Trade Liberalization and Wage Inequality: New Insights from a Dynamic Trade Model with Heterogeneous Firms and Comparative Advantage

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Abstract

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Trade Liberalization and Wage Inequality: New Insights from a Dynamic Trade

Model with Heterogeneous Firms and Comparative Advantage [*]

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We develop a dynamic general equilibrium trade model with comparative advantage, heterogeneous firms, heterogeneous workers and endogenous firm entry to study wage inequality during the adjustment after trade liberalization. We find that trade liberalization increases wage inequality both in the short run and in the long run. In the short run, inter-sectoral wage inequality is high but then recedes. The skill premium does not change much in the short run but increases substantially in the medium and long run. Incorporating worker training in the model considerably reduces the effects of trade liberalization on wage inequality. The effects on wage inequality are much more adverse when trade liberalization is unilateral instead of bilateral or restricted to specific sectors instead of including all sectors.
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1 Introduction

Trade liberalization can lead to higher welfare by allowing firms and workers to be put into more productive uses. However, to take advantage of these benefits both firms and workers need to be reallocated from the sectors with comparative disadvantage to the sectors with comparative advantage. This reallocation costs time and resources and is at the heart of popular concern about trade liberalization. In this paper we present a model with heterogeneous firms and heterogeneous workers and study the transitional dynamics after a reduction in trade barriers, with a special focus on two kinds of wage inequality, the wage inequality between skilled and unskilled workers and the wage inequality across sectors.

The increase in wage inequality in many developed countries over the past decades and its sources have been subject to a lively debate in the economic literature. Until recently the dispute seemed to be settled in favor of skill-biased technological change as being the main contributor to rising wage inequality (see Katz and Autor [1999]). However, while traditionally the trade of a developed country was mainly with other developed countries, the recent enormous rise in trade with low-income countries (most notably China and India) has brought a shift in the structure of trade. This shift is associated with fears that unskilled workers from developed countries might lose out from competition with workers from developing countries.

And indeed, Autor et al. [2013] show that in the United States (U.S.) increased trade with China goes hand in hand with a decrease in the share of manufacturing employment and that local labor markets that are exposed to Chinese imports suffer higher unemployment and lower wages. In a similar vein, Ebenstein et al. [2013] find that import competition is associated with wage declines. Pierce and Schott [2012] identify a direct causal link between the sharp drop in U.S. manufacturing employment after 2001 and the elimination of trade policy uncertainty that resulted

from the granting of permanent normal trade relations to China in late 2000. Industries that experienced the sharpest reduction in tariff threats experienced greater employment loss due to suppressed job creation, exaggerated job destruction and a substitution away from unskilled workers. [1] For Germany, Daut et al. [forthcoming] document that increased trade has lead to lower employment in import-competing sectors.

These recent empirical studies concentrate on inter-sectoral comparisons, i.e., how does a worker fare in the import-competing sector relative to other sectors. Therefore, the main source of inequality is due to the wage differential between workers employed in different sectors. Another potential effect of trade liberalization is that it increases the demand for skilled workers and thereby the skill premium, the wage differential between skilled and unskilled workers. This source of wage inequality has been less prominent in recent empirical papers, probably because these effects are harder to identify and take a longer time to materialize. Here the look through a modeling-lens can help clarify the picture.

A comprehensive study of the effects of trade liberalization on wage inequality should, in our view, contain the following features: i) comparative advantage to study the tension between shrinking, comparative disadvantage sectors and expanding, comparative advantage sectors; ii) skilled and unskilled workers to study changes in the skill premium; iii) adjustment dynamics, because the structure of the economy is unlikely to change over night iv) adjustment costs of workers, because it takes time and resources to switch sectors or to train; v) firm heterogeneity, endogenous firm entry and selection into export markets, because these features have

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[1]The import penetration ratio is defined as the host country's imports from China divided by the total host country's expenditure on goods, measured as host gross output plus host imports minus host exports. The share of working-age population employed in manufacturing is defined as the number of people employed in manufacturing divided by the number of working-age people employed (16-64 years old). The source of data is Eurostat.

been shown to be important ingredients of international trade.

In this paper we present a model that takes account of each aspect. It is based on the model of Bernard et al. [2007] (BRS henceforth) which consists of two countries, two factors and two sectors, introducing comparative advantage into the heterogeneous firm model of Melitz [2003]. It thus offers a framework that is rich enough to capture points i), ii) and v) above. However, the BRS analysis is restricted to the steady state and thus ignores adjustment problems. To be able to model adjustment dynamics we develop a dynamic version of BRS along the lines of Ghironi and Melitz [2005] (GM henceforth) and add labor adjustment costs.

As is standard in the literature, we model trade liberalization as a decrease in the costs of trade. This leads to a shift in production. Each country specializes production in the sector where it has its comparative advantage. The rich country, being endowed with more skilled labor, specializes in the production of the skill-intensive good. This leads to a reallocation of firms and workers from the unskilled-intensive sector to the skill-intensive sector.

In our model, newly entering firms need to pay a sunk entry cost in order to enter either of two sectors (one skill-intensive, one unskilled-intensive). Upon entering they draw their productivity from a Pareto distribution. In contrast to Melitz [2003], but in line with GM, firms do not have to pay fixed production costs, and therefore all newly entering firms take up production. However, firms have to pay a fixed cost of exporting if they want to serve the foreign market. This results in selection into export markets, as in Melitz [2003], i.e., only the most productive firms take up exporting.

Each firm is subject to an exogenous rate of exit. This gives rise to non-trivial but tractable adjustment dynamics after trade liberalization, because existing firms keep operating and are stuck in their sector, while newly entering firms are more

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flexible.[2] Thus, the reallocation of firms from one sector to the other takes place via the exit of old firms. They are replaced by newly entering firms which tend to prefer the expanding sector over the shrinking sector.

Workers can be either skilled or unskilled and can be employed in either of the two sectors. Concerning the mobility of workers we distinguish various adjustment mechanisms: i) workers retire at an exogenous rate and get replaced by newly entering workers who are more flexible in their choice of sector; ii) incumbent workers might or might not be allowed to switch sectors after paying a randomly distributed sector migration cost; iii) newly entering workers might or might not be allowed to become skilled after paying a randomly distributed training cost. By simulating various combinations of these mobility assumptions we are able to highlight the role of labor adjustment costs.

In our analysis we focus on the effects of trade liberalization on wage inequality in the rich country. We mainly concentrate on two measures of wage inequality: i) inter-sectoral wage inequality, i.e., the wage differential between workers who are in the same skill class but in different sectors and ii) the skill premium, i.e., the wage differential between skilled and unskilled workers.[3] The effects of trade liberalization on wage inequality depend importantly on the assumption whether the supply of skilled workers is endogenous or exogenous.

If we follow the standard practice in the trade literature and assume fixed endow-

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[2]Burstein and Melitz [2012] show that positive fixed costs of domestic production would eliminate all transitional dynamics in GM. This is not the case in our model due to the slow adjustment of workers. We nevertheless prefer to use the GM assumption that fixed costs of domestic production are zero, due to tractability and the numerical problems discussed by Chaney [2005]. In the robustness section in the appendix we discuss in more detail the role of firm adjustment.

[3]A recent literature analyzes the effects of trade liberalization on unemployment (see, e.g., Egger and Kreickemeier [2009], Felbermayr et al. [2010], Helpman and Itskhoki [2010], Helpman et al. [2010] or Larch and Lechthaler [2011]) and stresses within-group wage inequality as a contributor to overall wage inequality (see, e.g.,Helpman et al. [2010]). Given the already complicated structure of our model we concentrate on just two measures of wage inequality and leave the analysis of unemployment and within-group wage inequality for future research.

ments with skilled and unskilled workers (as, e.g., in BRS), we find that income inequality strongly increases after trade liberalization. In the short run, this is driven by a rise in inter-sectoral wage inequality. In the medium to long run, inequality rises due to a rising skill premium. The two inequality measures have starkly different dynamics: the skill premium reacts only slowly while inter-sectoral wage inequality jumps up on impact and then slowly recedes. Consider the extreme scenario where incumbent workers are completely immobile in the short run. Then, the supply of workers cannot respond to the changes in relative labor demand. In the short run wages in the skill-intensive sector have to go up relative to the wages in the unskilled-intensive sector. The skill premium, however, does not change in the short run, because the marginal productivity of skilled and unskilled workers cannot change as their composition in production does not change. In the longer run, when workers are more mobile across sectors, the wage differential between the two sectors recedes, while the skill premium increases due to higher demand for the skill-intensive good, which translates into higher demand for skilled workers. This suggests that the inter-sectoral wage inequality identified by the recent empirical literature is only a temporary phenomenon. However, this does not imply that trade liberalization does not have long run effects on wage inequality, because the skill premium is expected to increase. This discussion demonstrates that it is crucial to use a dynamic model in order to be able to distinguish between short-run and long-run effects. In the long run wage differentials between sectors are expected to vanish but in the short run they are an important source of wage inequality. This short run effect is completely ignored when analyzing steady state outcomes only, while the effect of the increased skill premium is exaggerated since it takes a long time to manifest.

The effects of trade liberalization on wage inequality are considerably different, when we relax the assumption of fixed endowments with skilled and unskilled

workers by allowing newly entering workers to train and become skilled workers. Under fixed endowments with skilled and unskilled workers, the overall supply of skilled workers cannot react to the increased demand for skilled workers that comes along with trade liberalization. Thus, the wage of skilled workers has to go up relative to the wage of unskilled workers. In contrast, with worker training the supply of skilled workers increases in response to trade liberalization, which has a dampening effect on the skill premium and thus overall wage inequality. This suggests that the common assumption of fixed endowments with skilled and unskilled workers is not an innocuous assumption, but instead crucial for the effects of trade liberalization on wage inequality.

We use a general equilibrium model because this implies that the terms of trade are endogenous and that bilateral trade liberalizations can be analyzed. Of course, history provides examples of unilateral trade liberalizations, but especially if one is interested in the effects of trade liberalization in rich, developed countries bilateral trade liberalization is definitely the more appropriate scenario because these countries are too powerful be forced into unilateral trade liberalization. This matters because in bilateral trade liberalizations the increase in competition in the import-competing sectors is typically accompanied by enhanced opportunities for the exporting sectors. And indeed, Daut et al. [forthcoming] find that in Germany trade with Eastern Europe and China has led to shrinking employment in import-competing sectors, but expanding employment in exporting sectors. Our flexible approach allows us to simulate various scenarios, including bilateral trade liberalization, unilateral trade liberalization, and the liberalization of specific sectors. Our results show that the effects of trade liberalization can differ a lot depending on how trade liberalization is specified.

Thus, it is crucial to use a general equilibrium model to be able to capture realistic trade liberalization scenarios. However, this does not come without a cost. The

general-equilibrium nature of our model makes it harder to bring it close to the data. Therefore, we have to rely on a parametrization of the model that is less rigorous than we would have wished. However, we think the benefits outweigh the costs and demonstrate in a number of robustness checks described in the appendix that our qualitative implications are not sensitive to changes in parameters.

There are at least three recent papers that also analyze labor market adjustments after trade liberalization: Artuç et al. [2010], Dix-Carneiro [2014] and Coşar [2013]. All of these papers use small open economy models which allows them to be estimated or calibrated in a more serious fashion. This is certainly an advantage but also implies that the terms-of-trade are exogenous and that their analysis is restricted to unilateral trade liberalization.

The rest of the paper is structured as follows. Section 2 describes the theoretical model. Section 3 describes the parametrization. In section 4 we describe our simulations of the symmetric trade liberalization scenarios, while section 5 shows the partial and unilateral trade liberalization scenarios. Section 6 concludes. The appendix provides a more detailed literature review, extensive robustness checks and discusses some of the transmission channels in more detail.

2 Theoretical model

Our model economy consists of two countries, Home (H) and Foreign (F). Each country produces two goods, good 1 and good 2. The production of each good requires two inputs, skilled and unskilled labor. The sector that produces good 1 is skill-intensive, i.e., the production of good 1 requires relatively more skilled labor than the production of good 2. We consider two versions of the model: in the first a country's endowments with skilled and unskilled labor are fixed while in the second only the total labor endowment is fixed and skilled and unskilled labor are

determined endogenously. In the first version, H has a comparative advantage in producing good 1 because it has a higher relative endowment with skilled labor. Similarly, F has a comparative advantage in sector 2 because it has a higher relative endowment with unskilled labor. In the second version, the supplies of skilled and unskilled labor become endogenous by allowing newly entering workers to train and become skilled. In this scenario, H has a comparative advantage in the production of the skill-intensive good due to a cheaper training technology. We assume that at the pre-liberalization steady state unskilled labor is more abundant than skilled labor in both countries in order to generate a positive skill-premium.[4] In the long run, all factors of production are assumed to be perfectly mobile between sectors but not across countries. In the short run, however, workers are imperfectly mobile both across sectors and across skill-classes. We discuss various scenarios with different degrees of short run mobility. In the following section we describe all the decision problems in H; equivalent equations hold for F.

2.1 Households

In our model there are four types of workers, skilled workers in sector 1, skilled workers in sector 2 and likewise for unskilled workers. The utility of a skilled worker in sector i is given by:

$$E_t \left\{ \sum_{k=0}^{\infty} \gamma^k (1-s)^k \left[log \left(C_{it+k}^s \right) - Cost_{t+k} \right] \right\}, \tag{1}$$

where C_{it+k}^s is the aggregate consumption bundle, γ is the subjective discount factor, s is the retirement rate, and the term $Cost_{t+k}$ summarizes the (potential) disutility from migration and training (see, e.g., Dix-Carneiro [2014]). A similar equation

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[4]What matters for comparative advantage are relative endowments, so skilled labor can be scarce in both countries.

holds for unskilled workers. We model workers as rule-of-thumb consumers or credit-constrained consumers, i.e., they consume all their income, and can neither borrow nor lend. Thus consumption is

$$C_{it}^s = w_{it}^s + \Pi_t, \tag{2}$$

where w_{it}^s is the wage income of the workers and Π_t are the transfers of a mutual fund to be described further below.

We assume that workers are credit-constrained because that allows for simple aggregation. If workers were allowed to save and to switch sectors/skill classes, then the bond level of workers would depend on the employment history of the worker. If a worker changes her sector of employment, then her incentives to save change. Thus, her desired savings would differ from the savings of workers employed in her old sector. But her current bond holdings are determined by her old sector and, thus, are different from the bond holdings of workers in her new sector. In the transition, savings histories of workers who switch would depend on the time of the switch. This implies the necessity to keep track of the whole employment history of workers. In the robustness section in the appendix we provide a version of the model in which workers are allowed to save but cannot switch across sectors. Results do not differ significantly.

To avoid this problem, the macro-literature often assumes that workers pool their income within large households (see, e.g., Andolfatto [1996]). Then the consumption of a worker no longer depends on her wage earnings and the whole economy can be characterized by one representative household. However, since the focus of our analysis is precisely on wage inequality and its welfare implications, we prefer the assumption of credit-constrained workers.

The composition of the aggregate consumption bundle is the same for all workers;

only the quantity of consumed goods differs across workers. Therefore, in the following description we omit the indices for workers to avoid cumbersome notation. The aggregate consumption bundle C_t is a Cobb-Douglas composite of the goods produced in the two sectors:

$$C_t = C_{1t}^{\alpha} C_{2t}^{1-\alpha}, \tag{3}$$

where α is the share of good 1 in the consumption bundle for both H and F. We can obtain relative demand functions for each good from the expenditure minimization problem of a household. The implied demand functions are:

$$C_{1t} = \alpha \frac{P_t}{P_{1t}} C_t \ \text{ and } \ C_{2t} = (1-\alpha) \frac{P_t}{P_{2t}} C_t, \tag{4}$$

where $P_t = \left(\frac{P_{1t}}{\alpha} \right)^{\alpha} \left(\frac{P_{2t}}{1-\alpha} \right)^{1-\alpha}$ is the price index that buys one unit of the aggregate consumption bundle C_t.

Goods 1 and 2 are consumption bundles defined over a continuum of varieties Ω_i:

$$C_{it} = \left[\int_{\omega \varepsilon \Omega_i} c_{it}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right]^{\frac{\theta}{\theta-1}}, \tag{5}$$

where $\theta > 1$ is the elasticity of substitution between varieties. Varieties are internationally traded. Thus a variety can either be produced at home or imported. At any given time, only a subset of varieties $\Omega_{it} \varepsilon \Omega_i$ is available in each sector. The consumption based price index for each sector is $P_{it} = \left[\int_{\omega \varepsilon \Omega_i} p_{it}(\omega)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}}$ and the household demand for each variety is $c_{it} = \left(\frac{p_{it}}{P_{it}} \right)^{-\theta} C_{it}$. It is useful to re-define these in terms of aggregate consumption units. Let us define $\rho_{it} \equiv \frac{p_{it}}{P_t}$ and $\psi_{it} \equiv \frac{P_{it}}{P_t}$ as the relative prices for individual varieties and for the sector bundles, respectively. Then, we can rewrite the demand functions for varieties and sector bundles as $c_{it} = \left(\frac{\rho_{it}}{\psi_{it}} \right)^{-\theta} C_{it}$ and $C_{it} = \alpha \psi_{it}^{-1} C_t$, respectively.

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2.2 Labor supply

We consider two versions of the model. In the first version, we make the assumption that the overall endowments with skilled and unskilled workers are exogenously fixed. This resembles the case in BRS. In the second version, we relax this assumption by allowing newly entering workers to train to become skilled workers (see, e.g., Larch and Lechthaler [2011]).

In both versions of the model, workers are perfectly mobile between sectors in the long run. However, in the short run, adjustment of workers will be slowed by adjustment costs: each worker has to pay a random, idiosyncratic sector migration cost in order to be able to switch sectors. We also assume that workers retire at rate s and are replaced by newly entering workers. These newly entering workers are free in their choice of sector and, thereby, also contribute to the reallocation of workers. Thus, even if the sector migration cost was so large that none of the incumbents would decide to switch sectors, the constant flow of more mobile new entrants would assure full adjustment of labor in the long run. We first describe the version of the model without training.

2.2.1 Worker mobility without training

Skilled workers are free to move between sectors but doing so implies a non-negative idiosyncratic sector migration cost, measured in disutility,[5] which is represented by an idiosyncratic ε_t^s, drawn each period from a random distribution $F(\varepsilon^s)$ with support on $[\varepsilon_{min}^s, \infty)$. Unskilled workers can also move between sectors but they draw their sector migration cost ε_t^l from a different distribution $H(\varepsilon^l)$. Since skilled and unskilled workers face symmetric mobility decisions, it suffices

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[5] As in Dix-Carneiro [2014] we assume that the sector migration cost is paid in terms of utility, which has the benefit that the sector migration cost need not be traded in the market.

to describe the decision of skilled workers. Analogous equations hold for unskilled workers.

A skilled worker decides to migrate from sector j to sector i whenever the corresponding gain in value is higher than the cost of switching sectors, i.e., if:

$$V_{it}^s - V_{jt}^s > \varepsilon_t^s. \tag{6}$$

Vice versa, a worker in sector i will migrate to sector j if $V_{jt}^s - V_{it}^s > \varepsilon_t^s$. Equation 6 defines a threshold, $\bar{\varepsilon}_t^s$, for which a worker is indifferent between switching and not switching sectors,

$$\overline{\varepsilon_t^s} = V_{it}^s - V_{jt}^s \tag{7}$$

and the probability of switching sectors is

$$
\begin{aligned}
\eta_{jit}^s &= F(\max(\overline{\varepsilon_t}^s, \varepsilon_{\min}^s)) \\
\eta_{ijt}^s &= F(\max(-\overline{\varepsilon_t}^s, \varepsilon_{\min}^s))
\end{aligned}
$$

where η_{jit}^s is the probability to switch from sector j to sector i and vice versa for η_{ijt}^s. We assume that moving costs are non-negative, i.e., $\varepsilon_{\min}^s \geq 0$. This implies that only one of the two rates can be positive, the other has to be zero. Thus we are restricting ourselves to net sector migration flows which are relevant for reallocation and wage inequality.[6]

The crucial part of equation 7 is the worker's value of being employed in a specific

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[6]Allowing for negative sector migration costs would imply positive gross flows across sectors, which are relevant empirically. However, for wage inequality only the relative supply of workers and thus net flows are relevant.

sector, defined as:

$$V_{it}^s = log\left(w_{it}^s + \Pi_t\right) + \gamma(1-s)[(1-\eta_{ijt+1}^s)V_{it+1}^s + \int_{\varepsilon_{\min}^s}^{max(-\bar{\varepsilon}_{t+1}^s, \varepsilon_{\min}^s)} \left(V_{jt+1}^s - \varepsilon_{t+1}^s\right) dF\left(\varepsilon_{t+1}^s\right)].$$
(8)

The worker's value is a function of contemporaneous utility and the expected discounted future value, adjusted for the probability of survival, and averaged over the cases where the worker will choose to stay in the same sector or switch to the other sector, taking account of eventual sector migration costs.

In order to keep the working population constant, we assume that each period the retiring workers are replaced by newly entering workers, Se_{it}. Newly entering workers are not attached yet to a specific sector and are, therefore, more flexible in their choices. We assume that the main factor influencing the choice of sector is the wage differential. Naturally, workers tend to prefer the sector that pays the higher wage. However, due to numerical reasons we assume that the choice of sector is also influenced by preferences: upon entering the workforce each worker draws her sector-preference from a symmetric random distribution. We will parametrize this random distribution such that it has a negligible effect on the choice of sector, but it simplifies numerical simulations and implies a smooth transition to the new steady state.[7]

We assume that the sector preference of a skilled worker is given by ε^{Se}, with a positive number meaning that the worker prefers sector 1 and a negative number meaning that the worker prefers sector 2. Every newly entering worker draws her sector preference from the random distribution $G(\varepsilon^{Se})$ with zero mean and support on $(-\infty, \infty)$ (unskilled workers draw their sector preference ε^{Le} from the random

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[7]Without this sector-preference the choice of sector would not be well defined in the steady state, because workers are indifferent between the two sectors in the absence of wage differentials. Additionally, there would be no mechanism assuring that the steady state is hit, potentially implying overshooting and oscillatory dynamics.

distribution $G(\varepsilon^{Le})$). An entering worker will choose to enter sector 1 if:

$$V_{1t}^s + \varepsilon_t^{Se} > V_{2t}^s. \tag{9}$$

Equation 9 defines a threshold value $\overline{\varepsilon_t^{Se}}$, for which a worker is indifferent between both sectors:

$$\overline{\varepsilon_t^{Se}} = V_{2t}^s - V_{1t}^s, \tag{10}$$

and the share of the newly entering skilled workers that choose sector 1 is:

$$\frac{Se_{1t}}{Se_{1t} + Se_{2t}} = 1 - G(\overline{\varepsilon_t^{Se}}), \tag{11}$$

where Se_{1t} is the number of skilled workers entering sector 1 and Se_{2t} is the number of skilled workers entering sector 2. Having characterized the exit and entry behavior of workers, we can now write the laws of motion for skilled and unskilled workers. The number of skilled workers in sector i at the end of period t equals the number of incumbents who did not switch sectors, the number of workers who switched from sector j to sector i and the new entrants, taking account of the retirement rate, such that:

$$S_{it} = (1 - s)\left((1 - \eta_{ijt}^s)S_{it-1} + \eta_{jit}^s S_{jt-1}\right) + Se_{it}. \tag{12}$$

In this version of the model, the supply of skilled workers is fixed so that:

$$S = S_{1t} + S_{2t}.$$

Finally, in equilibrium the total number of workers that retire has to equal the num-

ber of new entrants:

$$sS = Se_{1t} + Se_{2t}.$$

2.2.2 Worker mobility with training

In this section, we relax the assumption of perfect immobility between skill classes, by allowing newly entering workers to train to become skilled workers. In this way the number of skilled workers becomes an endogenous variable and can adjust in response to trade liberalization.

The mobility assumptions for incumbent workers are exactly the same as in the previous section, but newly entering workers now not only choose their sector but also their skill class. We assume that workers first make the training decision and then choose a sector.[8] We thus need to define the ex-ante value of a worker, i.e., the expected value of a worker before she has chosen a sector. For skilled workers this value is given by:[9]

$$V_t^s = (1 - G(\overline{\varepsilon_t^{Se}}))V_{1t}^s + G(\overline{\varepsilon_t^{Se}})V_{2t}^s. \tag{13}$$

A similar equation holds for unskilled workers. To become skilled a worker needs to pay a training cost ε^T that is drawn from the random distribution $\Gamma(\varepsilon^T)$ with support on $[\varepsilon_{min}^T, \infty)$. An entering worker decides to train if the value of being skilled is high enough to justify the training cost, i.e., if:

$$V_t^s - \varepsilon_t^T > V_t^l. \tag{14}$$

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[8]Usually young workers first decide about their education/training and then about their precise sector/profession. While this timing assumption has the advantage that the sector choice described in the previous section is still valid in this section, reversing the timing assumption would not have any implications for our results.

[9]Note that the expected value of the sector-preference is zero and therefore drops out of this equation.

Equation 14 defines a threshold $\bar{\varepsilon}_t^T$ for which a worker is indifferent between training and not training:

$$\overline{\varepsilon_t^T} = V_t^s - V_t^l, \tag{15}$$

so that the probability of training is:

$$\eta_T^t = \Gamma\left[\max(\overline{\varepsilon_t^T}, \varepsilon_{\min}^T)\right]. \tag{16}$$

Thus a share η^T of all newly entering workers is skilled:

$$\frac{Se_t}{Se_t + Le_t} = \eta_t^T, \tag{17}$$

and the remainder is unskilled. Again, the number of exiting workers must equal the number of newly entering workers:

$$Se_t + Le_t = sENDOW. \tag{18}$$

All the other flow equations stay the same as in the previous section. All that changes is the share of skilled workers among entering workers that is now endogenous and was exogenous in the previous section.

2.2.3 Measures for wage inequality

In order to analyze the effect of trade liberalization on wage inequality, we define a number of wage inequality measures. First, we define two measures of wage inequality across sectors. They measure the relative percentage difference across sectoral wages for skilled and unskilled workers

$$IndexS_t = \left(\frac{w_{1t}^s}{w_{2t}^s} - 1\right)100,$$

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$$IndexL_t = \left(\frac{w_{1t}^l}{w_{2t}^l} - 1 \right) 100.$$

Note that these indices are close to zero at the steady state, due to long run mobility across sectors. However, they might be different from zero out of the steady state. It is one of the advantages of our dynamic model that it can capture these temporary increases in inequality.

To measure wage inequality across the skill classes we define a skill premium for each sector and an average skill premium. The skill premium for sector i is defined as the percentage difference between the wage of skilled and unskilled workers

$$Skill_{it} = \left(\frac{w_{it}^s}{w_{it}^l} - 1 \right) 100.$$

To define the average skill premium for each country, we use the average wage of skilled workers, $w_t^s = \frac{S_{1t}}{S_t} w_{1t}^s + \frac{S_{2t}}{S_t} w_{2t}^s$, and the average wage of unskilled workers, $w_t^l = \frac{L_{1t}}{L_t} w_{1t}^l + \frac{L_{2t}}{L_t} w_{2t}^l$ to obtain

$$Skill_t = \left(\frac{w_t^s}{w_t^l} - 1 \right) 100.$$

Note that the average wage in country H is $w_t = \frac{S_{1t}}{S_t+L_t} w_{1t}^s + \frac{S_{2t}}{S_t+L_t} w_{2t}^s + \frac{L_{1t}}{S_t+L_t} w_{1t}^l + \frac{L_{2t}}{S_t+L_t} w_{2t}^l$.

Finally, we measure aggregate wage inequality for each country by constructing a theoretical Gini index, which is a standard measure of inequality. The Gini index measures the extent to which the distribution of wages among the different groups of workers within each country deviates from a perfectly equal distribution. A Gini index of 0 means perfect equality, while an index of 1 means perfect inequality. The Gini coefficient is defined as half the relative mean difference of a wage distribution. The Gini coefficient for country H is

$$Gini_t = \frac{1}{2w_t} \frac{1}{(S_t + L_t)^2} (2S_{1t}S_{2t} |w_{1t}^s - w_{2t}^s| + 2L_{1t}L_{2t} |w_{1t}^l - w_{2t}^l|$$
$$+ 2S_{1t}L_{1t} |w_{1t}^s - w_{1t}^l| + 2S_{2t}L_{2t} |w_{2t}^s - w_{2t}^l| + 2S_{1t}L_{2t} |w_{1t}^s - w_{2t}^l| + 2S_{2t}L_{1t} |w_{2t}^s - w_{1t}^l|).$$

2.3 Production

There are two sectors of production in each country. A continuum of firms with heterogeneous productivity operates in each sector. To avoid cumbersome notation, we omit a firm-specific index in the following description of production. The production technology is assumed to be Cobb-Douglas in the two inputs of production:

$$Y_{it} = z_i S_{it}^{\beta_i} L_{it}^{(1-\beta_i)}, \tag{19}$$

where z_i is firm-specific productivity, while S_{it} and L_{it} is the amount of skilled and unskilled labor used by a firm. β_i is the share of skilled labor required to produce one unit of output Y_i in sector i. Sector 1 is assumed to be skill-intensive and sector 2 unskilled-intensive which implies that $1 > \beta_1 > \beta_2 > 0$. The labor market is assumed to be perfectly competitive implying that the real wage of both skilled and unskilled workers equals the values of their marginal products of labor. In addition, workers are perfectly mobile across all firms in a specific sector which implies that all firms within a sector pay the same wage. Consequently, relative labor demand can be described by the following condition:

$$\frac{w_{it}^s}{w_{it}^l} = \frac{\beta_i}{(1-\beta_i)} \frac{L_{it}}{S_{it}}, \tag{20}$$

which says that the ratio of the skilled real wage w_{it}^s to the unskilled real wage w_{it}^l for sector i is equal to the ratio of the marginal contribution of each factor into pro-

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ducing one additional unit of output. Note that this condition implies that relative demand for labor is the same across firms within a sector. Since relative demand for labor is independent of firm-specific productivity, equation 20 also holds at the sector level, i.e., relative labor demand per sector is entirely determined by the relative wages paid by firms in that sector. This condition is valid for both sectors.

Firms are heterogeneous in terms of their productivity z_i. The productivity differences across firms translate into differences in the marginal cost of production. Measured in the units of the aggregate consumption bundle, the marginal cost of production is $\frac{(w_{it}^s)^{\beta_i}(w_{it}^l)^{1-\beta_i}}{z_i}$.

Prior to entry, firms are identical and face a sunk entry cost f_{et}, which is produced by skilled and unskilled labor, equal to $f_{et}(w_{it}^s)^{\beta_i}(w_{it}^l)^{1-\beta_i}$ units of aggregate H consumption. Note that entry costs can differ between sectors due to different factor intensities and due to inter-sectoral wage differentials. Upon entry firms draw their productivity level z_i from a common distribution $G(z_i)$ with support on $[z_{min},\infty)$. This firm productivity remains fixed thereafter. As in GM there are no fixed costs of production, so that all firms produce each period until they are hit by an exit shock, which occurs with probability $\delta\varepsilon(0,1)$ each period. This exit shock is independent of the firm's productivity level, so $G(z)$ also represents the productivity distribution of all producing firms.

Exporting goods to F is costly and involves both an iceberg trade cost $\tau_t \geq 1$ as well as a fixed cost f_{xt}, again measured in units of effective skilled and unskilled labor.[10] In real terms, these costs are $f_{xt}(w_{it}^s)^{\beta_i}(w_{it}^l)^{1-\beta_i}$. The fixed cost of exporting implies that not all firms find it profitable to export.

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[10]The Iceberg trade costs are proportional to the value of the exported product and represent a number of different barriers to trade. These include both trade barriers that can be influenced by policy, like restrictive product standards or slow processing of imports at the border, and trade barriers that cannot be influenced by policy, like the costs of transportation. We follow the standard practice in the literature and model trade liberalization as a decrease in the Iceberg trade cost.

All firms face a residual demand curve with constant elasticity in both H and F. They are monopolistically competitive and set prices as a proportional markup $\frac{\theta}{\theta-1}$ over marginal cost. Let $p_{d,it}(z)$ and $p_{x,it}(z)$ denote the nominal domestic and export prices of a H firm in sector i. We assume that the export prices are denominated in the currency of the export market. Prices in real terms, relative to the price index in the destination market are then given by:

$$\rho_{d,it}(z) = \frac{p_{d,it}(z)}{P_t} = \frac{\theta}{\theta-1} \frac{(w_{it}^s)^{\beta_i} (w_{it}^l)^{1-\beta_i}}{z}, \rho_{x,it}(z) = \frac{p_{x,it}(z)}{P_t^*} = \frac{1}{Q_t} \tau_t \rho_{d,it}(z), \quad (21)$$

where $Q_t \equiv \frac{P_t^*}{P_t}$ is the real exchange rate. Profits, expressed in units of the aggregate consumption bundle of the firm's location are $d_{it}(z) = d_{d,it}(z) + d_{x,it}(z)$, where

$$d_{d,it}(z) = \frac{1}{\theta} \left(\frac{\rho_{d,it}(z)}{\psi_{it}} \right)^{1-\theta} \alpha_i R_t \quad (22)$$

$$d_{x,it}(z) = \begin{cases} \frac{Q_t}{\theta} \left(\frac{\rho_{x,it}(z)}{\psi_{it}^*} \right)^{1-\theta} \alpha_i^* R_t^* - f_{xt} (w_{it}^s)^{\beta_i} (w_{it}^l)^{1-\beta_i}, & \text{if firm } z \text{ exports} \\ 0 & \text{otherwise,} \end{cases} \quad (23)$$

with R_t denoting total expenditures on the aggregate consumption bundle. A firm will export if and only if it earns non-negative profits from doing so. For H firms, this will be the case if their productivity draw z is above some cutoff level $z_{x,it} = \inf\{z : d_{x,it} > 0\}$. We assume that the lower bound productivity z_{min} is identical for both sectors and low enough relative to the fixed costs of exporting so that $z_{x,it}$ is above z_{min}. Firms with productivity between z_{min} and $z_{x,it}$, serve only their domestic market.

2.3.1 Firm Averages

In every period a mass $N_{d,it}$ of firms produces in sector i of country H. These firms have a distribution of productivity levels over $[z_{min}, \infty)$ given by $G(z)$, which is identical for both sectors and both countries. The number of exporters is $N_{x,it} = [1 - G(z_{x,it})] N_{d,it}$. It is useful to define two average productivity levels, an average $\tilde{z}_{d,it}$ for all producing firms in sector i of country H and an average $\tilde{z}_{x,it}$ for all exporters in sector i of country H:

$$\tilde{z}_{d,it} = \left[\int_{z_{min}}^{\infty} z^{\theta-1} dG(z) \right]^{\frac{1}{(\theta-1)}}, \tilde{z}_{x,it} = \left[\int_{z_{x,it}}^{\infty} z^{\theta-1} dG(z) \right]^{\frac{1}{(\theta-1)}}.$$

As in Melitz [2003], these average productivity levels summarize all the necessary information about the productivity distributions of firms.

We can redefine all the prices and profits in terms of these average productivity levels. The average nominal price of H firms in the domestic market is $\tilde{p}_{d,it} = p_{d,it}(\tilde{z}_{d,it})$ and in the foreign market is $\tilde{p}_{x,it} = p_{x,it}(\tilde{z}_{x,it})$. The price index for sector i in H reflects prices for the $N_{d,it}$ home firms and F's exporters to H. Then, the price index for sector i in H can be written as $P_{it}^{1-\theta} = [N_{d,it} (\tilde{p}_{d,it})^{1-\theta} + N_{x,it}^* (\tilde{p}_{x,it}^*)^{1-\theta}]$. Written in real terms of aggregate consumption units this becomes $\psi_{it}^{1-\theta} = [N_{d,it} (\tilde{\rho}_{d,it})^{1-\theta} + N_{x,it}^* (\tilde{\rho}_{x,it}^*)^{1-\theta}]$, where $\tilde{\rho}_{d,it} = \rho_{d,it}(\tilde{z}_{d,it})$ and $\tilde{\rho}_{x,it}^* = \rho_{x,it}^*(\tilde{z}_{x,it}^*)$ are the average relative prices of H's producers and F's exporters.

Similarly we can define $\tilde{d}_{d,it} = d_{d,it}(\tilde{z}_{d,it})$ and $\tilde{d}_{x,it} = d_{x,it}(\tilde{z}_{x,it})$ such that $\tilde{d}_{it} = \tilde{d}_{d,it} + [1 - G(z_{x,it})] \tilde{d}_{x,it}$ are average total profits of H firms in sector i.

2.3.2 Firm Entry and Exit

In every period there is an unbounded mass of prospective entrants in both sectors and both countries. These entrants are forward looking and anticipate their future

expected profits. We assume that entrants at time t only start producing at time t+1, which introduces a one-period time-to-build lag in the model. The exogenous exit shock occurs at the end of each period, after entry and production. Thus, a proportion δ of new entrants will never produce. Prospective entrants in sector i in H in period t compute their expected post-entry value given by the present discounted value of their expected stream of profits $\{\tilde{d}_{is}\}_{s=t+1}^{\infty}$,

$$\tilde{v}_{it} = E_t \sum_{s=t+1}^{\infty} \left[\gamma^{s-t}(1-\delta)^{s-t} \left(\frac{R_s}{R_t} \right)^{-1} \tilde{d}_{is} \right]. \tag{24}$$

This also corresponds to the average value of incumbent firms after production has occurred. Firms discount future profits using the aggregate stochastic discount factor adjusted for the probability of firm survival $1-\delta$. Note that equation 24 can be written in recursive form as:

$$\tilde{v}_{it} = \gamma(1-\delta)E_t \left[\left(\frac{R_{t+1}}{R_t} \right)^{-1} \left(\tilde{v}_{it+1} + \tilde{d}_{it+1} \right) \right]. \tag{25}$$

Entry occurs until the average firm value is equal to the entry cost:

$$\tilde{v}_{it} = f_{et} \left(w_{it}^s \right)^{\beta_i} \left(w_{it}^l \right)^{1-\beta_i}. \tag{26}$$

The firms are owned by a mutual fund which finances the entry of new firms and collects all the profits. The surplus of the mutual fund is distributed in a lump-sum fashion to the households:

$$\Pi_t ENDOW = \tilde{d}_{1t} N_{d,1t} + \tilde{d}_{2t} N_{d,2t} - \tilde{v}_{1t} N_{h,1t} - \tilde{v}_{2t} N_{h,2t} \tag{27}$$

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Finally, the number of firms evolves according to:

$$N_{d,it} = (1-\delta)(N_{d,it-1} + N_{e,t-1}).$$ (28)

2.3.3 Parametrization and productivity draws

Productivity z follows a Pareto distribution with lower bound z_{min} and shape parameter $k > \theta - 1$: $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^k$. Let $v = \left\{\frac{k}{[k-(\theta-1)]}\right\}^{\frac{1}{\theta-1}}$, then average productivities are

$$\tilde{z}_{d,it} = vz_{min} \text{ and } \tilde{z}_{x,it} = vz_{x,it}.$$ (29)

The share of exporting firms in sector i in H is

$$\frac{N_{x,it}}{N_{d,it}} = 1 - G(z_{x,it}) = 1 - \left(\frac{vz_{min}}{\tilde{z}_{x,it}}\right)^k.$$ (30)

Together with the zero export profit condition for the cutoff firm, $d_{x,it}(z_{x,it}) = 0$, this implies that average export profits must satisfy

$$\tilde{d}_{x,it} = (\theta-1)\left(\frac{v^{\theta-1}}{k}\right)f_{xt}\,(w_{it}^s)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}.$$ (31)

2.4 Market Clearing Conditions, Aggregate Accounting and Trade

Market clearing requires that total production in each sector must equal total income so that:

$$N_{d,it}\left(\frac{\tilde{\rho}_{d,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}\alpha_i R_t + Q_t N_{x,it}\left(\frac{\tilde{\rho}_{x,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}\alpha_i R_t^* + \tilde{v}_{it}N_{e,it} = w_i^s S_{it} + w_{it}^l L_{it} + \tilde{d}_{it}N_{d,it}.$$ (32)

Total production of the sector (on the left hand side) includes the production of the aggregate consumption bundle (both for the domestic market and the foreign

market) and the production of new firms. Total income generated by the sector (on the right hand side) includes wage earnings and profits.

Trade is balanced at any time so that the value of H exports must equal the value of F exports such that:[11]

$$
\begin{aligned}
Q_t N_{x,1t} \left(\frac{\tilde{\rho}_{x,1t}}{\tilde{\psi}_{1t}^*} \right)^{1-\theta} \alpha^* C_t^* + Q_t N_{x,2t} \left(\frac{\tilde{\rho}_{x,2t}}{\tilde{\psi}_{2t}^*} \right)^{1-\theta} (1-\alpha^*) C_t^* = \\
N_{x,1t}^* \left(\frac{\tilde{\rho}_{x,1t}^*}{\tilde{\psi}_{1t}} \right)^{1-\theta} \alpha C_t + N_{x,2t}^* \left(\frac{\tilde{\rho}_{x,2t}^*}{\tilde{\psi}_{2t}} \right)^{1-\theta} (1-\alpha) C_t.
\end{aligned}
\tag{33}
$$

3 Parametrization

This section describes the parametrization of the model that we use for the numerical simulations. In most aspects we follow GM and BRS. We interpret each period as a quarter and, set the household discount rate γ to 0.99, the standard choice for quarterly business cycle models. We set the elasticity of substitution between varieties to $\theta = 3.8$, based on the estimates from plant-level U.S. manufacturing data in Bernard et al. [2003]. In order to avoid asymmetry due to demand effects, we set the share of each good in consumer expenditures equal to ($\alpha_1 = \alpha_2 = 0.5$). We set the parameters of the Pareto distribution to $z_{\min} = 1$ and $k = 3.4$, respectively. This choice satisfies the condition for finite variance of log productivity: $k > \theta - 1$. Changing the sunk cost of firm entry f_e only re-scales the mass of firms in an industry. Thus, without loss of generality we can normalize it so that $f_e = 1$. We set the fixed cost of exporting f_x to 23.5 percent of the per-period, amortized flow value of the sunk entry costs, $[1 - \gamma(1 - \delta)] / [\gamma(1 - \delta)] f_e$. This leads to a steady state share of exporting firms of 21 percent. We set the size of the exogenous firm exit

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[11]Under the income-pooling assumption, we ran simulations allowing for trade in international bonds and unbalanced trade but the movements in trade balance were negligible.

probability to $\delta = 0.025$, to match the level of 10 percent job destruction per year in the US. These choices of parameter values are based on GM.

To focus on comparative advantage, we assume that all industry parameters are the same across industries and countries except factor intensity (β_i). We consider symmetric differences in factor intensities $(\beta_1 = 0.6, \beta_2 = 0.4)$. To assure a positive skill premium in both countries, we assume that unskilled labor is more abundant in both countries. The richer country, H, is endowed with more skilled labor than the poorer country, F. Specifically, we assume that $S = 700$ and $L = 1300$ for H and that $S^* = 370$ and $L^* = 1630$ for F. These numbers imply that the share of skilled workers in the whole workforce is 35% for the rich country and 18.5% for the poor country. This is in line with OECD indicators, where the percentage of individuals with tertiary education between the ages of 25 and 64 range from 29% (EU) to 41% (US) for developed countries and from 4% (China) to 14% (Argentina) for developing countries (see table A1.1a in OECD [2013]). We set the share of skilled workers in the F workforce at a value slightly higher than the quoted OECD numbers in order to ensure a feasible post-liberalization steady state in the scenario where we allow for training.[12] In the training scenario only the total endowment with labor is fixed at $ENDOW = S_t + L_t = 2000$ and $ENDOW^* = S_t^* + L_t^* = 2000$, while the share of skilled and unskilled workers is determined endogenously. The training cost follows an exponential distribution with a parameter $scaleT = 0.000447255$ for H and $scaleT^* = 0.000128056$ for F.[13] The parameters were set so that the pre-liberalization steady state training probability in H and F match the shares of skilled workers in the labor force of each country, such that $\eta_T = 0.35$ for H and $\eta_T = 0.185$ for F. This ensures that the pre-liberalization steady state is the same in

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[12]Otherwise, we would end up in a corner solution after trade liberalization.

[13]Note that an exponential distribution has only one parameter, the scale parameter, while the minimum of an exponential distribution is always zero.

the model with and without training.

Concerning the migration of incumbent workers across sectors we follow the evidence in Autor et al. [2013], who show that unskilled workers are very immobile across sectors while skilled workers are mobile to a certain extent. Thus for most of our analysis we assume that unskilled workers face such high migration cost that they prefer to not switch sectors. For the skilled workers we assume that the migration cost follows an exponential distribution with scale parameter $scaleS = 0.1$, which implies that the probability for a skilled worker to switch sectors in the period immediately after liberalization is 1%.[14]

Finally, we assume that entering worker's sector preferences follow a Normal distribution with a mean of zero and a standard deviation of $sd = 0.1$. We have set the standard deviation parameter in order to ensure a very narrow distribution so that the entry decision of a worker regarding sector entry is mostly determined by sectoral wage differentials instead of preferences.

4   Symmetric trade liberalization scenarios

In this section we describe the dynamic adjustment after a symmetric trade liberalization shock. We assume that the Iceberg trade costs decrease for both sectors and for both countries from 1.3 to 1.2. Naturally, the length of adjustment depends on the ability of workers to move between sectors. In the long run workers are fully mobile so that they earn the same wage in both sectors.[15] In the short run, however,

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[14]Unfortunately, the empirical literature is not entirely conclusive on the subject of worker mobility across sectors. E.g., Greenaway et al. [2000] as well as Elliott and Lindley [2006] find that unskilled workers are more mobile across sectors than skilled workers. Therefore, in the robustness section in the appendix we show the results under the assumption that unskilled workers are mobile across sectors while skilled workers are not. We will also illustrate a case where the migration costs for skilled workers are lower than in this scenario.

[15]Actually the wage differential between the two sectors will not go away completely in the long run due to the different sizes of both sectors and our assumption that entering workers have a

adjustment costs can lead to wage differentials between sectors. This effect can only be captured by using a dynamic model that can distinguish between the short run and the long run.

We distinguish three different scenarios: i) the first scenario features the slowest adjustment. Here we make the assumption that all incumbent workers cannot switch sectors due to sector-specific skills. However, there are still workers who retire and get replaced by newly entering workers. These workers are more flexible because they have not invested in their skills yet. We do not consider this scenario as the most realistic one, but it serves well to explain the workings of the model and to highlight the role of mobility assumptions by serving as a benchmark to the other scenarios. ii) In the second scenario we assume that skilled workers can switch sectors. We restrict this ability to skilled workers, because this is in line with the evidence in Autor et al. [2013].[16] iii) In the third scenario we relax the assumption of fixed endowments with skilled and unskilled workers by assuming that entering workers can invest in training to become skilled workers. In our view this is the most realistic scenario, especially in the long run. However, in the trade literature it is more common to assume fixed endowments with skilled and unskilled labor, and so scenario 2 is probably the better benchmark for comparisons against the related literature.

In the following we concentrate on the analysis of the effects of trade liberalization on H, the country with higher endowment of skilled labor.

preference for one sector or the other. However, because the preference distribution was calibrated very narrowly, the wage differential between sectors is almost zero in the long run.

[16]In the robustness section in the appendix we also discuss the case where unskilled workers are more mobile across sectors than skilled workers.

4.1 Scenario 1: No active switching

The dot-dash green line in figure 1 shows the dynamic adjustment of selected variables for the first scenario, where only newly entering workers can choose in which sector to work, and where the endowments with skilled and unskilled workers are exogenously fixed. We use this scenario to explain the mechanisms of the model in more detail. The scenario will also serve as a benchmark against the other scenarios to highlight the role of mobility across sectors and skill classes. In this figure, and all the following ones, the number of quarters is at the horizontal axis. The decrease in trade costs happens in period 1. The vertical axis shows the percentage deviation of a specific variable from the pre-liberalization steady state.[17]

The wages that we present in this and all the following figures are welfare-based real wages, i.e., nominal wages divided by the welfare-based price index. The welfare-based price index summarizes information on average prices and the number of available varieties. Thus it can change due to changes in prices or due to changes in the number of varieties. Using a data-consistent price index to calculate data-consistent real wages has only quantitative effects. Also note, that all our measures of wage inequality are based on the ratio of wages. Thus, they are unaffected by the choice of the price index, since the price index cancels out in any case. Results for data-consistent real wages are available upon request.

The decrease in trade costs implies that it is more beneficial for both countries to specialize more in the production of the good in which they have comparative advantage. Country H is endowed with relatively more skilled labor and thus has a comparative advantage in the production of the skill-intensive good. When trade costs are reduced, it specializes more in the production of that good so that the

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[17]Some variables such as the index for inter-sectoral wage inequality are reported as absolute deviations from their pre-liberalization steady state value rather than percent deviations because they are zero at the pre-liberalization steady state.

demand in the import-competing sector (which produces the unskilled-intensive good) goes down, while the demand in the exporting sector (which produces the skill-intensive good) goes up.

This increases the wages of both skilled and unskilled workers in the exporting sector relative to their wages in the import-competing sector. This in turn induces an increase in the number of workers in the exporting sector at the cost of employment in the import-competing sector, but the adjustment is not immediate because all active workers are stuck in the sector where they have acquired their skills. In contrast, newly entering workers are very responsive to wage differentials. In the initial periods after trade liberalization all newly entering workers choose the expanding exporting sector. Only later, when the wage differentials between sectors have decreased sufficiently, some of the newly entering workers choose the import-competing sector. In the new steady state, of course, the share of newly entering workers that chooses the exporting sector is permanently higher, because the number of workers in the exporting sector is also permanently higher (which implies that more workers are exiting the sector and thus for the number of workers to be stationary, more workers need to enter the sector).

The reduction of trade costs makes exports cheaper and thus increases the profits that can be gained from exporting. This has two separate implications. On the one hand, existing exporters increase their sales on the foreign market (intensive margin of trade). On the other hand, the share of exporting firms increases because more firms are able to finance the fixed cost of exporting (extensive margin of trade). The number of exporting firms jumps up immediately, because the decision to export is not associated with any sunk investment costs, so that active firms can react immediately to the drop in transport costs. In contrast, the total number of active firms takes a longer time to adjust. Remember that in our model firms that only serve the domestic market do not have to pay fixed production costs. Therefore, a firm that

has paid the sunk entry costs always makes positive profits. Consequently, firms exit the market only when they are hit by an exogenous exit shock. This explains why the number of firms in the import-competing sector decreases more slowly.[18] The focus of our analysis is on wage inequality. Due to restricted mobility in the short run, our model allows for wage inequality along two dimensions: i) a wage differential between the two sectors (see *IndexS* and *IndexL*); ii) a wage differential between skilled and unskilled workers (the skill premium, see *Skill*). The first of the two wage differentials is due to mobility restrictions in the short run and will go away almost completely in the long run (see also the discussion in footnote 15). The second exists even in the long run because otherwise workers would not have an incentive to invest in skills.

The drop in transport costs increases demand in the exporting sector and, thus, raises the price in the exporting sector relative to the import-competing sector. This has an immediate impact on wages, which rise in line with the prices in the exporting sector relative to the import-competing sector. This is, of course, not only true for skilled workers but also for unskilled workers - both earn now higher wages in the exporting sector than in the import-competing sector, while they were earning the same wage in both sectors in the pre-liberalization steady state. This implies that newly entering workers prefer the exporting sector, raising the supply of both skilled and unskilled workers in the exporting sector. This diminishes the inter-sectoral wage differential over time. In the new steady state workers again earn the same wage in both sectors, so that the distribution of workers across sectors can be stationary. Thus, trade liberalization brings along a temporary increase in wage inequality between the two sectors, which vanishes in the long run.

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[18]Setting the fixed cost of domestic production equal to zero implies that domestic firms cannot be driven out of the market through the competition from foreign firms. However, it is still true that the competition from foreign firms reduces the demand and thereby the market share of domestic firms.

While the wage differential across sectors peaks on impact and then slowly recedes over time, the development of the skill premium is the exact opposite. The wage differential between skilled and unskilled workers within one sector is solely determined by the relative productivity of both kinds of labor, which in turn is determined by their relative input shares. In other words, the skill premium in both sectors can only change when the relative input of skilled and unskilled workers changes. As a result, in the short run the skill premium does not change much because the supply of workers is slow to adjust. In the medium and longer run, the increased demand for the skill-intensive exporting good increases the demand for skilled labor and, thus, increases the skill premium. In the process of moving workers from the import-competing sector to the exporting sector, the ratio of unskilled to skilled workers rises in both sectors, and with it the relative marginal product of skilled workers.

Thus in the short run the measure of overall wage inequality, the Gini coefficient, increases mainly through the first effect, the increase in inter-sectoral wage dispersion for each skill-class. With the movement of workers from the import-competing sector to the exporting sector, the wage inequality from this source decreases, but the skill premium increases. Note, however, that the skill premium effect is quantitatively much more important. Therefore, overall wage inequality increases over time.

Another interesting feature can be found in the disaggregated data of wages. The wages of unskilled workers are overshooting quite substantially.[19] This is so because trade liberalization leads to an immediate drop in the price index, because imports become cheaper and more varieties are available. However, the ensuing

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[19]The overshooting is less severe for data-consistent wages, especially for the unskilled workers in the import-competing sector, for whom the wage drops below the pre-liberalization steady state very quickly.

reallocation of workers and firms favors the skilled workers so that the wage of unskilled workers drops during the adjustment period. In the new steady state the wage of unskilled workers even lies below its level in the old steady state. Thus, the efficiency-enhancing effect of trade liberalization that leads to lower prices and more varieties is not strong enough to offset the decrease in demand for unskilled workers.

A note of caution is expedient here. Being a 'real' model, our model can only be used to make inference about real wages. Thus, our model mixes the effects of trade liberalization on nominal wages and on nominal prices. The real wage can rise because the nominal wage rises or because the nominal price drops. The real wage can rise even when the nominal wage drops, if the ensuing drop in nominal prices is even larger. This might explain why, in this scenario our model is not able to replicate the result in Autor et al. [2013] that unskilled wages in the import-competing sector decrease even in the very short run. Note, however, that this is different in some of the partial trade liberalization scenarios in which the unskilled workers in the import-competing sector suffer immediate wage losses. Also note, that this does not matter for our measures of wage inequality, because the same price index applies to all wages and thus cancels out when taking the ratio of two wages. Finally, let us stress that from a welfare point of view, real wages are of course the appropriate measure. Even if some workers would suffer nominal wage cuts, if their real wage goes up, their welfare goes up, because they can afford to buy more products.

4.2   Scenario 2: Active switching of unskilled workers

So far we have assumed that only workers newly entering the labor market can choose in which sector they want to work. We will now relax this assumption by

allowing migration across sectors along the lines described in section 2.2.1.

In specifying the mobility assumptions we follow Autor et al. [2013]. This is the empirical study closest related to our analysis, since it also deals with the effects of trade of a large developing country (China) with a large developed country (the US). Autor et al. [2013] find that unskilled workers are very immobile across sectors. Skilled workers are much more mobile across sectors, but even their mobility is restricted. They also find that skilled workers gain higher wages when they migrate form an import-competing sector to another sector. Following their results we assume that skilled workers are mobile across sectors but face considerable migration costs, while unskilled workers are immobile across sectors. [20]

The solid blue line in figure 1 shows the results. As in scenario 1 workers in the comparative advantage sector benefit relative to the workers in the comparative disadvantage sector. Both measures of sectoral wage inequality rise. Note, however, that there are important differences between the skill classes. The inter-sectoral wage differential among unskilled workers increases considerably more than in scenario 1, is more persistent and takes much longer to recede. In contrast, the inter-sectoral wage differential among skilled workers increases by less and recedes much faster now.

The reason is that in this scenario skilled workers are more sensitive to wage differentials because of their higher mobility. This does not necessarily imply that the reallocation of workers across sectors happens much faster. Some of the incumbent skilled workers in sector 2 pay the migration cost and switch to sector 1. This puts upwards pressure on skilled wages in sector 2. This in turn reduces the incentives of newly entering workers to choose sector 1 over sector 2, reducing the speed of reallocation to a certain extent. In sum, the higher mobility of workers

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[20]In the robustness section in the appendix we also consider the case where unskilled workers are more mobile across sectors.

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is reflected mainly in a lower inter-sectoral wage differential, while the number of skilled workers in the exporting sector increases only a little bit faster.

As already noted, inter-sectoral wage inequality among unskilled workers increases by more than in scenario 1. The explanation for this lies in the relative shares of skilled and unskilled workers in the production of the import-competing sector. In that sector the number of skilled workers is much lower than in the exporting sector, so that the share of unskilled to skilled workers is rather high. Therefore, a given decrease in the number of skilled workers in the import-competing sector has a much larger impact on the marginal productivity of unskilled (and skilled) workers. Thus, a relatively small difference in terms of skilled workers in the import-competing sector can translate into a relatively large difference in marginal productivity and larger inter-sectoral wage inequality.

The asymmetric development of skilled and unskilled wages has also implications for the skill premium. Due to the reduced productivity of unskilled workers and the enhanced productivity of skilled workers in the import-competing sector, the skill premium there goes up much quicker than in scenario 1. In contrast, the development of the skill premium in the exporting sector and in the whole economy is less affected by the enhanced mobility of skilled workers.

The Gini coefficient, our measure of overall wage inequality, jumps up on impact and then slowly increases further due to the rising skill premium. Again the development of the Gini coefficient is mainly driven by the development of the skill premium.

4.3 Scenario 3: Training

In BRS and in our first two scenarios it is assumed that the endowments of skilled and unskilled workers are fixed. Although workers are mobile between the two

sectors, they are not mobile between skill classes. In this section we relax this assumption by allowing newly entering workers to invest in training to become skilled workers, as described in section 2.2.2. The assumptions concerning inter-sectoral migration we are using in this scenario are equivalent to scenario 2: skilled workers can switch sectors, while unskilled workers cannot.

The dashed red line in figure 1 illustrates the results. In the initial periods after trade liberalization the differences are not too big. The build-up in the number of skilled workers in the exporting sector is a bit faster but not by too much (this is apparent in $L_{1,t}/S_{1,t}$ which is slightly lower initially). Similarly, the reduction in the number of skilled workers in the import-competing sector is faster only very little. As a consequence, the wage trajectories and our measures of wage inequality are not affected by much either.

However, this drastically changes in the medium to long run. The total number of skilled workers increases because trade liberalization increases the demand for skilled workers and thereby the incentives to invest in training. In the medium to long run this materializes in lower wages for skilled workers (because of higher supply) and higher wages for unskilled workers (because of lower supply). As a consequence, the skill premium in both sectors is considerably reduced, relative to the no-training scenarios.

The effects of the training possibility on inter-sectoral wage inequality are only minor. For this type of wage inequality the mobility of workers across sectors is, of course, more important. Since overall long-run wage inequality is mainly driven by the skill premium, it is considerably lower in the training scenario.

Thus, allowing for training, the higher demand for skilled workers due to trade liberalization is channeled into both higher supply of skilled workers and higher wages of skilled workers, as one would expect. The first channel is ruled out by assumption in the no-training scenarios and therefore all of the adjustment is channeled

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into the skill premium. Ignoring training possibilities thus leads to exaggerated estimates of the effects of trade liberalization on the skill premium and overall wage inequality.

4.4 Wage inequality and welfare

So far we have discussed the development of various variables after trade liberalization. In this section we want to discuss welfare in more detail and highlight the role of inequality. The real wage is a very good measure for the welfare of a worker because consumption is mainly determined by wage income. Remember that we did not use the common income pooling assumption and so our model does not only feature wage inequality but also consumption inequality. In comparing the results to a model of income pooling in which all workers consume the same amount, we provide a measure for the costs of consumption inequality.

The best measure of welfare is the value function of a worker given in equation 8. This measure is superior to the real wage since it takes account of future developments of the real wage and of potential sector migration costs borne in the future. As a reference point to the value functions of workers in our model, we define a counterfactual value function of a worker who is member of a large income-pooling household, encompassing the whole economy:

$$
\begin{aligned}
V_t = log\left(\frac{R_t}{Endow}\right) + \gamma(1-s)[V_{t+1} - \frac{S_1}{Endow}\int_{\varepsilon_{\min}^s}^{max(-\bar{\varepsilon}_{t+1}^s,0)} \varepsilon_{t+1}^s dF\left(\varepsilon_{t+1}^s\right) \\
- \frac{S_2}{Endow}\int_{\varepsilon_{\min}^s}^{max(\bar{\varepsilon}_{t+1}^s,0)} \varepsilon_{t+1}^s dF\left(\varepsilon_{t+1}^s\right)].
\end{aligned} \tag{34}
$$

We assume that workers also share the migration cost within the large household. If all the wage income was shared with other workers but migration costs borne indi-

vidually, there would be no migration across sectors. Note that this value function does neither contain the sub-index for the sector of the worker nor the super index for the skill class of the worker, because consumption and utility are the same for all workers. Equation 34 is written under the assumption that unskilled workers do not migrate across sectors, so only the potential migration cost of skilled workers is included. Assuming that the household decides about sector migration, the dynamics of most variables in this model are the same as in our benchmark model, but the welfare implications are different because consumption differs.

The first four panels in figure 2 compare the value function of a specific worker in the non-pooling economy with the value function of a representative worker in the pooling economy. Not surprisingly, skilled workers have lower welfare in the pooling economy because they need to share their higher wage income with the unskilled workers who earn a lower wage. Conversely, unskilled workers are better off under income-pooling. The figure also shows that the difference in value functions can be quite substantial. E.g., the value function of skilled workers in the no-training scenario increases in the long run by almost twice as much under non-pooling than under pooling.[21]

The value functions can be interpreted as the welfare of a worker newly entering the workforce at period t, after eventual training costs are sunk. Thus another insight from figure 2 is that all workers who are already active at the time the trade liberalization is implemented, gain from trade liberalization. The unskilled workers gain only little, especially those in the import-competing sector, but they gain, too. Only the unskilled workers that enter the workforce a certain time later, and all unskilled workers that enter in the post-liberalization steady state, have lower welfare than

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[21]In the training scenario the difference for skilled workers vanishes in the long run, but note that these are relative changes. In absolute terms the value function of skilled workers in the benchmark economy is higher and increases by more than in the pooling economy.

unskilled workers that entered in the pre-liberalization steady state.

To be better able to compare aggregate outcomes, we define three more aggregate variables:

$$\bar{V}_t = \frac{S_{1t}}{Endow}V_{1t}^S + \frac{S_{2t}}{Endow}V_{2t}^S + \frac{L_{1t}}{Endow}V_{1t}^L + \frac{L_{2t}}{Endow}V_{2t}^L \tag{35}$$

$$\bar{U}_t = \frac{S_{1t}}{Endow}log(C_{1t}^S) + \frac{S_{2t}}{Endow}log(C_{2t}^S) + \frac{L_{1t}}{Endow}log(C_{1t}^L) + \frac{L_{2t}}{Endow}log(C_{2t}^L), \tag{36}$$

$$U_t = log\left(\frac{R_t}{Endow}\right) \tag{37}$$

where $\bar{V}_t$ is the average value function in the benchmark economy, $\bar{U}_t$ is average period-utility and U_t is the period-utility of average income (consumption), i.e., period-utility under income pooling.

The comparison of these aggregate variables is illustrated in the last two panels of figure 2 where the solid blue line illustrates the non-pooling case and the dashed red line the pooling case. Even though aggregate consumption is the same in both economies, the averages differ. The difference between pooling and benchmark economy stems from the curvature of the utility function. Due to decreasing marginal utility of consumption wage inequality leads to lower utility and welfare in the benchmark economy. Put differently, pooling income raises welfare, because the utility lost by workers with an originally high consumption level is lower than the utility gained by workers with an originally low consumption level.

In this way figure 2 presents a measure for the costs of consumption inequality and it can be seen that the costs are quite high. E.g., in the no-training scenario the gains from trade liberalization are almost 50% higher in the pooling economy compared to the benchmark economy. We can conclude that trade liberalization has important and non-negligible consequences for wage inequality, consumption inequality and welfare.

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5 Partial and unilateral trade liberalization scenarios

One of the advantages of our general-equilibrium, multiple-sector approach is that it allows us to analyze a broad scope of trade liberalization scenarios. So far we have concentrated on trade liberalization scenarios in which the trade costs were reduced for both sectors in both countries. In this section we will analyze scenarios in which only some of the sectors experience a decrease in trade costs.

These kinds of scenarios might be appealing for policy makers for at least two reasons. i) It might be easier to negotiate partial trade liberalizations with other countries. ii) Partial trade liberalization might meet lower opposition at home based on the hope that the adverse effects on the labor market are less severe because vulnerable sectors are spared from foreign competition.

We analyze three different scenarios. i) It appears plausible that the rich country is more powerful and thus able to push through its preferred agenda, liberalizing trade in the sector where it has its comparative advantage and leaving the other sector untouched. This is our fourth scenario.

ii) If the poor country is more powerful it might be able to push for a liberalization strategy that lowers the trade costs for exports of both countries' comparative-advantage sectors. This strategy is our fifth scenario and involves a reduction of the costs of exporting the skill-intensive good from the rich country to the poor country and of the costs of exporting the unskilled-intensive good from the poor to the rich country.

iii) Finally, we analyze a unilateral reduction in the trade costs for exporting the unskilled-intensive good from the poor country to the rich country (scenario 6). Although it appears unlikely that a country reduces the trade costs for one of its

sectors without any concessions from its trading partners, we include this scenario to make our results more comparable to the other recent papers studying the transitional dynamics of trade liberalization (Artuç et al. [2010], Dix-Carneiro [2014] and Coşar [2013])

In all three scenarios, we restrict our analysis to the mobility assumption that we, in line with empirical results from other papers, consider the most realistic, namely assuming that skilled workers are more mobile across sectors than unskilled workers. We will consider both the case with exogenous endowments with skilled workers (analogous to scenario 2 of the previous section), to be comparable to BRS, and the case with training (analogous to scenario 3).

5.1 Scenario 4: Liberalization of the skill-intensive sector

In this scenario the rich country manages to push through the liberalization of trade in the sector where it has its comparative advantage, i.e., τ_1 and τ_1^* are both reduced from 1.3 to 1.2, while τ_2 and τ_2^* remain unchanged at 1.3. With this strategy the rich country might hope to gain from increased exports in its comparative advantage sector, while at the same time avoiding stronger competition in its import-competing sector.

The results are illustrated in figure 3.[22] It is immediately evident that the wage gains of skilled workers are considerably reduced in this scenario under both training assumptions (relative to the full trade liberalization scenario of the previous section). In contrast, the wage of unskilled workers decreases by less.

In consequence, the increase in the skill premium is much lower in this scenario. While it increased by almost 14% in scenario 2, it increases by less than 5% under the no-training assumption of this scenario. The differences under the training as-

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[22]We limit the figures of this section to a smaller selection of variables. Full results are available upon request.

sumption are equally stark. Even inter-sectoral wage inequality increases by much less in this scenario and so overall wage inequality is considerably reduced.

Thus, if the goal is to reduce the effects of trade liberalization on wage inequality, this strategy is indeed successful. Note, however, that the costs of this strategy in terms of lost aggregate consumption are also quite large: the relative increase in aggregate consumption is less than half than the full trade liberalization scenarios. This is so, because the import-competing sector is spared from trade liberalization. This is the sector where F has its comparative advantage and, therefore, consumers in H would gain especially from liberalized trade in that sector.

5.2   Scenario 5: Liberalization of comparative-advantage sectors

In this scenario we assume that both countries agree on a one-sided reduction of trade barriers for the exports in their respective comparative advantage sectors, i.e., the poor country allows the rich country to export the products of the skill-intensive sector at lower costs (τ_1 goes down from 1.3 to 1.2), while the rich country allows the poor country to export the products of the unskilled-intensive sector at lower cost (τ_2^* goes down from 1.3 to 1.2).

The results are illustrated in figure 4. Relative to scenarios 2 and 3, the wage of skilled workers is not affected by much, they earn a bit less in the very short run but a bit more in the medium and long run. But the unskilled workers have to suffer now much larger drops in their real wage. Under the no-training assumption the long-run unskilled wage drops by almost 3%, while it dropped by less than 1% in scenario 2. Under the training assumption the long-run unskilled wage does not change, while it increased in scenario 3.

Also note that for the first time we have a scenario in which some workers suffer

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lower wages throughout the whole transition period after trade liberalization and in the new steady state. The unskilled workers in the import-competing sectors are especially hard hit in this scenario. In the short run they suffer from the increased competition from abroad (without gaining from better opportunities to export). In the long run they suffer from the generally lower demand for unskilled workers.

This has of course important consequences for wage inequality. All our measures of wage inequality increase by more in this scenario. E.g., under the no-training assumption the skill premium rises by more than 20% and the Gini increases by around 13%, whereas these numbers are around 14% and 8% in the corresponding full trade liberalization scenario, scenario 2.

5.3   Scenario 6: Unilateral Liberalization

This is the scenario that is most comparable to other recent studies of the dynamic adjustment to trade liberalization (Artuç et al. [2010], Dix-Carneiro [2014] and Coşar [2013]). These papers use small open economy models, which implies that world market prices are given exogenously and that bilateral trade liberalization scenarios are hard to model. Therefore, these papers restrict themselves to the analysis of a unilateral reduction in the costs of imports in one specific sector, typically the import-competing sector. Therefore, we assume in this scenario that the trade costs for exporting the unskilled-intensive good from the poor country to the rich country are reduced (τ_2^* goes down from 1.3 to 1.2).

The results are illustrated in figure 5. Not surprisingly, the implications of a unilateral reduction in trade costs are very different from the bilateral reduction in trade costs in our baseline scenario 2. The wages of skilled workers increase by less both in the short run and in the long run. The differences for the unskilled workers are even more noticeable. As in scenario 5, the unskilled workers in the import-

competing sector suffer lower wages throughout the whole transition period and in the new steady state.

Because the decrease in the skilled wage weighs stronger than the decrease in the unskilled wage, the skill premium and the Gini coefficient increase a little less in this scenario, relative to scenarios 2 and 3, while consumption growth is considerably reduced. We can conclude that the effects of unilateral and bilateral trade liberalization are very different. This is hardly surprising but underscores the value of having a general equilibrium model with two large economies, which allows for a meaningful simulation of both types of trade liberalization.

6 Conclusion

We build a two-country, two-factor, two-sector dynamic general equilibrium trade model with labor mobility costs in order analyze the transitional dynamic effects of permanent trade liberalization. Our analysis concentrates on the change of wage inequality that occurs in developed countries from increased trade with developing countries. The advantage of our analysis is that we use a general equilibrium model of two large countries, while other recent dynamic papers use small open economy models. This implies that we can analyze a broader scope of trade reforms, not just a decrease in the restriction to imports in a specific sector. Our results show that different types of trade reform lead to starkly different transitions. Thus it is essential to be able to capture a broad scope of trade reforms.

We distinguish two potential sources of wage inequality, the wage differential between workers who are in the same skill class but in different sectors (comparative advantage versus comparative disadvantage sectors) and the skill premium, i.e., the wage differential between skilled and unskilled workers. In the short run, inter-sectoral wage inequality increases because the demand for the good produced by

the exporting sector increases. In the medium run, inter-sectoral wage inequality recedes because workers move from the import-competing sector to the exporting sector. In contrast, the skill premium does not change much in the short run but constantly increases until it reaches a new plateau. This permanently increases overall wage inequality.

Another contribution of our paper is that we analyze scenarios in which we allow newly entering workers to train to become skilled workers. This has important implications for the long run effects of trade liberalization. The long run effects of trade liberalization on wage inequality are considerably reduced because more of the adjustment is accomplished via quantities (more skilled workers) and less via wages.

Our results also suggest that full trade liberalization (encompassing both sectors in both countries) is better than partial or unilateral trade liberalization. Restricting trade liberalization to the skill-intensive sector reduces the effects on wage inequality, but at the cost of considerably reduced consumption gains. If both countries restrict their trade liberalization to their respective comparative advantage sectors, the effects are more striking. The effects on wage inequality are much higher and unskilled workers in the import-competing sector suffer substantial losses in wage income throughout the whole transition and in the post-liberalization steady state. This is also true for unilateral trade liberalization.

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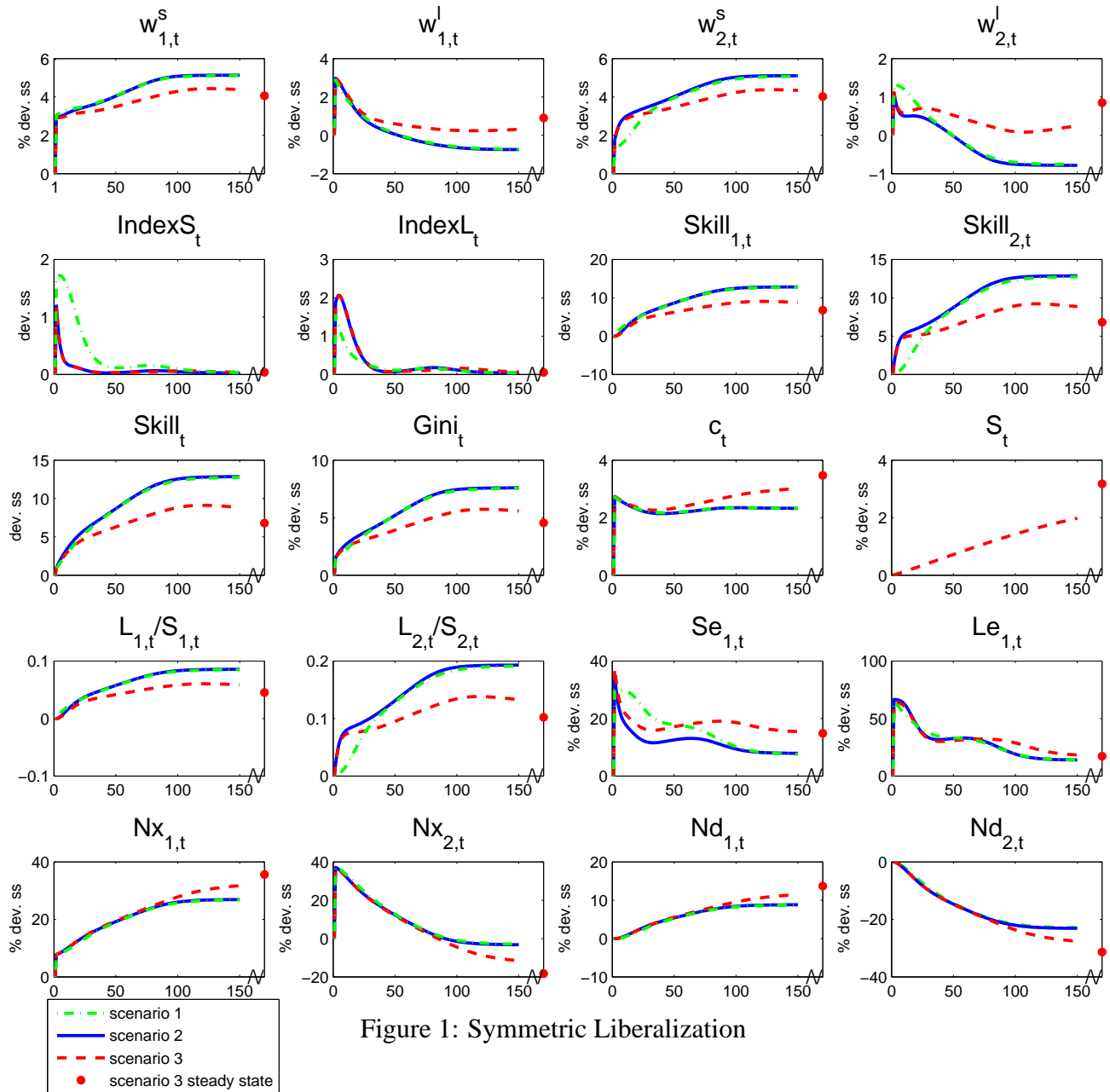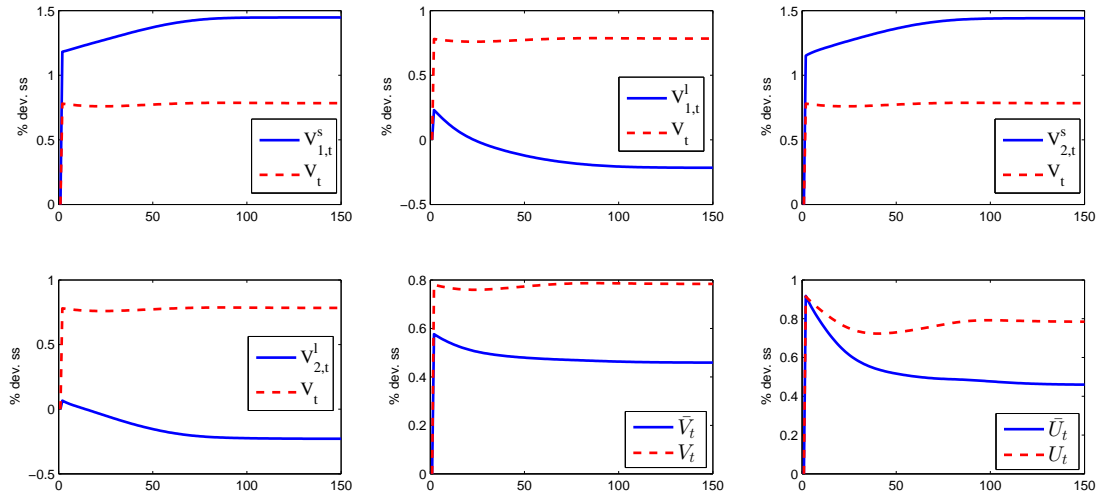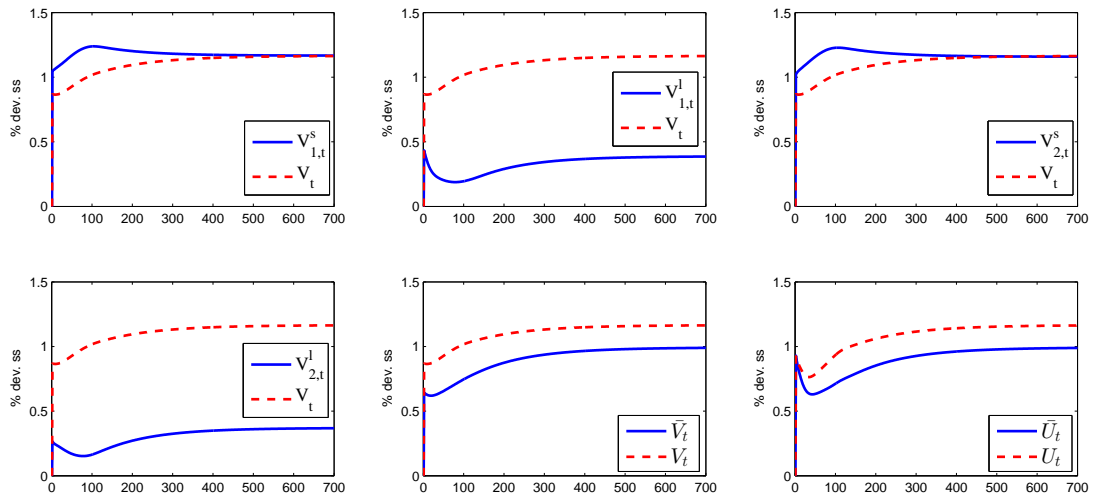
7   Figures

Figure 1: Symmetric Liberalization

(a) No training
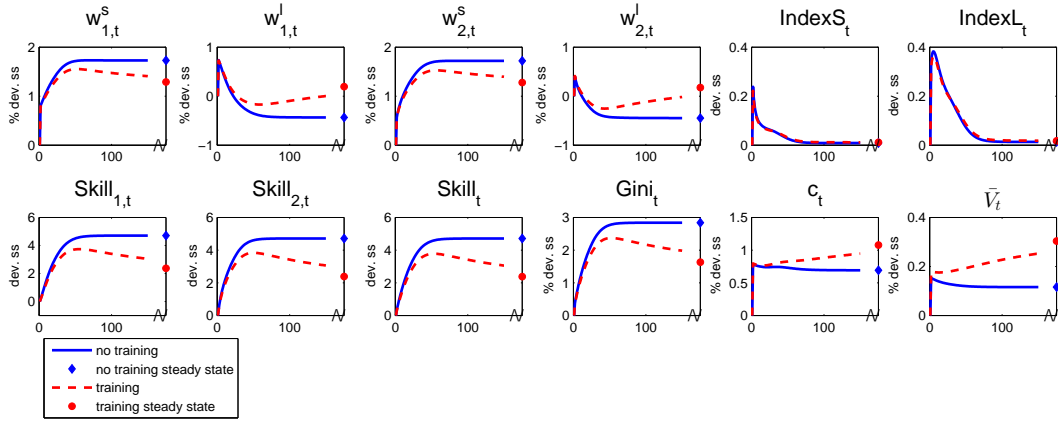
(b) Training

Figure 2: Welfare comparison

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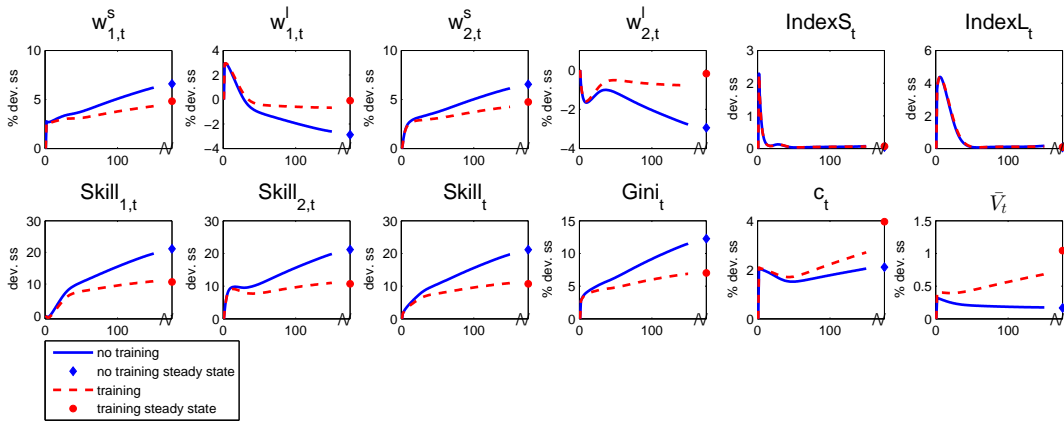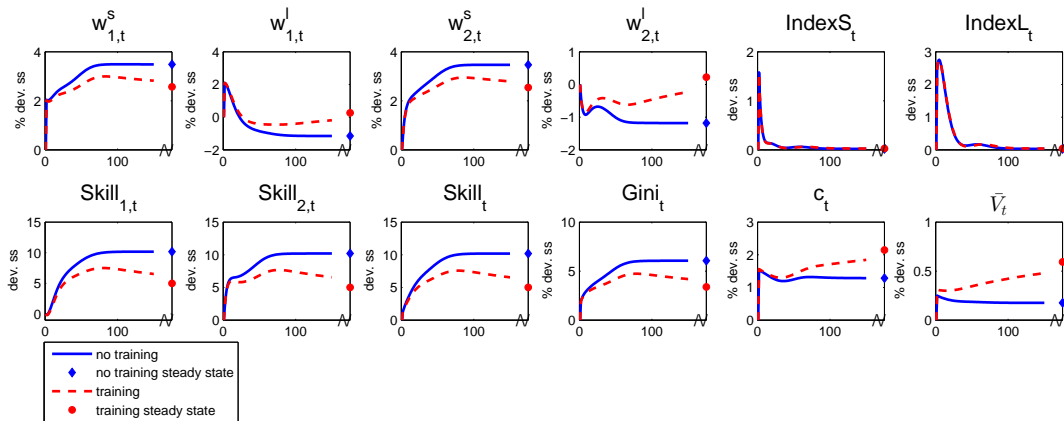Figure 3: Liberalization of Skill-Intensive Sector

Figure 4: Liberalization of Comparative-Advantage Sectors

Figure 5: Unilateral liberalization

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