = 0$ , the above implies

$$\lambda_i \int_{R_i}^1 J_i(s) dG(s) = \beta p_i c_i \theta_i - (1 - \beta)(p_i R_i - b) \quad (14)$$

Therefore, (13) can be written as

$$(r + \lambda_i)J_i(t) = (1 - \beta)p_i(t - R_i) \quad (15)$$

Next, note that the job creation condition (10) can be written using (15) as

$$\frac{(1 - \beta)(1 - R_i)}{(r + \lambda_i)} = \frac{c_i}{q(\theta_i)} \quad (16)$$

The left hand side of the above expression is the gain from a new job, while the right hand side is the expected recruitment cost. An increase in  $\theta_i$  implies higher recruitment cost and hence requires a lower  $R_i$  for the job creation to be viable. That is, the jobs should last longer. Alternatively, a higher  $R_i$  implies a greater probability of job destruction  $\lambda_i G(R_i)$ , and therefore, recruitment costs should be low as well which requires a lower  $\theta_i$ . Therefore, in  $(\theta, R)$  space, the curve representing (16) is downward sloping.

To get a simple expression for the job destruction condition, substitute (15) into (13) to get

$$(r + \lambda_i)J_i(t) = (1 - \beta)(p_i t - b) - \beta p_i c_i \theta_i + \frac{\lambda_i(1 - \beta)p_i}{r + \lambda_i} \int_{R_i}^1 (s - R_i) dG(s) \quad (17)$$

Now, the job destruction condition  $J_i(R_i) = 0$  can be written as

$$R_i - \frac{b}{p_i} - \frac{\beta}{1 - \beta} c_i \theta_i + \frac{\lambda_i}{r + \lambda_i} \int_{R_i}^1 (s - R_i) dG(s) = 0 \quad (18)$$

It can be verified that the l.h.s of (18) is increasing in  $R_i$  and decreasing in  $\theta_i$ . Intuitively, a higher  $\theta_i$  implies stronger bargaining position of workers, and therefore, reservation productivity must be higher for firms to break even or marginal jobs are destroyed. Therefore, the curve above is upward sloping in  $(\theta, R)$  space.

The two equations (16) and (18) determine the two key endogenous variables of interest:  $\theta_i$  and  $R_i$ .

The unemployment rate in sector- $i$  evolves according to

$$\dot{u}_i = \lambda_i G(R_i)(1 - u_i) - \theta_i q(\theta_i) u_i \quad (19)$$

The above implies that in steady-state ( $\dot{u}_i = 0$ )  $u_i$  is given by

$$u_i = \frac{\lambda_i G(R_i)}{\lambda_i G(R_i) + \theta_i q(\theta_i)} \quad (20)$$

### 2.3 Measures of Inequality

We define our measure of intra-sectoral inequality as the ratio of the top wage to the bottom wage:  $\frac{w_i(1)}{w_i(R_i)}$ . If the workers in the two sectors are different, then this can be viewed as a measure of within group inequality. Using the wage equation (12) this measure can be written as

$$\omega_i \equiv \frac{w_i(1)}{w_i(R_i)} = \frac{(1 - \beta)b + \beta p_i(1 + c_i \theta_i)}{(1 - \beta)b + \beta p_i(R_i + c_i \theta_i)} \quad (21)$$

We can also construct a measure of intersectoral wage inequality by computing the ratio of the average wages in the two sectors as follows. Define  $\bar{w}_i$  to be the average wage in sector- $i$  where  $\bar{w}_i$  is the total wage bill in sector- $i$ , denoted by  $WB_i$ , divided by the number of employed:  $(1 - u_i)L_i$ . The equation for the evolution of the total wage bill is as follows.

$$\dot{WB}_i = \theta_i q(\theta_i) u_i L_i w_i(1) + \lambda_i (1 - u_i) L_i \int_{R_i}^1 w(s) dG(s) - \lambda_i WB_i \quad (22)$$

The first term above is the wage bill from the new jobs created at full productivity. The second term is the wage bill from the existing jobs which are hit by a shock and survive and the last term is the loss in wage bill due to the change in the productivity of jobs resulting from the idiosyncratic shock. Therefore, the wage bill in steady state ( $\dot{WB}_i = 0$ ) is given by

$$WB_i = \frac{\theta_i q(\theta_i) u_i L_i w_i(1)}{\lambda_i} + (1 - u_i) L_i \int_{R_i}^1 w(s) dG(s) \quad (23)$$

And, the average wage is given by

$$\bar{w}_i = \frac{\theta_i q(\theta_i) u_i w_i(1)}{(1 - u_i) \lambda_i} + \int_{R_i}^1 w(s) dG(s) \quad (24)$$

Upon using the expression for  $u_i$  from (20) the above becomes

$$\bar{w}_i = G(R_i) w_i(1) + \int_{R_i}^1 w(s) dG(s) \quad (25)$$

Our measure of intersectoral wage inequality is going to be  $\frac{\bar{w}_x}{\bar{w}_y}$ .

## 2.4 Impact of a sectoral price change on unemployment and inequality

Let us first work out the implications of an increase in  $p_i$  on  $R_i$  and  $\theta_i$ . It is easy to verify from (16) and (18) that while the job creation curve remains unchanged, the job destruction curve shifts to the right because marginal jobs become viable now as firms have to pay less to workers due to a decrease in the outside opportunity of workers ( $\frac{b}{p_i}$  decreases). Therefore, an increase in  $p_i$  leads to an increase in  $\theta_i$  and a decrease in  $R_i$ .

Since an increase in  $p_i$  leads to an increase in  $\theta_i$  and a decrease in  $R_i$ , it can be verified from (20) that it must lead to a decrease in  $u_i$  as well.

An increase in the sectoral price  $p_i$  affects wage inequality through three channels. First, there is a direct effect working to increase inequality because the value of a job at full productivity increases more than the value at the cutoff productivity  $R_i$ , while the unemployment benefit is the same for all workers and does not depend on job productivity. Second, a decrease in the cutoff productivity  $R_i$  increases inequality. Finally, an increase in  $\theta_i$  tends to reduce inequality because the bargaining positions of all workers increases by the same magnitude. Therefore, the impact of an increase in  $p_i$  on  $\omega_i$  is theoretically ambiguous.

To resolve the ambiguity, we assume a Cobb-Douglas matching function of the form below.

$$\textit{Assumption 1: } M(v_i L_i, u_i L_i) = m_i (v_i L_i)^\gamma (u_i L_i)^{1-\gamma}$$

It is shown in the appendix that under assumption 1 a sufficient condition for  $\frac{d\omega_i}{dp_i} > 0$  is  $\beta p_i \left( \frac{\gamma c_i \theta_i}{1-\gamma} - 1 \right) < (1-\beta)b$ . This condition is easily satisfied for reasonable parameter values used in the search literature. As mentioned in the numerical example later, a reasonable value of  $\gamma$  in the literature is 0.5. For this value of  $\gamma$  the inequality in the sufficiency condition is satisfied irrespective of the values of  $b, \beta$ , and  $p_i$  as long as  $c_i \theta_i < 1$  which is very reasonable given the estimates of  $c_i$  and  $\theta_i$  in the literature. Therefore, it is reasonable to expect  $\omega_i$  to be increasing in  $p_i$ .

## 2.5 General Equilibrium

The model can be solved as follows. Start with a relative price  $\frac{p_x}{p_y}$ . Obtain  $p_x$  and  $p_y$  in terms of the numeraire final good from (3). Now, obtain the corresponding  $R_i$  and  $\theta_i$  from (16) and (18). Then, obtain the unemployment rate  $u_i$  from (20). Next, the total output of good- $i$  can be computed as follows. Denote the total amount of labor available for employment in good- $i$  by  $L_i$ . The amount of labor employed in sector- $i$  is  $(1 - u_i)L_i$ . Denote the output per unit of labor force in the two sectors by  $x$  and  $y$ , respectively. That is:  $x = X/L_x; y = Y/L_y$ . The equation for the evolution of the sectoral output per unit of labor force is given below.

$$\dot{i} = \theta_i q(\theta_i) u_i + \lambda_i (1 - u_i) \int_{R_i}^1 s dG(s) - \lambda_i i; \quad i = x, y \quad (26)$$

The first term above is the output resulting from new matches which are created at full efficiency. The second term is the output of the existing jobs that are hit by a shock and survive. The last term is the output that is lost due to the arrival of the idiosyncratic shock. In steady state  $\dot{i} = 0$ , therefore,

$$i = \frac{\theta_i q(\theta_i)}{\lambda_i} u_i + (1 - u_i) \int_{R_i}^1 s dG(s); \quad i = x, y \quad (27)$$

Next, note from (19) that in steady-state  $\theta_i q(\theta_i) u_i$  must equal  $\lambda_i G(R_i)(1 - u_i)$ . Therefore, (27) can be written as

$$i = (1 - u_i) \left[ G(R_i) + \int_{R_i}^1 s dG(s) \right]; \quad i = x, y \quad (28)$$

Thus, we can write the relative output of good- $X$  at relative price  $\frac{p_x}{p_y}$  as

$$\left( \frac{X}{Y} \right)^s = \frac{\left[ (1 - u_x) (G(R_x) + \int_{R_x}^1 s dG(s)) \right] L_x}{\left[ (1 - u_y) (G(R_y) + \int_{R_y}^1 s dG(s)) \right] L_y} \quad (29)$$

Next, we establish that the relative supply above is increasing in the relative price  $\frac{p_x}{p_y}$ . An increase in  $\frac{p_x}{p_y}$  implies an increase in  $p_x$  and a decrease in  $p_y$ . This in turn implies that  $u_x$  and  $R_x$  decrease while  $u_y$  and  $R_y$  increase. While changes in  $u_i$  raise the relative supply of  $X$ , the impact of changes in  $R_i$  is ambiguous. To get intuition for the ambiguity, note from (28) that decreases in

$u_i$  and  $R_i$  increase the output from existing jobs  $((1 - u_i) \int_{R_i}^1 s dG(s))$ , but they have an ambiguous effect on the output from new jobs  $((1 - u_i)G(R_i))$ .

To resolve the ambiguity in the response of relative supply to the relative price, we make the following functional form assumption which is also useful in deriving some later results.

*Assumption 2:*  $t_i \sim Uniform[0, 1]$

Under the above functional form assumption

$$i = (1 - u_i) \left[ R_i \left(1 - \frac{R_i}{2}\right) + \frac{1}{2} \right] \quad (30)$$

Therefore,

$$\frac{di}{dp_i} = - \left[ R_i \left(1 - \frac{R_i}{2}\right) + \frac{1}{2} \right] \frac{du_i}{dp_i} + (1 - u_i)(1 - R_i) \frac{dR_i}{dp_i} \quad (31)$$

As well, using assumption 1 for the matching function, the expressions for job creation (16) and job destruction (18) can be written as

$$\frac{(1 - \beta)(1 - R_i)}{(r + \lambda_i)} = \frac{c_i}{m_i} \theta_i^{1-\gamma} \quad (32)$$

$$\frac{r}{r + \lambda_i} R_i + \frac{\lambda_i}{r + \lambda_i} \frac{R_i^2}{2} - \frac{\beta}{1 - \beta} c_i \theta_i + \frac{\lambda_i}{2(r + \lambda_i)} = \frac{b}{p_i} \quad (33)$$

Using the above two it is shown in the appendix that

$$\frac{di}{dp_i} > (<) 0 \text{ iff } u_i > (<) \frac{2R_i(1 - R_i)^2(1 - \gamma)}{((1 - R_i)(1 - \gamma) + \gamma R_i)(R_i(2 - R_i) + 1)} \equiv \Psi(R_i) \quad (34)$$

Numerical simulations using the standard values of parameters taken from the search literature<sup>2</sup> suggest that  $\frac{di}{dp_i} > 0$ .

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<sup>2</sup>In the numerical example below  $r = .0033$ , (monthly rate of discount) corresponds to 4% annual rate of interest;  $\eta = .5$ ;  $\beta = .5$ ;  $\lambda = .035$  (monthly job destruction rate);  $m = .64$  (scale parameter in the matching function); these parameters are taken from Felbermayr et al. (2011).

Numerical example 1:  $r = .0033$ ;  $\lambda = .035$ ;  $m = .64$ ;  $\gamma = .5$ ;  $\beta = .5$ ;  $b = .7$ ;  $c = .4$

With these parameter values, the initial wage turns out to be 0.98 when the price is set at 1. Therefore, the unemployment benefit and home production is roughly 75% of the initial wage and the recruitment cost is roughly 40% of the initial wage, which is broadly consistent with the literature (example, Delacroix (2006)). Also, these parameters lead to reasonable values of the market tightness variable,  $\theta$ , of 0.65, and the unemployment rate of 6%. For these parameters,  $u$  is always greater than  $\Psi(R)$  defined in (34) for any value of  $p$  and therefore,  $\frac{di}{dp_i} > 0$ .

Small perturbations of the parameters above leave the result intact. Therefore, we acknowledge the theoretical possibility of  $\frac{di}{dp_i} < 0$ , but assume  $\frac{di}{dp_i} > 0$  in rest of the paper. Effectively, we are assuming that the output effect from existing jobs dominates the output effect from the new jobs in response to an increase in  $p_i$ . In this case we get an upward sloping relative supply curve. Given the downward sloping relative demand in (4), we get a unique equilibrium in autarky.

What are the determinants of the pattern of comparative advantage in the model? One obvious determinant of comparative advantage is the relative endowment of the two types of workers:  $\frac{L_x}{L_y}$ . The greater the  $\frac{L_x}{L_y}$  the greater the relative supply of  $X$  and hence the lower the relative price of  $X$ . Therefore, a country with a greater  $\frac{L_x}{L_y}$  will have a comparative advantage in  $X$ . In addition, it is possible for parameters like  $b$ ,  $c_i$ ,  $m_i$ ,  $\lambda_i$ ,  $\beta$  etc. to differ across sectors and countries and give rise to comparative advantage. We refer the reader to Davidson, Martin, and Matusz (1999) for a rich discussion of the determinants of pattern of comparative advantage in a search model of this type.

### 3 Trade liberalization

Suppose the economy has a comparative advantage in producing input  $X$ . That is, the autarky relative price  $\frac{p_x}{p_y}$  is less than the world price. In this case, trade liberalization will lead to an increase in the relative price of good  $X$ . This implies from (3) that  $p_x$  increases and  $p_y$  decreases.

Below we study the impact of these changes in the input prices on the job creation, job destruction and unemployment in the two sectors.

It can be verified from (16) and (18) that an increase in  $p_x$  leads to an increase in  $\theta_x$  and a decrease in  $R_x$ . A decrease in  $p_y$  leads to a decrease in  $\theta_y$  and an increase in  $R_y$ . It is clear from (20) that  $u_x$  decreases and  $u_y$  increases. Therefore, the impact of trade liberalization on aggregate unemployment is ambiguous.

While the result on steady state unemployment is similar to those obtained in a model with exogenous job destruction, we obtain interesting results on job flows below which are absent in models with exogenous job destruction.

### 3.1 Impact of trade liberalization on job creation and job destruction

Define job destruction rate as the ratio of total job destruction to employment:  $\frac{\lambda_i G(R_i)(1-u_i)L_i}{(1-u_i)L_i} = \lambda_i G(R_i)$ . Similarly, the rate of job creation is equal to the number of matches over employment:  $\frac{\theta_i q(\theta_i) u_i}{1-u_i}$

The discussion earlier implies that there is an increase in the rate of job destruction in the  $Y$  sector due to import competition. Now, in steady-state this also implies an increase in the rate of job creation since the two are equal. Therefore, trade liberalization leads to increases in the rates of job creation and job destruction in the  $Y$  sector and decreases in the rates of job creation and job destruction in the  $X$  sector. The result is summarized in the proposition below.

**Proposition 1** *Trade liberalization increases job flows in the import competing sector and reduces job flows in the export sector.*

The result above is consistent with the findings of Groizard et al. (2011) where a reduction in the trade cost in an industry leads to greater job destruction for the industry. If one interpreted the two sectors as tradable and non-tradable sectors, then the model would imply an increase in job destruction in the traded sector in response to an appreciation of the real exchange rate. This

is consistent with the evidence in Klein et al. (2003) that exchange rate appreciation is associated with increased job destruction in the manufacturing industries in the U.S.

Since much of the literature on trade and unemployment uses models with exogenous job destruction we can contrast our result with that in the exogenous job destruction model as follows. The exogenous job destruction model is a special case of our model where  $R_i = 1$ . Note that, by definition this also implies  $G(R_i) = 1$ . Therefore, the rate of job destruction is identically equal to  $\lambda_i$ . Thus, trade liberalization has no effect on job destruction in either sector.

### 3.1.1 Transition Dynamics

Since the equations determining  $R$  and  $\theta$ , (16) and (18), do not depend on the unemployment rate,  $R$  and  $\theta$  jump to their new steady-state values instantaneously in response to trade liberalization. However, the unemployment rate adjusts gradually. Denote the pre-liberalization values of the endogenous variables with a superscript 0 and the post-liberalization values with a superscript 1. We assume that firms can destroy jobs costlessly and therefore, the job destruction condition  $J_i(R_i) = 0$  always holds (even outside steady-state). We prove the following result below.

**Proposition 2** *During transition from the pre-liberalization steady-state to the post-liberalization steady-state, the rate of job destruction exceeds the rate of job creation in the import competing sector while the rate of job creation exceeds the rate of job destruction in the export sector.*

Proof: As shown earlier,  $u_y^0 < u_y^1$ . As well,  $\lambda_y G(R_y^1) = \frac{\theta_y^1 q(\theta_y^1) u_y^1}{1 - u_y^1}$ , since in steady-state the rate of job destruction must equal the rate of job creation. Therefore,  $\lambda_y G(R_y^1) > \frac{\theta_y^1 q(\theta_y^1) u_y^1}{1 - u_y^1}$  for  $u_y^1 < u_y^0$ . By a similar argument it follows that  $\lambda_x G(R_x^1) > \frac{\theta_x^1 q(\theta_x^1) u_x^1}{1 - u_x^1}$  for  $u_x^1 < u_x^0$ . *QED*

What is even more interesting is the impact effect of trade liberalization. Since the rate of job destruction jumps up to  $\lambda_y G(R_y^1)$ , on impact a fraction  $\lambda_y [G(R_y^1) - G(R_y^0)]$  of extra jobs are destroyed in the  $Y$  sector immediately. That is, all the jobs with productivity  $t \in (R_y^0, R_y^1)$  were

viable before liberalization, however, now they must be destroyed. In the  $X$  sector the rate of job destruction goes down from  $\lambda_x G(R_x^0)$  to  $\lambda_x G(R_x^1)$ . However, this has no immediate effect because there are no jobs with productivity  $t \in (R_x^1, R_x^0)$  in the  $X$  sector at the time of trade liberalization that can survive now. Thus, on impact the rate of job destruction does not decrease in the  $X$  sector. Therefore, there is an asymmetry in the impact effect of trade liberalization on the two sectors. While a fraction  $\lambda_y [G(R_y^1) - G(R_y^0)]$  of jobs are destroyed in the  $Y$  sector immediately leading to a large increase in unemployment upon impact, there is no commensurate decrease in job destruction in the  $X$  sector immediately upon trade liberalization. The lower rate of job destruction in the  $X$  sector will show up in the medium run when jobs with  $t \in (R_x^1, R_x^0)$  will survive.

The impact effect on the rate of unemployment is as follows.

$$u'_y = u_y^0 + \dot{u}_y = u_y^0 + \lambda_y G(R_y^1)(1 - u_y^0) - \theta_y^1 q(\theta_y^1) u_y^0 > u_y^0 \quad (35)$$

Note from the expression for  $u'_y$  that if  $u'_y > u_y^1$ , then there is overshooting of unemployment. That is, the unemployment rate jumps up and then decreases gradually to its new steady state. Therefore, it is possible for the unemployment rate to shoot up in the import competing sector in response to trade liberalization and then come down gradually.

The results on the impact effect of trade liberalization are consistent with some stylized facts which are hard to reconcile with the model of exogenous job destruction. For example, Dutt, Mitra and Ranjan (2009) find that trade liberalization leads to short term spikes in unemployment followed by long-run declines. The short term spike in unemployment can be explained using the asymmetric responses of the two sectors above with regard to job destruction.

In the model with exogenous job destruction, all the adjustment in the jobs takes place through job creation. Therefore, during transition from pre-liberalization steady-state to post-liberalization steady-state, the rate of job destruction will remain unchanged, but the rate of job creation will slow down to a rate below the rate of job destruction in the import competing sector. In steady-state the rate of job creation will go back to the autarky level. The opposite will happen in the export sector. Since all the action takes place through job creation, one cannot get an asymmetric

response across the two sectors either.

Before ending this section, it is worth pointing out another interesting implication of trade liberalization in a model with endogenous job destruction. Since the productivity cutoff increases in the import competing sector, trade liberalization increases the productivity of the import competing sector. This is similar to the selection effect of globalization operating in the Melitz type heterogeneous firm models due to a fixed cost of trading. It arises in the current framework due to labor market frictions.

### 3.2 Trade Liberalization and Wage Inequality

Given the discussion of the impact of sectoral price,  $p_i$ , on the intra-sectoral wage inequality,  $\omega_i$ , in the previous section, it is straightforward to study the impact of trade liberalization on  $\omega_i$ . Since trade liberalization leads to an increase in  $p_x$  and a decrease in  $p_y$ , it also leads to an increase in  $\omega_x$  and a decrease in  $\omega_y$ . In other words, in the short to medium run, trade liberalization leads to an increase in the within group inequality among workers employed in the export sector and a decrease in the within group inequality among workers employed in the import competing sector.

Given our functional form assumption 2, the measure of intersectoral wage inequality defined earlier can be written as

$$\frac{\overline{w_x}}{\overline{w_y}} = \frac{R_x w_x(1) + \int_{R_x}^1 w_x(s) ds}{R_y w_y(1) + \int_{R_y}^1 w_y(s) ds} \quad (36)$$

Since  $w_i(s)$  is increasing in  $p_i$  as is easily verified from (12),  $w_x(s)$  increases and  $w_y(s)$  decreases upon trade liberalization. This would tend to increase the intersectoral wage inequality. However,  $R_x$  decreases and  $R_y$  increases. The decrease in  $R_x$  decreases the first term in the numerator but increases the second term. Similarly, an increase in  $R_y$  increases the first term, but decreases the second term. Therefore, the only force that works against an increase in intersectoral wage inequality is the impact of a change in  $R_i$  on the first terms in both the numerator and the denominator. Intuitively, a decrease in  $R_x$  implies less job destruction and consequently less job creation as well in the  $X$  sector. A lower job creation in steady state implies smaller number of jobs

at full productivity which serves to lower the average wage. The opposite happens in the  $Y$  sector. However, this effect by itself cannot outweigh the other effects tending to raise intersectoral wage inequality. It is shown in the appendix that a sufficient condition for intersectoral wage inequality to increase is

$$\beta c_i \theta_i + \beta \left( R_i + \frac{1 - R_i^2}{2} \right) + \beta p_i c_i \frac{d\theta_i}{dp_i} + \beta p_i (1 - R_i) \frac{dR_i}{dp_i} > 0 \quad (37)$$

Note that since  $\frac{d\theta_i}{dp_i} > 0$ , the only negative term on the l.h.s of the inequality above is the last term because  $\frac{dR_i}{dp_i} < 0$ . This captures the effect on average wage arising from lower job creation. However, the last term by itself is unlikely to outweigh the first three terms. In fact, if  $c_i \theta_i > (1 - \gamma)(1 - R_i)^2$ , then, as shown in the appendix, the sum of last two terms is positive which is sufficient for the above inequality to be true. The condition  $c_i \theta_i > (1 - \gamma)(1 - R_i)^2$  is easily satisfied in the numerical simulations with reasonable parameter values.

Therefore, we conclude that the intersectoral wage inequality is likely to increase upon trade liberalization.

### 3.3 Impact of unemployment benefits on job flows and unemployment in the open economy

In this section we study how generous unemployment benefits interact with trade liberalization. In particular, whether a generous unemployment benefit amplifies or moderates the impact of trade liberalization on unemployment.

Taking the total derivative of equations (32) and (33) with respect to  $b$  obtain

$$\frac{-(1 - \beta) dR_i}{(r + \lambda_i) db} = \frac{c_i}{m_i} (1 - \gamma) \theta_i^{-\gamma} \frac{d\theta_i}{db} \quad (38)$$

$$\frac{1}{r + \lambda_i} (r + R_i \lambda_i) \frac{dR_i}{db} - \frac{\beta c_i}{1 - \beta} \frac{d\theta_i}{db} = \frac{1}{p_i} \quad (39)$$

To reduce notational clutter, define

*Definition:*  $\Phi(R_i, \theta_i) \equiv ((r + R_i \lambda_i) + \frac{\beta m_i \theta_i^\gamma}{1 - \gamma})$

Now, (38) and (39) imply

$$\frac{\Phi(R_i, \theta_i) dR_i}{r + \lambda_i db} = \frac{1}{p_i} \quad (40)$$

Therefore,

$$\frac{dR_i}{db} = \frac{r + \lambda_i}{p_i \Phi(R_i, \theta_i)} > 0; \quad \frac{d\theta_i}{db} = \frac{-(1 - \beta)m_i \theta_i^\gamma}{(r + \lambda_i)c_i(1 - \gamma)} \frac{dR_i}{db} < 0 \quad (41)$$

Taking the total derivative of the expression for unemployment in (20) with respect to  $b$  we obtain

$$\frac{du_i}{db} = u_i(1 - u_i) \left( \frac{1}{R_i} \frac{dR_i}{db} - \frac{\gamma}{\theta_i} \frac{d\theta_i}{db} \right) > 0 \quad (42)$$

That is, a higher unemployment benefit implies greater rate of job destruction, lower market tightness and a higher unemployment rate. Again, it is worth pointing out that in a model with exogenous job destruction, the impact of unemployment benefit on job flows works only through job creation. An increase in unemployment benefit will reduce job creation resulting in a lower market tightness and higher unemployment. The steady state rates of job creation and job destruction are left unaffected.

Next, we study how unemployment benefit affects the impact of trade on the rate of job destruction and unemployment. Use the following definition:

*Definition:*  $\varepsilon_{R_i p_i} = \frac{p_i}{R_i} \frac{dR_i}{dp_i}; \varepsilon_{\theta_i b} = \frac{b}{\theta_i} \frac{d\theta_i}{db}$

It is shown in the appendix that

$$\frac{d\varepsilon_{R_i p_i}}{db} = \frac{\varepsilon_{R_i p_i}}{b} \left( 1 + \left( \frac{R_i \lambda_i + \Phi(R_i, \theta_i)}{\Phi(R_i, \theta_i)} - \frac{R_i \gamma \beta m_i \theta_i^\gamma}{\Phi(R_i, \theta_i)(1 - R_i)(1 - \gamma)^2} \right) \varepsilon_{R_i p_i} \right) \quad (43)$$

That is, the sign of  $\frac{d\varepsilon_{R_i p_i}}{db}$  is theoretically ambiguous. However, numerical simulations with the parameter values in the neighborhood of those in numerical example 1 confirm that  $\frac{d\varepsilon_{R_i p_i}}{db} < 0$ .

Numerical Example 2:  $r = .0033; \lambda = .035; m = .64; \gamma = .5; \beta = .5; b = .7; c = .4;$   
for  $p_i = 1$ , then  $\frac{d\varepsilon_{R_i p_i}}{db} = -.15$  and it asymptotes towards zero for higher values of  $p_i$ . For lower values of  $p_i$  it is a larger negative number. For example, for  $p_i = .75$ ,  $\frac{d\varepsilon_{R_i p_i}}{db} = -1.5$ .

Since  $\varepsilon_{R_i p_i}$  is negative,  $\frac{d\varepsilon_{R_i p_i}}{db} < 0$  implies that an increase in  $b$  increases the magnitude of  $\varepsilon_{R_i p_i}$ . That is, an increase in  $b$  increases the responsiveness of  $R_i$  to trade liberalization. Therefore, other things equal, a more generous unemployment benefit is likely to amplify the effect of trade liberalization on job destruction.

It is also shown in the appendix that

$$\frac{d\varepsilon_{\theta_i p_i}}{db} = -\frac{R_i}{1-R_i} \frac{d\varepsilon_{R_i p_i}}{db} - \frac{1}{(1-R_i)^2(1-\gamma)} \varepsilon_{R_i p_i} \frac{dR_i}{db} \quad (44)$$

Again, the sign of the derivative above is theoretically ambiguous. However, if  $\frac{d\varepsilon_{R_i p_i}}{db} < 0$  as found in the numerical simulations, then  $\frac{d\varepsilon_{\theta_i p_i}}{db} > 0$ . That is, a more generous unemployment benefit increases the responsiveness of the market tightness to trade liberalization.

Next, it is shown in the appendix that  $\frac{d\varepsilon_{R_i p_i}}{db} < 0$  also implies  $\frac{d(\frac{du_i}{dp_i})}{db} < 0$ . Since  $\frac{du_i}{dp_i} < 0$ , it implies that a more generous unemployment benefit increases the responsiveness of unemployment to trade liberalization as well. Note again that compared to the model with exogenous job destruction where changes in unemployment benefits affect unemployment only through job creation (see for example, Moore and Ranjan (2005)), here they have an impact on job destruction as well. Therefore, the responsiveness of job flows as well as the rate of unemployment to trade liberalization is larger when the unemployment benefit is more generous.

Even though a more generous unemployment benefit increases the responsiveness of unemployment as well as job flows to trade liberalization, this cannot be an argument against having a more generous unemployment benefit in an open economy. To arrive at a normative conclusion about unemployment benefits, one will have to introduce risk aversion in the household utility function because the key motivation behind unemployment benefits is to insure households against labor market risk arising from unemployment. We leave this exercise for future research.

## 4 Conclusions

This paper has shown how studying trade liberalization in a model of endogenous job destruction can provide results on job flows and unemployment consistent with the recent empirical work. It was shown that trade liberalization increases both job creation and job destruction in the import competing sector and reduces them in the export sector. Since trade liberalization also increases unemployment in the import competing sector and reduces it in the export sector, the impact on economywide unemployment is ambiguous. More interestingly, trade liberalization also has an asymmetric impact effect on the two sectors. While there is a lot of job destruction in the import competing sector upon impact, the reduction in job destruction in the export sector takes effect only in the medium run. This can lead to short term spikes in the net job destruction and unemployment rates in response to trade liberalization. The paper also shows how trade liberalization could lead to an increase in the within group wage inequality in the export sector and a decrease in the within group wage inequality in the import competing sector. The intersectoral wage inequality is likely to increase as well as a consequence of trade liberalization. Finally, it was shown that a more generous unemployment benefit increases the responsiveness of job destruction to trade liberalization.

Before ending the paper, it should be noted that the framework can also be used to study the implications of other labor market regulations such as more stringent firing restrictions on job flows and unemployment in the open economy. Since unemployment benefits and firing restrictions are two alternative instruments used to protect workers against the volatility in the labor market, it would be a useful exercise to study the implications of firing restrictions as well. To prevent the paper from becoming too cumbersome, this is left for future research.

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## 5 Appendix

### 5.1 Impact of an increase in $p_i$ on wage inequality

From (21) in the text obtain the expression for  $\frac{d\omega_i}{dp_i}$ , which after canceling terms can be written as

$$\frac{d\omega_i}{dp_i} = \frac{\beta(1-\beta)b(1-R) - \beta^2 p_i^2 c_i(1-R_i) \frac{d\theta_i}{dp_i} - ((1-\beta)b + \beta p_i(1+c_i\theta_i)) \beta p_i \frac{dR_i}{dp_i}}{((1-\beta)b + \beta p_i(R_i + c_i\theta_i))^2} \quad (45)$$

From (16) and (18) in the text obtain

$$\begin{aligned} \frac{-(1-\beta)}{(r+\lambda_i)} \frac{dR_i}{dp_i} &= \frac{c_i}{m_i} (1-\gamma) \theta_i^{-\gamma} \frac{d\theta_i}{dp_i} \\ \frac{1}{r+\lambda_i} (r+\lambda_i G(R)) \frac{dR_i}{dp_i} - \frac{\beta c_i}{1-\beta} \frac{d\theta_i}{dp_i} &= -\frac{b}{p_i^2} \end{aligned} \quad (46)$$

The above two imply that

$$\frac{d\theta_i}{dp_i} = \frac{-(1-\beta)m_i\theta_i^\gamma}{(r+\lambda_i)c_i(1-\gamma)} \frac{dR_i}{dp_i} = -\frac{\theta_i}{(1-\gamma)(1-R_i)} \frac{dR_i}{dp_i}; \quad \frac{dR_i}{dp_i} = -\frac{b(r+\lambda_i)}{p_i^2 \left( (r+\lambda_i G(R_i)) + \frac{\beta m_i \theta_i^\gamma}{(1-\gamma)} \right)} \quad (47)$$

where the last expression for  $\frac{d\theta_i}{dp_i}$  is obtained upon using (16). Next, substitute the expression for  $\frac{d\theta_i}{dp_i}$  in  $\frac{d\omega_i}{dp_i}$  above to get

$$\frac{d\omega_i}{dp_i} = \frac{\beta(1-\beta)b(1-R) + \beta p_i \left( \beta p_i \left( \frac{\gamma c_i \theta_i}{1-\gamma} - 1 \right) - (1-\beta)b \right) \frac{dR_i}{dp_i}}{((1-\beta)b + \beta p_i(R_i + c_i\theta_i))^2} \quad (48)$$

Therefore, a sufficient condition for  $\frac{d\omega_i}{dp_i} > 0$  is  $\left( \beta p_i \left( \frac{\gamma c_i \theta_i}{1-\gamma} - 1 \right) - (1-\beta)b \right) < 0$ .

### 5.2 Impact of an increase in $p_i$ on sectoral output

Take the total derivatives of (32) and (33) in the text with respect to  $p_i$  to obtain

$$\frac{-(1-\beta)}{(r+\lambda_i)} \frac{dR_i}{dp_i} = \frac{c_i}{m_i} (1-\gamma) \theta_i^{-\gamma} \frac{d\theta_i}{dp_i} \quad (49)$$

$$\frac{1}{r+\lambda_i} (r+R_i\lambda_i) \frac{dR_i}{dp_i} - \frac{\beta c_i}{1-\beta} \frac{d\theta_i}{dp_i} = -\frac{b}{p_i^2} \quad (50)$$

Using the definition,  $\Phi(R_i, \theta_i) \equiv ((r + R_i \lambda_i) + \frac{\beta m_i \theta_i^\gamma}{1-\gamma})$ , already defined in the text, write

$$\frac{\Phi(R_i, \theta_i)}{r + \lambda_i} \frac{dR_i}{dp_i} = -\frac{b}{p_i^2} \quad (51)$$

or

$$\frac{dR_i}{dp_i} = -\frac{b(r + \lambda_i)}{p_i^2 \Phi(R_i, \theta_i)} < 0; \quad \frac{d\theta_i}{dp_i} = \frac{-(1-\beta)m_i \theta_i^\gamma}{(r + \lambda_i)c_i(1-\gamma)} \frac{dR_i}{dp_i} > 0 \quad (52)$$

Given assumption 1 regarding the functional forms, the expression for unemployment in (20) becomes

$$u_i = \frac{\lambda_i R_i}{\lambda_i R_i + m_i \theta_i^\gamma} \quad (53)$$

Next, take the derivative of the expression for unemployment in (20) to get

$$\frac{du_i}{dp_i} = u_i(1-u_i) \left( \frac{1}{R_i} \frac{dR_i}{dp_i} - \frac{\gamma}{\theta_i} \frac{d\theta_i}{dp_i} \right) < 0 \quad (54)$$

Next, using (54), re-write (31) in the text as

$$\frac{di}{dp_i} = - \left[ R_i \left(1 - \frac{R_i}{2}\right) + \frac{1}{2} \right] u_i(1-u_i) \left( \frac{1}{R_i} \frac{dR_i}{dp_i} + \frac{\gamma}{\theta_i} \frac{(1-\beta)m_i \theta_i^\gamma}{(r + \lambda_i)c_i(1-\gamma)} \frac{dR_i}{dp_i} \right) + (1-u_i)(1-R_i) \frac{dR_i}{dp_i} \quad (55)$$

Next, using (49) re-write (55) as

$$\frac{di}{dp_i} = -(1-u_i) \frac{dR_i}{dp_i} \left[ \left( \frac{2R_i - R_i^2 + 1}{2} \right) \left( \frac{(1-R_i)(1-\gamma) + \gamma R_i}{(1-R_i)R_i(1-\gamma)} \right) u_i - (1-R_i) \right] \quad (56)$$

Since  $\frac{dR_i}{dp_i} < 0$ , the sign of  $\frac{di}{dp_i}$  depends on the sign of the term in the square bracket in (56). In particular,

$$\frac{di}{dp_i} > (<)0 \text{ if } u_i > (<) \frac{2R_i(1-R_i)^2(1-\gamma)}{((1-R_i)(1-\gamma) + \gamma R_i)(R_i(2-R_i) + 1)} \equiv \Psi(R_i) \quad (57)$$

### 5.3 Impact of trade liberalization on intersectoral wage inequality

Upon using the expression for  $w_i(t)$  from (12), the intersectoral wage ratio can be written as

$$\frac{\bar{w}_x}{\bar{w}_y} = \frac{(1-\beta)b + \beta p_x c_x \theta_x + \beta p_x (R_x + \frac{1-R_x^2}{2})}{(1-\beta)b + \beta p_y c_y \theta_y + \beta p_y (R_y + \frac{1-R_y^2}{2})} \quad (58)$$

Note from above that it is enough to show that  $\beta p_i c_i \theta_i + \beta p_i (R_i + \frac{1-R_i^2}{2})$  is increasing in  $p_i$ . Taking the derivative of  $\beta p_i c_i \theta_i + \beta p_i (R_i + \frac{1-R_i^2}{2})$  with respect to  $p_i$  obtain

$$\beta c_i \theta_i + \beta (R_i + \frac{1-R_i^2}{2}) + \beta p_i c_i \frac{d\theta_i}{dp_i} + \beta p_i (1-R_i) \frac{dR_i}{dp_i} \quad (59)$$

Re-write the above as

$$\beta c_i \theta_i + \beta (R_i + \frac{1-R_i^2}{2}) - \left( \frac{c_i \theta_i}{(1-\gamma)(1-R_i)} - (1-R_i) \right) \beta p_i \frac{dR_i}{dp_i} \quad (60)$$

Therefore, since  $\frac{dR_i}{dp_i} < 0$ , a sufficient condition for  $\frac{\bar{w}_x}{\bar{w}_y}$  to increase upon trade liberalization is  $c_i \theta_i > (1-\gamma)(1-R_i)^2$ .

#### 5.4 Impact of generous unemployment benefit in the open economy

From (51) above obtain

$$\varepsilon_{R_i p_i} = \frac{-b(r + \lambda_i)}{p_i R_i \Phi(R_i, \theta_i)} = -\varepsilon_{R_i b} \quad (61)$$

where the last equality can be verified from the expression for  $\frac{dR_i}{db}$  given in the text in (42).

Therefore,

$$\frac{d\varepsilon_{R_i p_i}}{db} = \frac{\partial \varepsilon_{R_i p_i}}{\partial b} + \frac{\partial \varepsilon_{R_i p_i}}{\partial R_i} \frac{dR_i}{db} + \frac{\partial \varepsilon_{R_i p_i}}{\partial \theta_i} \frac{d\theta_i}{db} \quad (62)$$

Using (49) the above can be re-written as

$$\frac{d\varepsilon_{R_i p_i}}{db} = \frac{\varepsilon_{R_i p_i}}{b} + \left( \frac{\partial \varepsilon_{R_i p_i}}{\partial R_i} - \frac{(1-\beta)m_i \theta_i^\gamma}{(r + \lambda_i)c_i(1-\gamma)} \frac{\partial \varepsilon_{R_i p_i}}{\partial \theta_i} \right) \frac{dR_i}{db} \quad (63)$$

Next, note from (61) that

$$\frac{\partial \varepsilon_{R_i p_i}}{\partial R_i} = -\varepsilon_{R_i p_i} \frac{\Phi(R_i, \theta_i) + R_i \lambda_i}{R_i \Phi(R_i, \theta_i)} > 0; \quad \frac{\partial \varepsilon_{R_i p_i}}{\partial \theta_i} = -\varepsilon_{R_i p_i} \frac{\gamma \beta m_i \theta_i^{\gamma-1}}{\Phi(R_i, \theta_i)(1-\gamma)} > 0 \quad (64)$$

Using (64) in (63), and making use of the fact that  $\varepsilon_{R_i p_i} = -\varepsilon_{R_i b}$  we get

$$\frac{d\varepsilon_{R_i p_i}}{db} = \frac{\varepsilon_{R_i p_i}}{b} \left[ 1 + \left( \frac{\Phi(R_i, \theta_i) + R_i \lambda_i}{\Phi(R_i, \theta_i)} - \frac{R_i \gamma \beta m_i \theta_i^{\gamma-1}}{\Phi(R_i, \theta_i)} \frac{(1-\beta)m_i \theta_i^\gamma}{(1-\gamma)^2 (r + \lambda_i) c_i} \right) \varepsilon_{R_i p} \right] \quad (65)$$

Next, using (32) in the text, re-write the above as

$$\frac{d\varepsilon_{R_i p_i}}{db} = \frac{\varepsilon_{R_i p_i}}{b} \left[ 1 + \left( \frac{\Phi(R_i, \theta_i) + R_i \lambda_i}{\Phi(R_i, \theta_i)} - \frac{R_i \gamma \beta m_i \theta_i^\gamma}{\Phi(R_i, \theta_i) (1-R_i) (1-\gamma)^2} \right) \varepsilon_{R_i p_i} \right] \quad (66)$$

Next, we find out  $\frac{d\varepsilon_{\theta_i p_i}}{db}$ .

Using (52) above obtain

$$\varepsilon_{R_i p_i} = -\frac{c_i}{m_i} \frac{(r + \lambda_i)(1-\gamma)\theta_i^{1-\gamma}}{(1-\beta)R_i} \varepsilon_{\theta_i p_i} \quad (67)$$

Upon using (32), the above can be written as

$$\varepsilon_{\theta_i p_i} = -\frac{R_i}{(1-R_i)(1-\gamma)} \varepsilon_{R_i p_i} \quad (68)$$

Therefore,

$$\frac{d\varepsilon_{\theta_i p_i}}{db} = -\frac{R_i}{(1-R_i)(1-\gamma)} \frac{d\varepsilon_{R_i p_i}}{db} - \frac{1}{(1-\gamma)(1-R_i)^2} \varepsilon_{R_i p_i} \frac{dR_i}{db} \quad (69)$$

Next, using the expression for unemployment in (53) obtain

$$\frac{du_i}{dp_i} = \frac{u_i(1-u_i)}{p_i} \left( 1 + \frac{\gamma R_i}{(1-R_i)(1-\gamma)} \right) \varepsilon_{R_i p_i} < 0 \quad (70)$$

Therefore,

$$\begin{aligned} \frac{d\left(\frac{du_i}{dp_i}\right)}{db} &= (1-2u_i) \left( 1 + \frac{\gamma R_i}{(1-R_i)(1-\gamma)} \right) \varepsilon_{R_i p_i} \frac{du_i}{db} + (1-u_i) \frac{\gamma}{(1-R_i)^2 (1-\gamma)} \varepsilon_{R_i p_i} \frac{dR_i}{db} \\ &\quad + (1-u_i) \left( 1 + \frac{\gamma R_i}{(1-R_i)(1-\gamma)} \right) \frac{d\varepsilon_{R_i p_i}}{db} \end{aligned} \quad (71)$$

The sign of the derivative above is ambiguous, however, when  $\frac{d\varepsilon_{R_i p_i}}{db} < 0$ , the derivative above is negative under the reasonable assumption that  $u_i < 1/2$  because all 3 terms are negative.