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We use a dynamic general equilibrium trade model with comparative advantage, heterogeneous firms, heterogeneous workers and endogenous firm entry to analyze economic policy meant to compensate the losers of trade liberalization and reduce the ensuing wage inequality. We consider several instruments of economic policy: a wage tax to redistribute income between skilled and unskilled workers; sector-specific consumption taxes and profit taxes to affect inter-sectoral wage inequality; sector-specific firm entry subsidies, worker sector-migration subsidies and training subsidies to speed up the adjustment process. We find that the re-distributional and efficiency effects of these instruments differ very much. Probably the most potent instrument to reduce the wage inequality after trade liberalization are training subsidies. They increase the supply of skilled workers and thereby reduce the skill premium. The policy also generates inefficiencies because too many workers are trained, but the costs of these inefficiencies are relatively low.

Keywords: trade liberalization; wage inequality; adjustment dynamics; redistribution

JEL classification: E24, F11, F16, J62

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1 Introduction

Trade with China has been recently identified as an important driver of wage inequality in developed countries (see, e.g., Ebenstein et al. [2013] or Pierce and Schott [2012]). Autor et al. [2013] found that workers employed in sectors that are exposed to competition from Chinese imports suffer lower wages and lower employment. Thus, trade liberalization creates winners and losers which in some cases leads to strong opposition against free trade and calls for protectionist measures. Survey-based empirical evidence suggests that the political support for free trade might be higher when trade liberalization is accompanied by a compensatory mechanism (see Hays et al. [2005] for OECD countries and Ehrlich and Hearn [2013] for the U.S.). Thus, it is not surprising that countries that are more open redistribute more, as figure 1 illustrates. The question arises, what is the best way to compensate the losers of trade liberalization and to reduce the ensuing wage inequality.

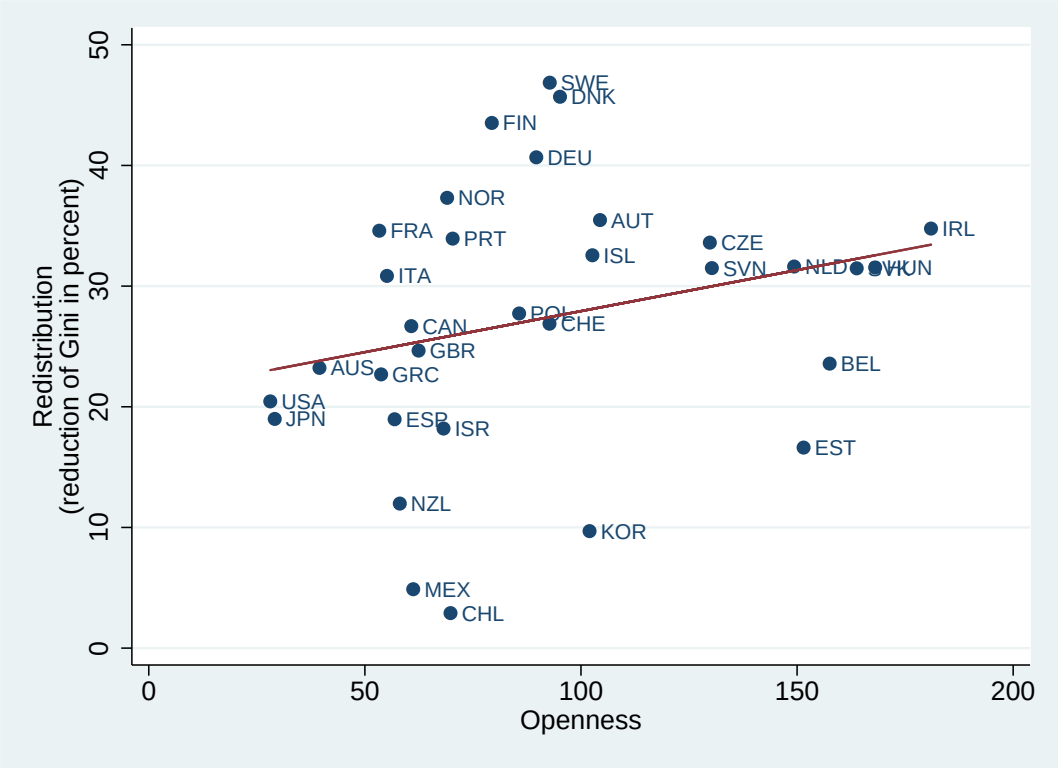

Figure 1: Openness and Redistribution

Openness on the horizontal axis is measured as the sum of exports and imports divided by nominal GDP. Redistribution on the vertical axis is measured as the difference between a Gini index based on market income and a Gini index based on net income (see Solt [2009]). The solid line is based on a linear regression between openness and redistribution, where $\underset{}{Redistribution} = \underset{(3.598)}{21.13} + \underset{(.029)}{0.068}\ Openness$ with robust standard errors in the parentheses. The coefficient is significant at the 5% level. The data sample includes all OECD countries except Luxemburg and dates to 2010.

To answer this question we extend the model developed in Lechthaler and Mileva [2013] to include a variety of policy instruments that can be used to redistribute the gains from trade. Our analysis shows that training subsidies are probably the most efficient instrument to reduce the wage inequality that results from trade liberalization.

The model in Lechthaler and Mileva [2013] combines a number of features that are crucial to analyze the effects of trade liberalization on wages and wage inequality. The model features two factors of production (skilled and unskilled workers) and two sectors of production with different degrees of skill intensity. This is important because the trade of a developed country with a developing country is primarily based on inter-industry trade, exploiting comparative advantages, in contrast to trade among developed countries which is primarily based on intra-industry trade. The model also features firm heterogeneity, endogenous firm entry and selection into export markets as in Melitz [2003], ingredients which have been found to be empirically important. Finally, the model is not restricted to steady state comparisons but explicitly models the transitional dynamics after trade liberalization.[1] This is crucial because it is mainly the adjustment process after trade liberalization that causes policy debates.

Our model is rich enough to capture inequality along two dimensions: the wage differential between skilled and unskilled workers, the skill premium, and the wage differential between the two sectors for a specific skill class, inter-sectoral wage inequality.

Concerning the mobility of workers we consider two different assumptions. In the first case we assume that the number of skilled workers is exogenously given. This is the standard case in many models of international trade (e.g., Bernard et al. [2007]). In the second case we endogenize the number of skilled workers by allowing newly entering workers to train to become skilled workers.

These assumptions matter very much for the long-run equilibrium. A country that is skill abundant specializes more in the production of the skill intensive good when trade is liberalized. This leads to a higher demand for skilled workers. When the number of skilled workers is exogenously given, this must manifest in a higher skill premium. The relatively lower demand for unskilled workers can lead to a permanent drop in unskilled wages. When workers can train the number of skilled workers will increase, too, dampening the effect of trade liberalization on the skill premium and overall wage inequality.

Although the two versions of the model imply different long-run outcomes, the short run effects of trade liberalization are quite similar because they are driven by the slow reallocation of workers: inter-sectoral wage inequality increases, especially for unskilled workers, and the skill premium also increases, but more gradually.

We extend the model in Lechthaler and Mileva [2013] to include several instruments of economic policy: a wage tax to redistribute income between skilled and unskilled workers; sector-specific consumption taxes and profit taxes to affect inter-sectoral wage inequality; sector-specific firm entry subsidies, worker sector-migration subsidies and training subsidies to speed up the adjustment process.

We find that the re-distributional and efficiency effects of these instruments differ very much. An increase in the wage tax on skilled workers that finances a wage subsidy for unskilled workers can dampen the increase in the skill premium and thus the increase in wage inequality, but it reduces the incentives to invest in training and hurts the skilled workers in the import-competing sector to such an extent that they suffer temporary wage reductions.

Temporary, sector-specific taxes on consumption and profits can not only reduce inter-sectoral wage inequality but also the skill premium. Instead of the fast increase in wage inequality that follows trade liberalization without any accompanying policy intervention, the increase in wage inequality becomes much more gradual and thus probably easier to digest. However, the policy distorts the reallocation decision of firms and workers and thereby reduces aggregate consumption.

[1] Basically, Lechthaler and Mileva [2013] puts Bernard et al. [2007] into a dynamic setting along the lines of Ghironi and Melitz [2005].

Firm entry subsidies have the potential to speed up the adjustment process but they do so at the cost of considerably increasing wage inequality. Worker's sector migration subsidies can improve the sectoral mobility of unskilled workers, which helps unskilled workers in the import-competing sector. However, the effects on wage inequality and welfare are only minor, because they tend to hurt the unskilled workers in the exporting sector.

Probably the most potent tool are training subsidies. Naturally, they lead to a higher number of skilled workers. This makes unskilled workers scarcer and increases their wage. Skilled workers become more abundant and the skilled wage is lowered. Thus, the skill premium is reduced and with it overall wage inequality. Although the policy also generates inefficiencies because too many workers are trained, the costs of these inefficiencies are relatively low.

2 Literature review

Economists have invested a great deal of effort in analyzing the effect of international trade on the relative distribution of income. Most studies on the distributional effects of international trade are based on either the Heckscher-Ohlin or the Ricardo-Viner model. The Heckscher-Ohlin model predicts that the owners of abundant production factors gain from trade while the owners of scarce factors lose, whereas the Ricardo-Viner model predicts that opening up to trade harms factors specific to the import-competing sector. More recent contributions have also analyzed the effects of international trade on the distribution of income in trade models with heterogeneous firms. In general, there is broad agreement among economists that the globalization process will generate net aggregate benefits but will also harm some groups in society. Governments in most developed countries have implemented some sort of compensation scheme for the losers from trade liberalization. The most well-known compensation policy is the Trade Adjustment Assistance (TAA) program of the United States. The TAA program is a set of policies that offer loan assistance, plus measures to compensate displaced workers with extended unemployment benefits, relocation expenses and training for jobs in a new industry. Canada and Australia have implemented similar schemes, such as the General Adjustment Assistance Program and Special Adjustment Assistance. Yet, surprisingly little research has been devoted to the question of how welfare policies can optimally compensate the losers of globalization. As Feenstra [1998, p.48] has put it: "We know surprisingly little about redistribution schemes, other than that they often fail".

Following the lead by Dixit and Norman [1980, 1986], most of the earlier papers on redistribution schemes concentrate on the possibility of compensating the losers from trade without exhausting the net gains from trade. The policy analyzed by Dixit and Norman specifies a scheme of commodity taxes and subsidies such that consumers face autarky prices for goods and factors. Free trade then leaves individuals as well off as under autarky. Dixit and Norman [1980, 1986] show that such a policy raises non-negative revenue for the government and thus results in a Pareto improvement.

There are several limitations of the earlier literature in the tradition of Dixit and Norman [1980, 1986]. The compensation scheme considered by Dixit and Norman [1986] has little repercussions in the real world. As Davidson and Matusz [2006, p. 724] have put it: "We know of no government that has ever considered such a scheme to compensate workers harmed by changes in trade policies". In contrast, labor market policies, such as wage or training subsidies or minimum wages, are at the heart of the policy debate on how to assist the losers of the globalization process. Much of the earlier literature uses static models of international trade and, thus, considers only the long-run effect of trade liberalization. Hence, the literature abstracts from the potentially large short- and-medium-run costs of adjusting to trade liberalization. In addition, labor is usually supplied inelastically and the skill level of workers is exogenous. Therefore, welfare policies

have, by assumption, no effect on the incentives to work or the education decision of workers. Yet, these effects are at the heart of the policy debate on the adverse effects of globalization.

We contribute to the literature by addressing some of these limitations. We analyze a large variety of labor market policies and their effects on inequality and employment across sectors. We use a dynamic general equilibrium model which allows us to study the short-run as well as the long-run effects of trade liberalization. Finally, in our model the skill level and the supply of skilled labor are endogenous so that we can analyze the effects of redistributive policies such as training subsidies on the decision of workers. Several other recent papers also address some of these limitations in the literature on trade and re-distribution but they either have a different focus of analysis than us or limit their analysis to particular policy scenarios.

Janeba [2003] analyzes the role of government policies in the case where the wage gap between high-skilled and low-skilled workers is widening due to increasing foreign competition in low-skilled intensive goods. A two-period, three-sector general-equilibrium model of a small open economy is developed in which individuals choose whether to invest in skills or not. The paper shows that increasing import competition or lowering wage taxes on skilled workers widens inequality when the skill distribution is exogenous because increased demand for skilled labor manifests in increased skilled wages. But when the skilled distribution is endogenous, the opposite occurs because lowering taxes on skilled workers or import competition acts as an additional incentive to become skilled, i.e. increased demand for skilled labor manifests in increased quantity of skilled labor. Similarly to us, Janeba [2003] analyzes the role of wage taxes when the education decision of workers is exogenous or endogenous but he uses a two-period model which makes it difficult to discuss short- versus long-run trade-offs of government policies. In addition, the trade experiment performed by Janeba [2003] is unilateral liberalization and implicitly assumes that the terms of trade are exogenous. Lechthaler and Mileva [2013] show that the effects of unilateral and bilateral trade liberalization can differ very much and argue that bilateral trade liberalization is the more relevant case, especially when one is interested in the effects of trade in a developed country, because these are too powerful be pushed into unilateral trade liberalization.

Davidson and Matusz [2006] compare a variety of labor market policies designed to compensate workers that are harmed by trade liberalization. Their model incorporates two sectors, a low- and a high-tech sector, and two types of workers, a low- and a high-ability worker. Labor supply in the model is fixed but workers choose a sector, and acquire the necessary training, based on expected income. In the initial equilibrium, the low-tech sector is protected by a tariff. The removal of the tariff increases the real wage in the high-tech sector but reduces the real wage in the low-tech sector. The losers from liberalization consist of "Stayers" that are stuck in the low-tech sector and "movers" that go through costly training to switch from the low- to the high-tech sector. The authors then use the model to analyze whether unemployment benefits, wage subsidies, employment subsidies or training subsidies compensate the losers of globalization at the lowest cost. They find compensation policies should not be general but always targeted to those workers harmed by liberalization. In a follow-up paper, Davidson et al. [2007] show that compensation policies can increase the likelihood that trade liberalization is chosen in a political process. This is an important result, as it suggests that compensation policies might be necessary to reap the aggregate benefits of free trade. However, the trade experiment analyzed by Davidson and Matusz [2006] is unilateral liberalization and implicitly assumes that the terms of trade are exogenous.

Itskhoki [2008] considers optimal redistribution through the tax system in a model with heterogeneous worker-entrepreneurs who earn firm revenues as income. Entrepreneurs differ in terms of their productivity and face fixed costs of exporting. As a consequence, trade liberalization disproportionately benefits the most productive entrepreneurs,

which are able to engage in export activities, and thus increases income inequality. The government chooses income taxes so as to maximize a social welfare function that features positive inequality aversion. Itskhoki [2008] shows that trade liberalization increases the incentives for redistribution, but also aggravates the equity-efficiency trade-off associated with re-distribution. The paper does not consider labor market institutions and restricts its analysis to tax policies. In addition, it focuses on intra-industry trade between countries while inter-industry trade is more important if one aims to analyze redistribution in the context of increased trade between developed and developing countries.

Egger and Kreickemeier [2009] build a model with heterogeneous firms who pay firm-specific wages to ex-ante identical workers. Workers have fairness preferences and expect that the most productive firms will pay higher wages so that free trade gives rise to within-group inequality. The authors then analyze the effects of a redistribution scheme consisting of lump-sum transfers to all workers financed by a linear profit tax. They show that such a redistribution scheme can, under certain conditions, lead to a more equal income distribution than in autarky without exhausting the gains from trade. This paper restricts its analysis to static outcomes and, therefore, considers only the long-run effect of trade liberalization. Its analysis of redistribution abstracts from the potentially large short- and medium-run costs of adjusting to trade liberalization. Like Itskhoki [2008] the paper focuses on intra-industry trade.

de Pinto [2013] investigates the impact of three different forms of financing unemployment benefits : (i) a wage tax paid by employees, (ii) a payroll tax paid by firms and (iii) a profit tax paid exclusively by exporters. He uses a model with heterogeneous firms and workers who operate in unionized labor markets. Trade liberalization results in winners (the high-skilled workers) and losers (the low-skilled workers). His analysis reveals that there is a threshold level of unemployment benefits where all trade gains are destroyed, but this threshold varies with the unemployment benefit's source of funding. There is a clear-cut ranking in terms of welfare for the chosen funding of the unemployment benefit: 1. wage tax, 2. profit tax, 3. payroll tax. This paper also restricts its analysis to static outcomes and focuses on intra-industry trade.

Coşar [2013] builds an overlapping generations model where workers accumulate sector-specific human capital on the job that is not transferable across sectors. Workers can either be employed in the exporting sector in which the economy has a comparative advantage or in the import-competing sector of the economy which is initially protected by a tariff. Coşar [2013] uses the model to simulate the dynamic effects of trade liberalization that Brazil underwent between 1988 and 1991. Once workers in the import-competing sector lose their jobs as a result of trade liberalization, they might experience long unemployment spells or find lower-paid jobs in the exporting sector due to loss of sector-specific human capital. The author distinguishes between three policy scenarios. In the first scenario, workers receive no income support after trade liberalization. In the second scenario, workers who become unemployed receive unemployment benefits for a limited period of time.[2] In the third scenario, old workers who were employed in the previously protected import-competing sector and move to the exporting sector after trade liberalization receive a subsidy. Coşar [2013] finds that relative to the scenario without income support, unemployment insurance slows down the reallocation of workers from the import-competing to the exporting sector and therefore leads to an output loss. In contrast, targeted employment subsidies can not only compensate the losers of liberalization but can also increase aggregate output. Therefore, Coşar [2013] concludes that compensation policies should foster the mobility of workers adversely affected by liberalization. Similarly to Davidson and Matusz [2006], however, this paper assumes exogenous terms of trade and restricts its analysis to a unilateral liberalization scenario. Apart from we analyze a much broader spectrum of policy instruments.

Finally, without a formal model, Kletzer [2004] sheds light on the effectiveness of a wage insurance program in compen-

[2]In fact, Brazil introduced an extensive unemployment insurance system just before the trade liberalization.

sating the losers of trade liberalization, and compares the program to unemployment insurance benefits. Wage insurance is paid to workers who were employed in the import-competing sector, conditional on finding a new job. In contrast to unemployment benefits, wage insurance increases the returns to job search, since it is paid only to workers who find a new job. The incentives to search are greater for workers who can expect high re-employment losses.

3 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 is 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.[3] 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 assume endogenous firm entry and heterogeneous firms as in Melitz [2003] and Bernard et al. [2007]. Firms have to pay a sunk entry cost to become active in a specific sector to which they are bound for their whole life-time. After paying the sunk entry cost the firms draw their productivity from a random distribution. Firms have to pay fixed costs of exporting which implies that only the most productive firms export. In contrast to Melitz [2003], but in line with Ghironi and Melitz [2005], there are no fixed costs of production, so that every entering firm takes up production.

In each country we add a variety of policy instruments: a wage tax, a consumption tax, a profit tax, a subsidy on sector migration, a subsidy on training and a subsidy on firm entry. In each case the instruments can differ between the two sectors, the wage tax and the migration subsidy can also differ between skill classes. We assume that the government budget constraint is balanced at all times. Depending on the configuration of instruments we consider, the policy instrument could be an exogenous policy variable or an endogenous variable that balances out the government budget constraint. In the following section we describe all the decision problems in H; equivalent equations hold for F.

3.1 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:

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

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

where C^s_{it+k} 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 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

$$C^s_{it} = (1 - \chi^s_{it})\, w^s_{it} + \Pi_t + T^s_{it}, \tag{2}$$

where w^s_{it} is the wage income of the workers, χ^s_{it} is the wage tax, Π_t are the transfers of a mutual fund to be described further below, and T^s_{it} are transfers from the government including training and migration subsidies.

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.[4]

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, the policy-reactions to increased wage inequality and the implications for welfare, 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 good C_t is a Cobb-Douglas composite of the goods produced in the two sectors $C_t = C^{\alpha}_{1t} C^{1-\alpha}_{2t}$, where α is the share of good 1 in the consumption basket for both H and F. Then, the relative demand for good 1 is $C_{1t} = \alpha \frac{P_t}{P_{1t}} C_t$ and for good 2 is $C_{2t} = (1-\alpha)\frac{P_t}{P_{2t}} C_t$, 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 basket C_t.[5]

Goods 1 and 2 are consumption baskets defined over a continuum of varieties Ω_i such that $C_{it} = \left[\int_{\omega \epsilon \Omega_i} c_{it}(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{\theta-1}}$, where $\theta > 1$ is the elasticity of substitution between varieties. Varieties are internationally traded, subject to iceberg trade costs. The consumption based price index for each sector is $P_{it} = \left[\int_{\omega \epsilon \Omega_i} p_{it}(\omega)^{1-\theta} d\omega\right]^{\frac{1}{1-\theta}}$ and the household demand for each variety is $c_{it} = \left(\frac{p_{it}}{P_{it}}\right)^{-\theta} C_{it}$. 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 baskets, respectively. Then, we can rewrite the demand functions for varieties and sector baskets as $c_{it} = \left(\frac{\rho_{it}}{\psi_{it}}\right)^{-\theta} C_{it}$ and $C_{it} = \alpha \psi^{-1}_{it} C_t$, respectively.

3.2 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 Bernard et al. [2007]. In the second version,

[4] In Lechthaler and Mileva [2013] we also consider a version of the model in which workers are allowed to save but cannot switch across sectors. The differences between the two versions of the model are minor.

[5] Prices are gross prices, i.e., including the consumption tax.

we relax this assumption by allowing unskilled workers to train and 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.

3.2.1 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,[6] 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 to describe the decision of skilled workers. Analogous equations hold for unskilled workers.

We assume that the government can subsidize the migration of workers, so that, a worker will move from sector j to sector i if:

$$V_{it}^s - V_{jt}^s > \left(1 - \chi_{jit}^{mS}\right) \varepsilon_t^s. \tag{3}$$

where χ_{jit}^{mS} is the migration subsidy that skilled workers receive if they migrate from sector j to i. Vice versa, a worker in sector i will move to sector j if $V_{jt}^s - V_{it}^s > \left(1 - \chi_{ijt}^{mS}\right) \varepsilon_t^s$. Equation 3 defines a threshold, $\bar{\varepsilon}_t^s$, for which a worker is indifferent between switching and not switching the sector

$$\overline{\varepsilon_t^s} = \frac{V_{it}^s - V_{jt}^s}{1 - \chi_{jit}^{mS}} \tag{4}$$

and the probability of switching from sector j to sector i is $\eta_{jit}^s = F(\max(\overline{\varepsilon_t}^s, \varepsilon_{\min}^s))$ and likewise for the migration from sector i to sector j . We assume that $\varepsilon_{\min}^s \geq 0$ so that workers only migrate in one direction.

A skilled worker's value of being employed in sector i is defined as:

$$V_{it}^s = log\left(C_{it}^s\right) + \gamma(1-s)\left[(1-\eta_{ijt+1}^s)V_{it+1}^s + \int_{\varepsilon_{\min}^s}^{max(-\bar{\varepsilon}_{t+1}^s, \varepsilon_{\min}^s)} \left(V_{jt+1}^s - \varepsilon_{t+1}^s\right) dF\left(\varepsilon_{t+1}^s\right)\right]. \tag{5}$$

where s is the probability of retiring. The worker's value is a function of current consumption 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. Note that migration subsidies are money transfers. Therefore, they are included in the consumption of the worker but not directly subtracted from the migration cost.

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

[6] 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.

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

$$V_{1t}^s + \varepsilon_t^{Se} > V_{2t}^s. \tag{6}$$

Equation 6 defines a threshold value $\overline{\varepsilon^{Se}}$, for which a worker is indifferent between both sectors:

$$\overline{\varepsilon_t^{Se}} = V_{2t}^s - V_{1t}^s, \tag{7}$$

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

$$\frac{Se_{1t}}{Se_{1t} + Se_{2t}} = 1 - G(\overline{\varepsilon_t^{Se}}), \tag{8}$$

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:

$$S_{it} = (1-s)\left((1-\eta_{ijt}^s)S_{it-1} + \eta_{jit}^s S_{jt-1}\right) + Se_{it}. \tag{9}$$

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 number of new entrants:

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

3.2.2 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

[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.

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]

$$V_t^s = (1 - G(\overline{\varepsilon_t^{Se}}))V_{1t}^s + G(\overline{\varepsilon_t^{Se}})V_{2t}^s. \tag{10}$$

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 $[\varepsilon_{\min}^T, \infty)$. We assume that the government can subsidize the training costs of unskilled workers with a training subsidy χ_t^t. An entering worker decides to train if the value of being skilled is high enough to justify the training cost, i.e., if:

$$V_t^s - \left(1 - \chi_t^t\right) \varepsilon_t^T > V_t^l. \tag{11}$$

Equation 11 defines a threshold $\bar{\varepsilon}_t^T$ for which a worker is indifferent between training and not training:

$$\overline{\varepsilon_t^T} = \frac{V_t^s - V_t^l}{1 - \chi_t^t}, \tag{12}$$

so that the probability of training is $\eta_T^t = \Gamma\left[\max(\overline{\varepsilon_t^T}, \varepsilon_{\min}^T)\right]$. Thus a share η^T of all newly entering workers is skilled:

$$\frac{Se_t}{Se_t + Le_t} = \eta_t^T, \tag{13}$$

and the remainder is unskilled. Again, the number of exiting workers must equal the number of newly entering workers $Se_t + Le_t = sENDOW$. 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.

3.2.3 Measures for wage inequality

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

$$\begin{aligned} IndexS_t &= \left(\frac{(1-\chi_{1t}^s)w_{1t}^s}{(1-\chi_{2t}^s)w_{2t}^s} - 1\right) 100, \\ IndexL_t &= \left(\frac{(1-\chi_{1t}^l)w_{1t}^l}{(1-\chi_{2t}^l)w_{2t}^l} - 1\right) 100. \end{aligned}$$

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

[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.

these temporary increases in inequality.

To measure wage inequality across 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

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

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

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

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

$$\begin{aligned} Gini_t &= \frac{1}{2w_t}\frac{1}{(S_t+L_t)^2}(2S_{1t}S_{2t}\left|(1-\chi_{1t}^s)w_{1t}^s - (1-\chi_{2t}^s)w_{2t}^s\right| + 2L_{1t}L_{2t}\left|(1-\chi_{1t}^l)w_{1t}^l - (1-\chi_{2t}^l)w_{2t}^l\right| \\ &+ 2S_{1t}L_{1t}\left|(1-\chi_{1t}^s)w_{1t}^s - (1-\chi_{1t}^l)w_{1t}^l\right| + 2S_{2t}L_{2t}\left|(1-\chi_{2t}^s)w_{2t}^s - (1-\chi_{2t}^l)w_{2t}^l\right| \\ &+ 2S_{1t}L_{2t}\left|(1-\chi_{1t}^s)w_{1t}^s - (1-\chi_{2t}^l)w_{2t}^l\right| + 2S_{2t}L_{1t}\left|(1-\chi_{2t}^s)w_{2t}^s - (1-\chi_{1t}^l)w_{1t}^l\right|), \end{aligned}$$

where w_t is the average after-tax wage.

3.3 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 $Y_{it} = z_i S_{it}^{\beta_i} L_{it}^{(1-\beta_i)}$, 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 the firms in a specific sector which implies that all firms within the sector pay the same wage. Consequently, relative labor demand can be described by the following condition:

$$\frac{w_{it}^s}{w_{it}^l} = \frac{\beta_i}{(1-\beta_i)}\frac{L_{it}}{S_{it}}, \tag{14}$$

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 producing one additional unit of output. Note that this condition uses before-tax producer wages and 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 14 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 good, C_t, the marginal cost of production is $\frac{(w_{it}^s)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}}{z_i}$.

Prior to entry, firms are identical and face a sunk entry cost f_{et}, which is produced by skilled and unskilled labor, equal to $f_{et}\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}$ 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 Ghironi and Melitz [2005] 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 $\delta\epsilon(0,1)$ 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 $f_{xt}\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}$. The fixed cost of exporting implies that not all firms find it profitable to export.

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 and have to be adjusted for the consumption-based real exchange rate Q_t, defined in terms of units of home consumption per unit of foreign consumption adjusted for the nominal exchange rate e, i.e., $Q_t \equiv eP_t^*/P_t$. We also assume that consumption in each country is subject to sector-specific consumption taxes χ_{it}^c for country H and χ_{it}^{*c} for country F. Prices in real terms, relative to the price index in the destination market are then given by:

$$\rho_{d,it}(z) = \frac{p_{d,it}(z)}{P_t} = (1+\chi_{it}^c)\frac{\theta}{\theta-1}\frac{\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}}{z_{it}} \tag{15}$$

$$\rho_{x,it}(z) = \frac{p_{x,it}(z)}{P_t^*} = \frac{1}{Q_t}(1+\chi_{it}^{*c})\tau_t\frac{\theta}{\theta-1}\frac{\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}}{z_{it}}. \tag{16}$$

Profits, expressed in units of the aggregate consumption good of the firm's location are $d_{it}(z) = d_{d,it}(z) + d_{x,it}(z)$, where $d_{d,it}(z)$ and $d_{x,it}(z)$ are after-tax profits, subject to a sector-specific profit tax χ_{it}^p, so that

$$d_{d,it}(z) = (1-\chi_{it}^p)\frac{1}{\theta}\left(\frac{\rho_{d,it}(z)}{\psi_{it}}\right)^{1-\theta}\alpha_i C_t \tag{17}$$

$$d_{x,it}(z) = \begin{cases} (1-\chi_{it}^p)\left[\frac{Q_t}{\theta}\left(\frac{\rho_{x,it}(z)}{\psi_{it}^*}\right)^{1-\theta}\alpha_i^* C_t^* - f_{xt}\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}\right], & \text{if firm z exports} \\ 0 & \text{otherwise.} \end{cases} \tag{18}$$

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

[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.

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.

3.3.1 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 $\tilde{z}_{d,it} = \left[\int_{z_{min}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{(\theta-1)}}$ for all producing firms in sector i of country H and an average $\tilde{z}_{x,it} = \left[\int_{z_{x,it}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{(\theta-1)}}$ for all exporters in sector i of country H. 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 $P_{it}^{1-\theta} = \left[N_{d,it} \left(\tilde{p}_{d,it}\right)^{1-\theta} + N_{x,it}^{*} \left(\tilde{p}_{x,it}^{*}\right)^{1-\theta}\right]$. Written in real terms of aggregate consumption units this becomes $\psi_{it}^{1-\theta} = \left[N_{d,it} \left(\tilde{\rho}_{d,it}\right)^{1-\theta} + N_{x,it}^{*} \left(\tilde{\rho}_{x,it}^{*}\right)^{1-\theta}\right]$, 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.

3.3.2 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 $\{\tilde{d}_{is}\}_{s=t+1}^{\infty}$, so that $\tilde{v}_{it} = E_t \sum_{s=t+1}^{\infty} \left[\gamma^{s-t}(1-\delta)^{s-t} \left(\frac{C_s}{C_t}\right)^{-1} \tilde{d}_{is}\right]$. In recursive form this can be written as $\tilde{v}_{it} = \gamma(1-\delta) E_t \left[\left(\frac{R_{t+1}}{R_t}\right)^{-1} \left(\tilde{v}_{it+1} + \tilde{d}_{it+1}\right)\right]$. Firms discount future profits using the household's stochastic discount factor, adjusted for the probability of firm survival $1 - \delta$.

Entry occurs until the average firm value is equal to the entry cost. We assume that the government can subsidize firm entry with a sector specific entry subsidy χ_{it}^{e}, so that the free entry condition is

$$\tilde{v}_{it} = (1 - \chi_{it}^{e}) f_{et} \left(w_{it}^{s}\right)^{\beta_i} \left(w_{it}^{l}\right)^{1-\beta_i}. \tag{19}$$

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:

$$\Pi_t ENDOW = \tilde{d}_{1t} N_{d,1t} + \tilde{d}_{2t} N_{d,2t} - \tilde{v}_{1t} N_{h,1t} - \tilde{v}_{2t} N_{h,2t}. \tag{20}$$

Finally, the number of firms evolves according to the law of motion, $N_{d,it} = (1 - \delta)(N_{d,it-1} + N_{e,t-1})$.

3.3.3 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 $\nu = \left\{\frac{k}{[k-(\theta-1)]}\right\}^{\frac{1}{\theta-1}}$, then average productivities are $\tilde{z}_{d,it} = \nu z_{min}$ and $\tilde{z}_{x,it} = \nu z_{x,it}$. The share of exporting firms in sector i in H is $\frac{N_{x,it}}{N_{d,it}} = 1 - G(z_{x,it}) = 1 - \left(\frac{\nu z_{min}}{\tilde{z}_{x,it}}\right)^k$. 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 $\tilde{d}_{x,it}/\left(1 - \chi^p_{it}\right) = (\theta - 1)\left(\frac{\nu^{\theta-1}}{k}\right) f_{xt}\left(w^s_{it}\right)^{\beta_i}\left(w^l_{it}\right)^{1-\beta_i}$.

3.4 Government

We assume that the government budget is balanced at all times. The simulation experiments that we analyze in section 5 use different configurations of policy instruments which means that the government budget constraint varies depending on the configuration. In our benchmark simulation where all taxes and subsidies are exogenous and zero we do not need a government budget constraint. In the other scenarios we usually pick a combination of two policy instruments and treat one as an exogenous variable and the other as an endogenous variable that balances out the government budget. To avoid repetition we do not write the government budget constraint pertaining to each simulation here but only in section 5. Instead, here we define the different sources of revenue and expenditure of the government.

The government obtains revenue from consumption taxes, profit taxes and wage taxes. The revenue from the consumption tax in sector i consists of the tax proceeds on both domestically produced and imported varieties $\frac{\chi^c_{it}}{1+\chi^c_{it}} N_{d,it}\left(\frac{\tilde{\rho}_{d,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}\alpha_i C_t$ $+\frac{\chi^c_{it}}{1+\chi^c_{it}} N^*_{x,it}\left(\frac{\tilde{\rho}^*_{x,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}\alpha_i C_t$. The revenue from the profit tax in sector i is $\frac{\chi^p_{it}\tilde{d}_{it}}{1-\chi^p_{it}} N_{d,it}$. The revenue from the wage tax in sector i is $\chi^s_{it} w^s_i S_{it}$ for the skilled workers and $\chi^l_{it} w^l_{it} L_{it}$ for the unskilled workers.

The government can spend its revenue on firm entry subsidies, migration subsidies and training subsidies. The expenditures for the firm entry subsidy in sector i are $\chi^e_{it} f_{et}\left(w^s_{it}\right)^{\beta_i}\left(w^l_{it}\right)^{1-\beta_i} N_{e,it}$. The expenditures for the migration subsidy for skilled workers who want to switch from sector j to i is $\frac{\chi^{mS}_{jit}}{\left(C^s_{it}\right)^{-1}} \int_{\varepsilon^s_{\min}}^{max(-\bar{\varepsilon}^s_{t+1}, \varepsilon^s_{\min})} \varepsilon^s_{t+1} dF\left(\varepsilon^s_{t+1}\right) S_{jt}$. Because the migration cost is in terms of utility we need to transform the subsidy into terms of the final good by dividing through the marginal utility of consumption. Similar equations hold for the subsidy of unskilled migration. Finally, the expenditures for the training subsidy are $\frac{\chi^t_{it} \int_{\varepsilon^T_{\min}}^{\bar{\varepsilon}^T_t} \varepsilon^T_t d\Gamma\left(\varepsilon^T_t\right)}{\left(1-G\left(\overline{\varepsilon^{Se}_t}\right)\right)\left(C^s_{1t}\right)^{-1} + G\left(\overline{\varepsilon^{Se}_t}\right)\left(C^s_{2t}\right)^{-1}}\left(Se_{1t} + Se_{2t} + Le_{1t} + Le_{2t}\right)$.[11]

3.5 Aggregate accounting and International Trade

In each sector the total value of production is distributed among three parties, the private households, the domestic government and the foreign government

$$
\begin{aligned}
&N_{d,it}\left(\frac{\tilde{\rho}_{d,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}\alpha_i C_t + Q_t N_{x,it}\left(\frac{\tilde{\rho}_{x,it}}{\tilde{\psi}^*_{it}}\right)^{1-\theta}\alpha^*_i C^*_t + f_{et}\left(w^s_{it}\right)^{\beta_i}\left(w^l_{it}\right)^{1-\beta_i} N_{e,it} = \\
&(1-\chi^s_{it}) w^s_i S_{it} + (1-\chi^l_{it}) w^l_{it} L_{it} + \tilde{d}_{it} N_{d,it} + \\
&\frac{\chi^c_{it}}{1+\chi^c_{it}} N_{d,it}\left(\frac{\tilde{\rho}_{d,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}\alpha_i C_t + \chi^s_{it} w^s_i S_{it} + \chi^s_{it} w^l_{it} L_{it} + \frac{\chi^p_{it}\tilde{d}_{it}}{1-\chi^p_{it}} N_{d,it} + \chi^e_{it} f_{et}\left(w^s_{it}\right)^{\beta_i}\left(w^l_{it}\right)^{1-\beta_i} N_{e,it} + \\
&Q_t \frac{\chi^{*c}_{it}}{1+\chi^{*c}_{it}} N_{x,it}\left(\frac{\tilde{\rho}_{x,it}}{\tilde{\psi}^*_{it}}\right)^{1-\theta}\alpha^*_i C^*_t. \qquad (21)
\end{aligned}
$$

[11] We need to multiply with the total number of entrants because the integral gives the unconditional expectation of training costs.

Total production is in the first line (including the production of new firms), the income of the private sector (including wage and dividend income) is in the second line, the tax income of the domestic government is in the third line and the tax income of the foreign government is in the fourth line.

Financial autarky implies balanced trade so that the value of H exports after consumption taxes must equal the value of F exports after consumption taxes, such that

$$\frac{1}{1+\chi_{1t}^{*c}} Q_t N_{x,1t} \left(\frac{\tilde{\rho}_{x,1t}}{\tilde{\psi}_{1t}^*}\right)^{1-\theta} \alpha^* C_t^* + \frac{1}{1+\chi_{2t}^{*c}} Q_t N_{x,2t} \left(\frac{\tilde{\rho}_{x,2t}}{\tilde{\psi}_{2t}^*}\right)^{1-\theta} (1-\alpha^*) C_t^* =$$
$$\frac{1}{1+\chi_{1t}^{c}} N_{x,1t}^* \left(\frac{\tilde{\rho}_{x,1t}^*}{\tilde{\psi}_{1t}}\right)^{1-\theta} \alpha C_t + \frac{1}{1+\chi_{2t}^{c}} N_{x,2t}^* \left(\frac{\tilde{\rho}_{x,2t}^*}{\tilde{\psi}_{2t}}\right)^{1-\theta} (1-\alpha) C_t. \tag{22}$$

4 Parametrization

This section describes the parametrization of the model that we use for the numerical simulations. In most aspects we follow Ghironi and Melitz [2005] and Bernard et al. [2007]. A full list of the parameters and their values is provided in table 1. 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, $[1-\gamma(1-\delta)]/\left[\gamma(1-\delta)\right] f_e$. This leads to a steady state share of exporting firms of 21 percent. We set the size of the exogenous firm exit 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 Ghironi and Melitz [2005].

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 our 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 that scenario only the total endowment of 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 $scaleT^* =$

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

Parameter	Description	Value
α	share of skill-intensive good in household consumption	0.5
γ	household discount factor	0.99
θ	elasticity of substitution between varieties	3.8
δ	probability of firm exit	0.025
$z_{\min}$	minimum value of firm productivity	1
k	shape parameter for firm Pareto distribution	3.4
β_1	skilled labor intensity parameter	0.6
β_2	unskilled labor intensity parameter	0.4
S	endowment with skilled labor at Home	700
L	endowment with unskilled labor at Home	1300
S^*	endowment with skilled labor at Foreign	370
L^*	endowment with unskilled labor at Foreign	1630
s	retirement rate of workers	0.005
$scaleS$	parameter for sector migration cost distribution for skilled labor	0.1
$scaleT$	parameter for training cost distribution at Home	0.000447255
$scaleT^*$	parameter for training cost distribution at Foreign	0.000128056
sd	standard deviation of preferences distribution for sector entry	0.1
f_x	fixed cost of exporting at Home	$0.235[1-\beta(1-\delta]/[\beta(1-\delta)]f_e$
f_x^*	fixed cost of exporting at Foreign	$0.235[1-\beta(1-\delta)]/[\beta(1-\delta)]f_e^*$
f_e	fixed entry cost at Home	1
f_e^*	fixed entry cost at Foreign	1
τ	iceberg trade cost at Home	1.3
τ^*	iceberg trade cost at Foreign	1.3

Table 1: Parametrization table

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 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%.

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.

To allow for a clearer interpretation of our results we assume that the pre-liberalization steady state is not distorted by taxes or subsidies. Thus, $\chi_{it}^s = \chi_{it}^l = \chi_{it}^c = \chi_{it}^p = \chi_{it}^e = \chi_{it}^{mS} = \chi_{it}^{mL} = \chi_{it}^t = 0$ in the pre-liberalization steady state.

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

5 Results

5.1 Introductory thoughts

This section describes how economic policy can change the effects of trade liberalization. There are at least three potential goals that policy makers could follow: i) reduce medium- and long-run wage inequality by reducing the skill premium, the gap between skilled and unskilled wages; ii) reduce short-run wage inequality by reducing inter-sectoral wage inequality; iii) speed up the adjustment after trade liberalization. It should be noted that these goals can and will be in conflict with each other. In general, the policy makers will face a trade off between reducing short-run and long-run wage inequality. Additionally, wage differentials induce workers to migrate and to train. Thus, a policy that reduces wage differentials can slow down the adjustment process.

The most likely choice to tackle the first goal to reduce the skill premium is to use the wage tax system. Skilled workers earn more than unskilled workers and making the wage tax system more progressive would already redistribute wage income from skilled workers to unskilled workers. Another policy that has an immediate impact on the skill premium are training subsidies. They are meant to increase the number of skilled workers, making them more abundant and, thus, reducing the skill premium. However, since the skill premium depends on the share of skilled and unskilled workers in the labor force, any other policy might also affect the skill premium indirectly.

The second goal to reduce inter-sectoral wage inequality is not as easily tackled by using the wage tax system. Unskilled workers in both sectors earn the same wage in steady state. The inter-sectoral wage inequality that follows after trade liberalization might not be large enough and the wage tax system might not be fine-tuned enough to tackle this source of wage inequality. Taxes that can address the goal more easily are taxes that can be made sector-specific, like a consumption tax that can differ between goods or a profit tax that can differ between sectors.

Finally, the third goal to speed up the adjustment process can be tackled by subsidies meant to encourage reallocation of firms or workers such **as** entry subsidies for firms, or sector migration subsidies and training subsidies for workers.

In the following section we discuss each instrument in turn, focusing on its effects on wages, wage inequality, the speed of adjustment and welfare. To do so, we consider two different assumptions concerning the mobility of workers across sectors and skill classes. In the first case we assume that the number of skilled workers is exogenously given, a standard assumption in many trade models (see, e.g., Bernard et al. [2007]). In the second case we assume that the number of skilled workers is endogenous, allowing unskilled workers to invest in training to become skilled workers. In both cases we assume that skilled workers are more mobile across sectors than unskilled workers (for a discussion of the related empirical evidence see section 4). In our analysis we concentrate on the skill-abundant country.

5.2 Exogenous share of skilled workers

5.2.1 Benchmark: no policy change

Before analyzing the effects of the modeled policy instruments, we describe our benchmark case, which is trade liberalization, modeled as a decrease in the Iceberg trade costs from 30% to 20% without any change in the other policy instruments. We assume that the Iceberg trade costs are the same for both sectors and both countries and restrict our discussion to the variables of most interest. For a more detailed description and a discussion of a broader set of trade liberalization scenarios the reader is referred to Lechthaler and Mileva [2013].

Figure 2 shows the effects of trade liberalization without any change in the other policy instruments. Time, in terms of quarters, is on the horizontal axis, while the vertical axis shows the percent deviations of a specific variable from its value in the pre-liberalization steady state.[14]

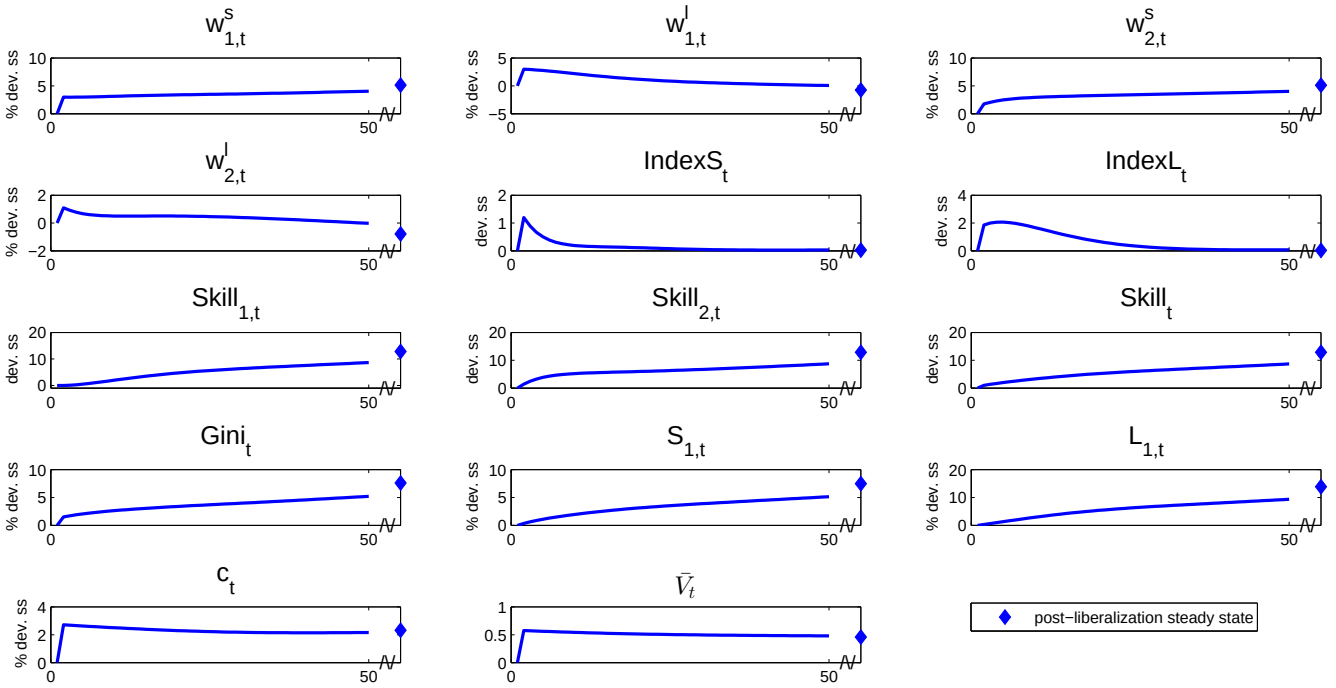

Figure 2: Benchmark scenario without training
Iceberg trade costs fall from 1.3 to 1.2

The decrease in trade costs induces both countries to specialize more in the sector where they have their comparative advantage. Thus, the skill-abundant country specializes more in the production of the skill-intensive good. This implies higher demand for both capital (in the form of firms) and workers in the exporting sector which produces the skill-intensive good. As a consequence, the number of workers and the number of firms in the exporting sector increase.

However, the reallocation of workers and firms costs time and resources. Firms have invested in a specific sector and cannot switch to another sector. The reallocation of firms can only take place via the death of existing firms. The exiting firms get replaced by newly created firms, which tend to prefer the expanding sector over the shrinking sector. Similarly, workers are potentially restricted by their investments in sector-specific human capital. In principle, they could migrate to the other sector but this necessitates re-training costs, which prevent many workers from migrating to the other sector. At the same time, workers constantly retire and get replaced by newly entering workers. Newly entering workers are more flexible in their sectoral choice than incumbent workers and tend to prefer the expanding sector.

This migration behavior has important implications for wages and wage inequality. With the decrease in trade costs, the demand for workers in the exporting sector immediately increases. But quantities are slow to adjust and thus the

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

shift in demand must be reflected in wages. The wages of workers in the exporting sector increase relative to the wages of workers in the import-competing sector which leads to a sharp increase in inter-sectoral wage inequality in the short run. As more and more workers migrate to the exporting sector, inter-sectoral wage inequality decreases until it vanishes in the new steady state.

The dynamic adjustment of the skill premium is very different. In the short run it changes very little because the increased demand in the exporting sector benefits both skilled and unskilled workers. Perhaps surprisingly, the skill premium in the import-competing sector increases faster than in the exporting sector. This is explained by the faster reallocation of skilled workers, which reduces the productivity of unskilled workers in the import-competing sector (remember that skilled and unskilled workers are complements in the production function). The diverse development of our wage inequality measures over time, underlines the importance of having a dynamic model.

Note that there can be losers from trade liberalization. Although in the short run all wages increase, in the long run the lower demand for the import-competing sector good leads to lower demand for unskilled workers. The efficiency gains from trade liberalization which tend to increase the real wages of all workers are not strong enough to overcome the lower demand for unskilled workers, so that the wage of unskilled workers is lower in the steady state after trade liberalization.[15]

Why is this effect only present in the long run? Because it depends on the reallocation of workers. In the short run real wages increase because of the increased variety of goods (more goods are imported) and because of lower prices (importing goods becomes cheaper). In the long run, the lower demand for unskilled workers leads to an allocation of workers which is detrimental to unskilled workers (the share of skilled to unskilled workers decreases in both sectors) and thus implies lower wages for them.

Not surprisingly, wage inequality also increases a lot. The average skill premium ($Skill$) increases by approximately 13% and the Gini coefficient, our measure of overall wage inequality increases by approximately 8%.

From a welfare perspective two points have to be noted. First, the slow adjustment to trade liberalization is in fact efficient. Switching sectors and retraining workers is very costly. Therefore, from an efficiency-point of view it makes perfectly good sense that this process is slow. Steady state taxes are assumed to be zero and there are no externalities in our model. Thus the outcome of the decentralized economy is efficient.[16] Second, wage inequality leads to consumption inequality and thus inequality in utility. Due to the curvature of the utility function this implies that average present discounted value of utility ($\bar{V}_t$) is lower than under income pooling (in which case everybody consumes the same).

Thus trade liberalization does not necessarily lead to a Pareto-improvement and wage inequality increases both in the short run and in the long run. It is, therefore, understandable that there is resistance to trade liberalization in many developed countries as the public wants to preserve equality and unskilled workers want to prevent income losses. This underlines the importance of having a model with heterogeneous workers and comparative advantage which allows to exactly identify the causes for the adverse effects of trade liberalization. We can use our model to pose the question whether economic policy can be used to reduce the adverse effects of trade liberalization.

[15] Depending on the exact specification of the model and the trade liberalization scenario, unskilled workers might suffer lower wages throughout the transition. In Lechthaler and Mileva [2013] we discuss a broader range of trade liberalization scenarios and show that the effects of trade liberalization can be even more adverse when it is restricted to specific sectors or done unilaterally.

[16] This could easily change in the presence of labor market frictions. E.g., in a search and matching model where the Hosios condition is not fulfilled or were unemployed workers receive government-sponsored unemployment benefits, the decentralized economy is no longer efficient.

5.2.2 Wage tax

The first changes in a policy instrument that we consider are changes in the wage tax. It is the instrument that directly affects wages and wage inequality since workers care most about their after-tax wage. We will consider two different scenarios, which differ with respect to the magnitude of the tax change.

Scenario 1. In our first scenario we assume that policy makers have a very ambitious goal: to avoid the long run increase in wage inequality after trade liberalization. This goal can be achieved by raising the tax on skilled workers and using the proceeds of this tax to subsidize the wages of unskilled workers. In our first exercise we assume that the tax is immediately and permanently raised to its new level. This is certainly an extreme exercise but nevertheless useful to explain the workings of this instrument.

Figure 3 illustrates the effects of an increase in the tax on the wages of skilled workers, χ^s, by 2.58%. The tax on the wages of unskilled workers, χ^l, is set endogenously to keep the government's budget balanced at all times. The implied government budget constraint is $\chi_t^s \left(w_{1t}^s S_{1t} + w_{2t}^s S_{2t}\right) + \chi_t^l \left(w_{1t}^l L_{1t} + w_{2t}^l L_{2t}\right) = 0$. To improve the visibility of short-run movements, we do not show the whole process but only the first 50 periods. The value of a variable in the post-liberalization steady state is indicated by a dot on the right margin of each panel.

In the long run the policy change implies that the skill premium returns to its pre-liberalization level. In the short run, however, the skill premium becomes lower than at the pre-liberalization steady state. This is the case because the tax increase is implemented immediately while the increase in the skill premium is very slow to build up.

When looking at the dynamic path of sectoral wages, we see who suffers the most from this redistribution policy. The (after-tax) wage of skilled workers in the import-competing sector falls below the pre-liberalization steady state in the initial periods after trade liberalization. As an alternative to the immediate jump to the new tax level, Figure 14 in the Appendix considers a gradual increase in the tax rate for skilled workers. The figure shows that a gradual increase in the wage tax on skilled workers can avoid the drop in the wage of skilled workers in the import-competing sector and considerably reduces the decrease in the skill premium**.**

The results illustrate that a policy that is meant to help unskilled workers to participate in the gains from trade liberalization can have negative 'side-effects'. These negative side effects are only revealed when looking at the disaggregated wage data. Since the wage of skilled workers in the exporting sector still increases, this implies that the average wage of skilled workers also increases.

There is another notable result revealed in figure 3. While the policy change has huge distributional consequences, it has no impact on the efficiency of the economy. The policy does not affect the movement of workers across sectors and thereby does not affect relative inputs in production. Output and aggregate consumption are the same, with and without the tax change, only the distribution of wages is affected. The reason for this result is simple. In this scenario the number of skilled workers is given exogenously and so cannot be distorted. The decision of whether to migrate between the two sectors depends on the inter-sectoral wage differential. Since the taxes affect both sectors in the same way, the migration decision is not affected. The irrelevance of the wage tax for the efficiency of the economy hinges crucially on the exogenous supply of skilled workers. In our scenarios that allow for endogenous skill formation the wage tax is indeed distortionary.

Measuring welfare as the average present discounted value of utility this policy is clearly beneficial. However, this result should be taken with care since in this setup there is no trade off for income redistribution. Taxation does not distort and thus a more equal distribution of income is beneficial by construction. This will change in the version of the model

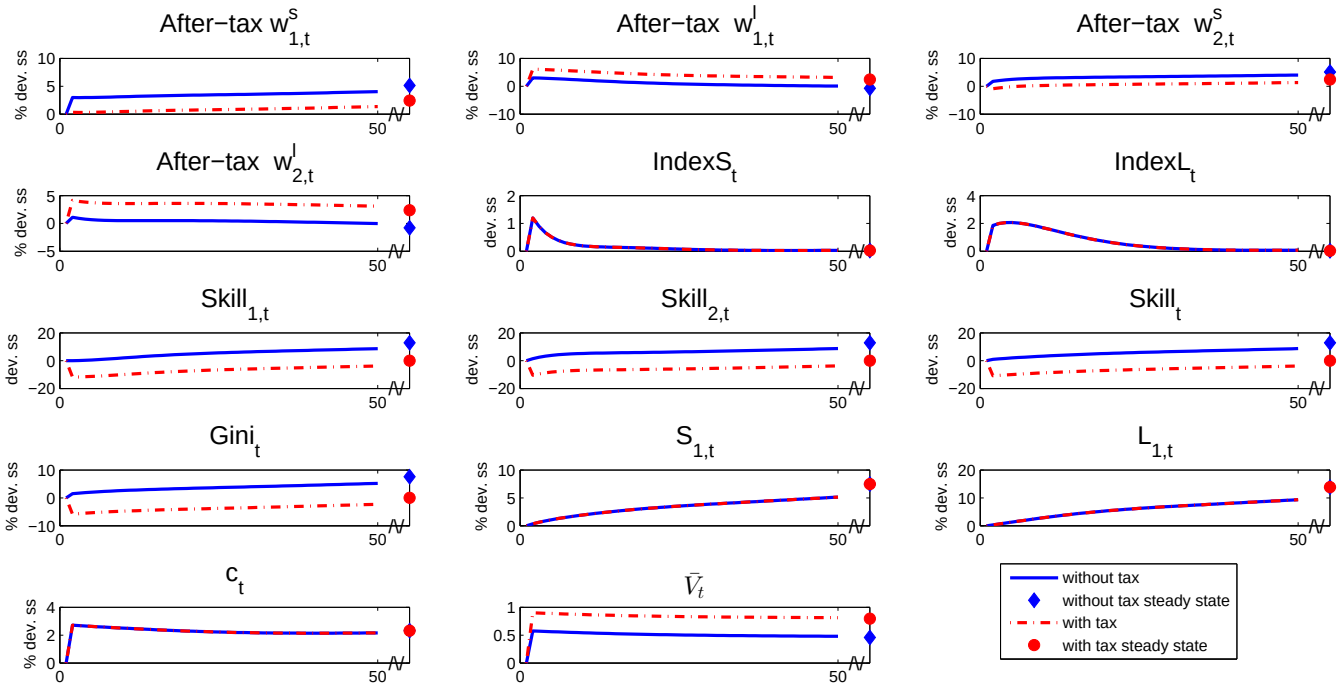

Figure 3: Permanent wage tax on skilled labor financing wage subsidy on unskilled labor
Tax on skilled rises by 2.58 percentage points.

in which skill formation is endogenous. Then, economic policy faces a real trade off between efficiency and redistribution because skill formation can be distorted. We will show that in such a setup a tax on skilled workers can reduce long run welfare.

Scenario 2. Next we consider a more modest policy that aims to avoid the long run decrease in the unskilled wage observed in the no-policy scenario. This goal can be achieved by increasing the wage tax on skilled workers by 0.63%. For the moment we assume that the tax immediately jumps to the new level. Again, we set the wage tax on unskilled workers endogenously to keep the government budget balanced at all times, implying that the unskilled workers are receiving a wage subsidy. The results are illustrated in figure 4.

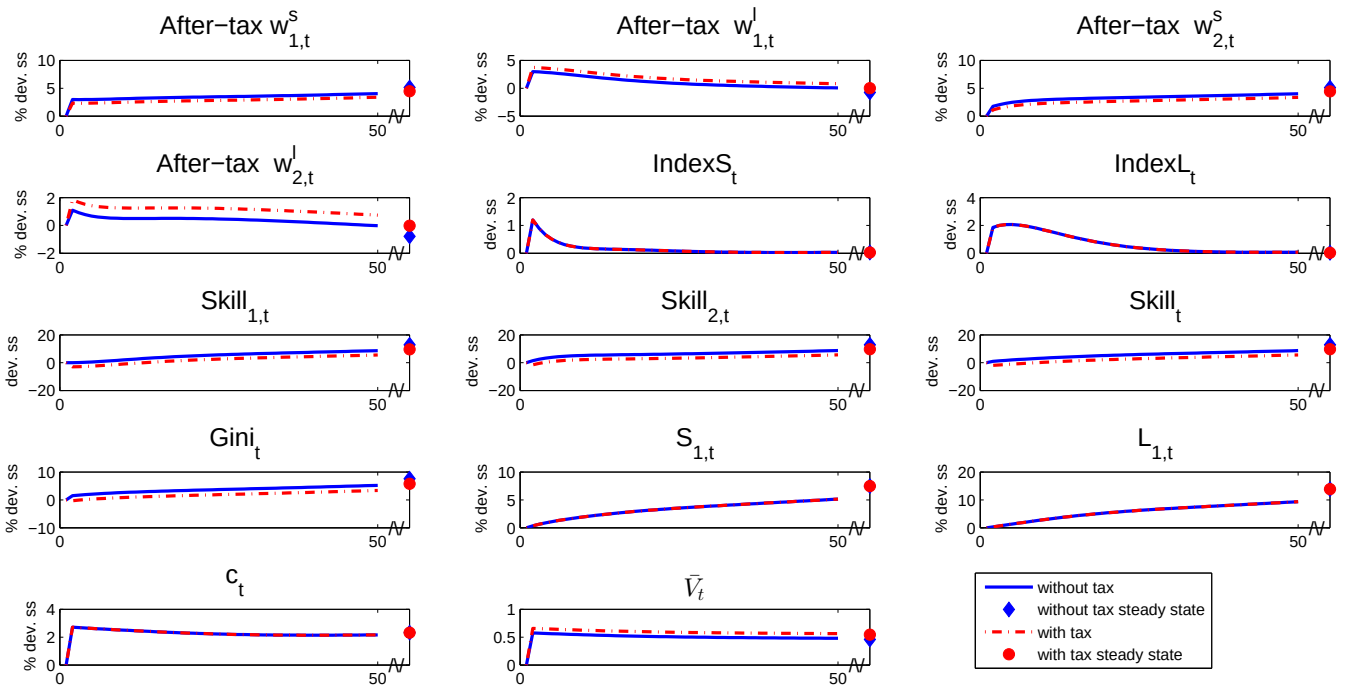

Figure 4: Permanent wage tax on skilled labor financing wage subsidy on unskilled labor
Tax on skilled rises by 0.63 percentage points

Naturally, this experiment is much more beneficial for skilled workers. The tax on skilled wages is much smaller, small enough to reduce the long-run skill premium by only about 3%. But even in this scenario the short-run effects are more in favor of the unskilled workers, so that the skill premium initially decreases.

Although unskilled workers do not earn higher wages in the new steady state, overall they unambiguously gain from trade liberalization. While in the no-policy scenario short run gains have to be weighed against long-run losses, in this scenario unskilled workers never earn less than in the pre-liberalization steady state and in the short run they earn more. Thus, under this policy trade liberalization constitutes a Pareto improvement.

In the Appendix we present a scenario in which the tax does not jump immediately to the new steady state level but instead only grows gradually. Figure 15 illustrates that this can avoid the decrease in the aggregate skill premium.

5.2.3 Consumption tax

Although the wage tax policy works well to reduce the after-tax skill premium, it can hardly be used to reduce inter-sectoral wage inequality. A more plausible route to compensate the import-competing sector for the enhanced competition and to help workers in that sector, is to use consumption taxes that can be easily changed for a specific sector. We analyze the effects of consumption taxes in this section.

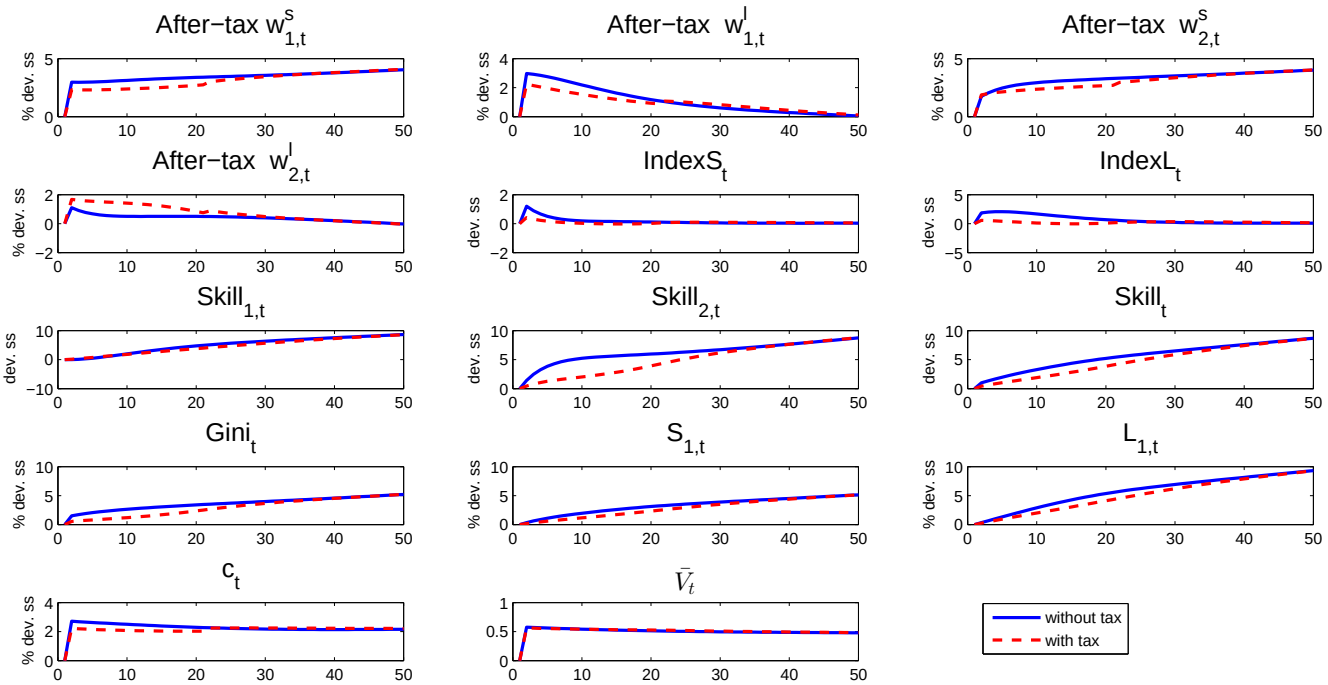

Figure 5:
Temporary consumption tax on in sector 1 financing consumption subsidy in sector 2
Tax in sector 1 rises by 3 percentage points for 20 periods

Figure 5 shows the effects of a temporary increase in the consumption tax charged on the good produced by the exporting sector by 3%. The tax charged on the good produced by the import-competing sector is used as an endogenous variable to keep the government budget balanced at any time, which implies that consumption in the import-competing sector is subsidized. The implied government budget constraint is then $\frac{\chi^c_{1t}}{1+\chi^c_{1t}}\left[N_{d,1t}\left(\frac{\tilde{\rho}_{d,1t}}{\tilde{\psi}_{1t}}\right)^{1-\theta}+N^*_{x,1t}\left(\frac{\tilde{\rho}^*_{x,1t}}{\tilde{\psi}_{1t}}\right)^{1-\theta}\right]\alpha C_t+\frac{\chi^c_{2t}}{1+\chi^c_{2t}}\left[N_{d,2t}\left(\frac{\tilde{\rho}_{d,it}}{\tilde{\psi}_{it}}\right)^{1-\theta}+N^*_{x,2t}\left(\frac{\tilde{\rho}^*_{x,2t}}{\tilde{\psi}_{2t}}\right)^{1-\theta}\right](1-\alpha)C_t=0$. We have chosen the level of the tax rate so as to dampen the jump in inter-sectoral wage inequality and to smooth out the adjustment of aggregate wage inequality. The change in the tax policy lasts for 20 periods, which corresponds to 5 years. We have chosen this number of periods because it corresponds to the duration of a typical legislative term.

Figure 5 illustrates that economic policy can achieve this goal. Taxing the good of the exporting sector lowers the demand for the exporting good. This reduces the producer price relative to the no-policy scenario although the consumer price is increased. Since producer prices are determined as a markup over wages, wages in the exporting sector are reduced as well. It is the opposite for the import-competing sector where the consumption tax policy raises producer prices and tends to raise wages relative to the exporting sector. Thus in the initial periods inter-sectoral wage inequality is relatively flat and then it gradually increases. In contrast, inter-sectoral wage inequality jumps up on impact in the scenario without tax adjustment.

However, while smoothing out the adjustment of wage inequality, this policy severely distorts price and wage signals, leading to a slowdown in the reallocation process of skilled and unskilled workers. This has the additional effect of slowing

down the increase in the skill premium in the import-competing sector but also implies that the economy is less efficient, as illustrated by lower aggregate consumption. Our welfare measure shows that the distortion created by the tax policy and the redistribution effect more or less offset each other so that welfare does not change much.

5.2.4 Profit tax

An alternative way to help the import-competing sector would be to use profit taxes instead of consumption taxes. By temporarily increasing the tax on profits in the exporting sector and using the proceeds of this tax to subsidize the profits in the import-competing sector, the effects of trade liberalization on inter-sectoral wage inequality can be smoothed out. Figure 6 shows a scenario in which the profit tax in the exporting sector is increased by 1.5%. The profit tax in the import-competing sector is used as an endogenous variable to keep the government budget balanced at all times such that $\frac{\chi^p_{1t}\tilde{d}_{1t}}{1-\chi^p_{1t}}N_{d,1t} + \frac{\chi^p_{2t}\tilde{d}_{2t}}{1-\chi^p_{2t}}N_{d,2t} = 0$. Again the level of the tax rate is chosen so as to dampen and to smooth the effect of trade liberalization on inter-sectoral wage inequality.

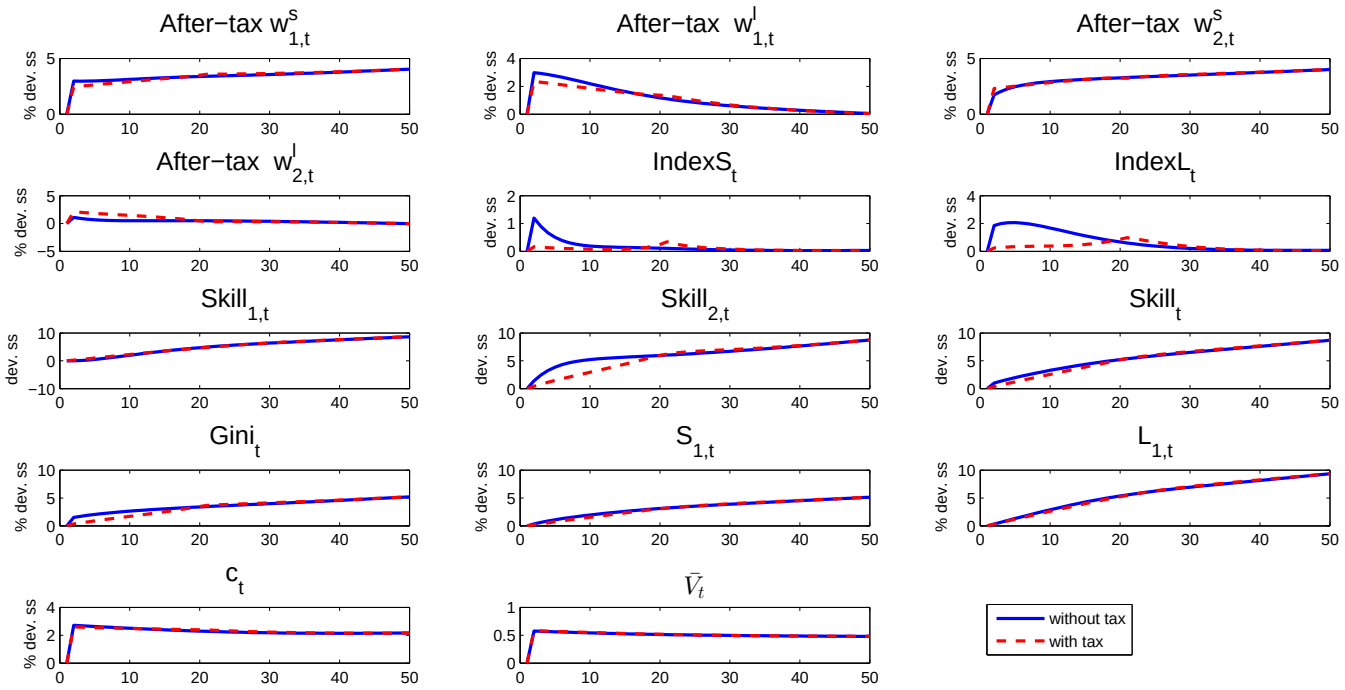

Figure 6:
Temporary profit tax on in sector 1 financing profit subsidy in sector 2
Tax in sector 1 rises by 1.5 percentage points for 20 periods

The development of most variables is similar to their development in the previous consumption tax scenario. Wages in the exporting sector are lower than in the benchmark while wages in the import-competing sector are higher. Inter-sectoral wage inequality increases more gradually and only very little. Workers are slower to migrate between sectors which implies that the skill premium in the import-competing sector is flatter in the first periods after trade liberalization.

Note, however, that the adverse effects on worker reallocation are much milder than in the consumption tax scenario, with the result that the effects on aggregate consumption and on welfare are very small. Thus, this policy succeeds in smoothing the adjustment to trade liberalization without imposing large inefficiencies.

5.2.5 Firm entry subsidy

All the scenarios considered so far have revealed a very slow adjustment in the number of firms. If economic policy would like to speed up this process, a plausible instrument to achieve this would be a subsidy to firms entering the exporting sector. We assume that this subsidy is financed by a wage tax on all workers so that the government budget constraint becomes $\chi^e_{1t} f_{et} \left(w^s_{1t}\right)^{\beta_1} \left(w^l_{1t}\right)^{1-\beta_1} N_{e,1t} = \chi_t \left(w^s_{1t} S_{1t} + w^s_{2t} S_{2t} + w^l_{1t} L_{1t} + w^l_{2t} L_{2t}\right)$.

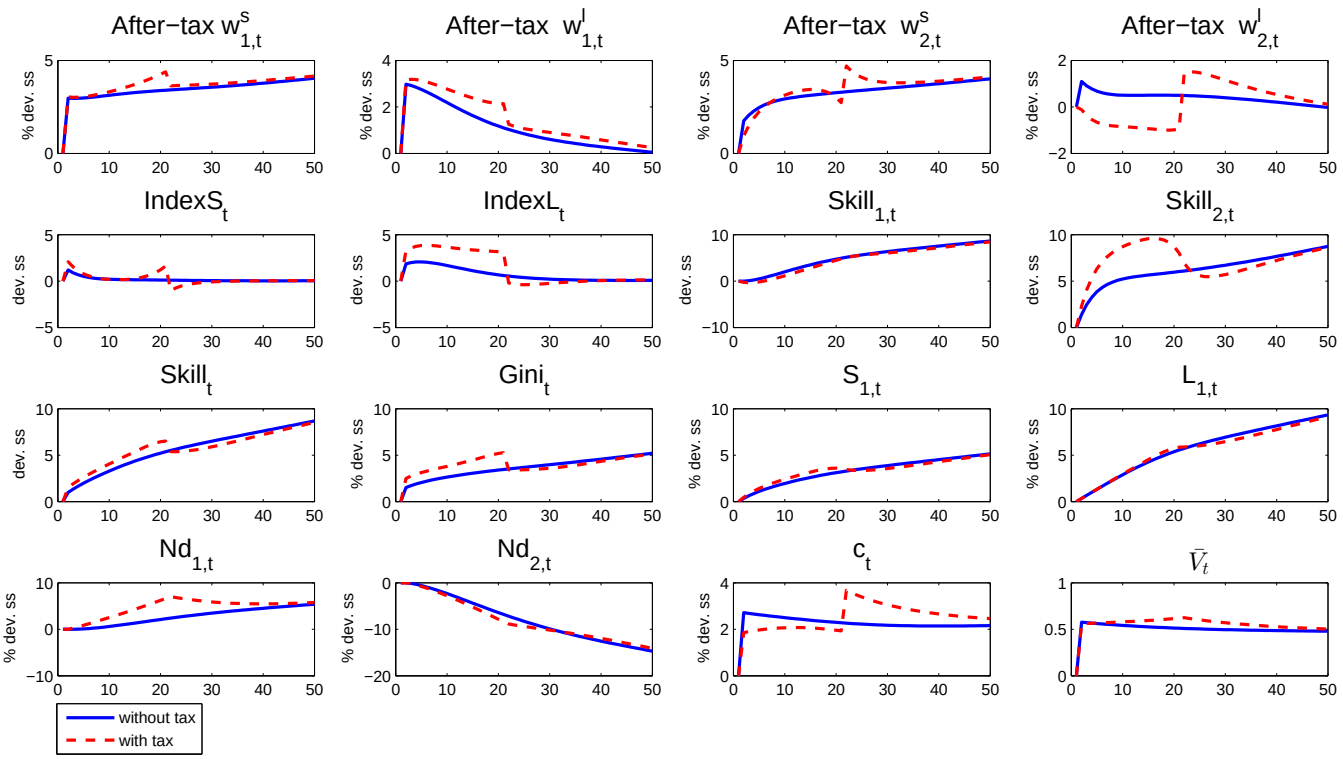

Figure 7:
Temporary firm entry subsidy in sector 1 financed by firm wage tax on all workers
Subsidy in sector 1 rises by 3 percentage points for 20 periods

Figure 7 shows the effects of a temporary (20 periods) entry subsidy of 3%. As designed the entry subsidy speeds up the creation of new firms in the exporting sector. This is mainly accomplished by drawing resources from the production of consumption goods to the production of firms. Investment in new firms for the importing-competing sector, which is already low, decreases only little. The shift in production leads to a reduction in aggregate consumption for as long as the subsidy is granted. As soon as the subsidy is stopped, the investment in new firms drops so substantially that the number of firms in the exporting sector actually drops for some time and quickly converges to the path without policy intervention. Reduced investment in new firms implies that more resources can go into the production of the consumption good and so aggregate consumption increases after the subsidy is stopped.

The policy has substantial effects on wages. The higher investment in new firms in the exporting sector raises the demand for workers in the exporting sector so that the inter-sectoral wage differential increases. This implies that more skilled workers of the importing-competing sector find it worthwhile to migrate to the exporting sector. Thus, the firm entry subsidy not only speeds up the reallocation of firms but also the reallocation of workers.

The faster migration of skilled workers to the exporting sector implies that the ratio of skilled to unskilled workers in the import-competing sector drops more quickly, so that the relative productivity of unskilled workers decreases. The wage of unskilled workers decreases for as long as the subsidy is granted and at the end of the 20 periods lies 1% below the old steady state level. In sum, both inter-sectoral wage inequality and the skill premium are increased by the entry subsidy, so that overall wage inequality increases substantially. At the end of the 20 periods the Gini-coefficient is approximately 2 percentage points higher than in the scenario without policy intervention. Thus this policy succeeds at speeding up the adjustment process but at the cost of considerably increased wage inequality.

5.2.6 Migration subsidy

In the short run much of wage inequality is driven by the inter-sectoral wage inequality among unskilled workers that is caused by the low mobility of unskilled workers across sectors. Therefore, it seems sensible to subsidize the sectoral migration of these workers. To analyze this kind of scenario we assume that the migration cost of unskilled workers follows the same distribution as the migration cost of skilled workers but on top of that unskilled workers have to pay a fixed amount that is large enough to prevent them from migrating in the absence of migration subsidies. We then assume that the government subsidizes the migration cost of unskilled workers by 75% and for 20 periods. This assures that in the first period after trade liberalization one percent of the unskilled workers in the import-competing sector decide to migrate to the exporting sector.

This scenario is illustrated in figure 8. To avoid mixing up the results of the subsidy with the effects of financing the subsidy we assume that it is financed by a proportional tax on all wages, χ,[17] so that $\frac{\chi_{21,t}^{mL}}{\left(C_{it}^{l}\right)^{-1}}(\int_{\varepsilon_{\min}^{l}}^{max(\bar{\varepsilon}_{t}^{l},\varepsilon_{\min}^{l})}\varepsilon_{t}^{l}dF\left(\varepsilon_{t}^{l}\right)+cost\,\eta_{21,t})S_{2t}=\chi_{t}\left(w_{1t}^{s}S_{1t}+w_{2t}^{s}S_{2t}+w_{1t}^{l}L_{1t}+w_{2t}^{l}L_{2t}\right)$ where $\bar{\varepsilon}_{t}^{l}=(v_{1,t}^{l}-v_{2,t}^{l})/(1-\chi_{21,t}^{mL})-cost$, $\varepsilon_{\min}^{l}=0$ and $cost=0.4$.

As expected this policy speeds up the reallocation of unskilled workers and decreases inter-sectoral wage inequality among unskilled workers considerably. Unskilled workers in the import-competing sector become more scarce while unskilled workers in the exporting sector become more abundant. This lowers unskilled wages in the exporting sector and raises unskilled wages in the import-competing sector and inter-sectoral wage inequality goes down.

The change in the reallocation of unskilled workers also affects skilled workers. Skilled workers in the import-competing sector lose productivity because of the decrease in the number of unskilled workers and because of the complementarity of skilled and unskilled workers in the production function. The opposite is true for the skilled workers in the exporting sector, so that the skill premium in the exporting sector goes up while it goes down in the import-competing sector. Inter-sectoral wage inequality among skilled workers therefore also goes up. This further speeds up the reallocation of skilled workers. Due to the counteracting effects overall wage inequality does not move by much.

[17] Remember that aggregate labor supply in this model is exogenous, so a tax on all wages is not distortionary.

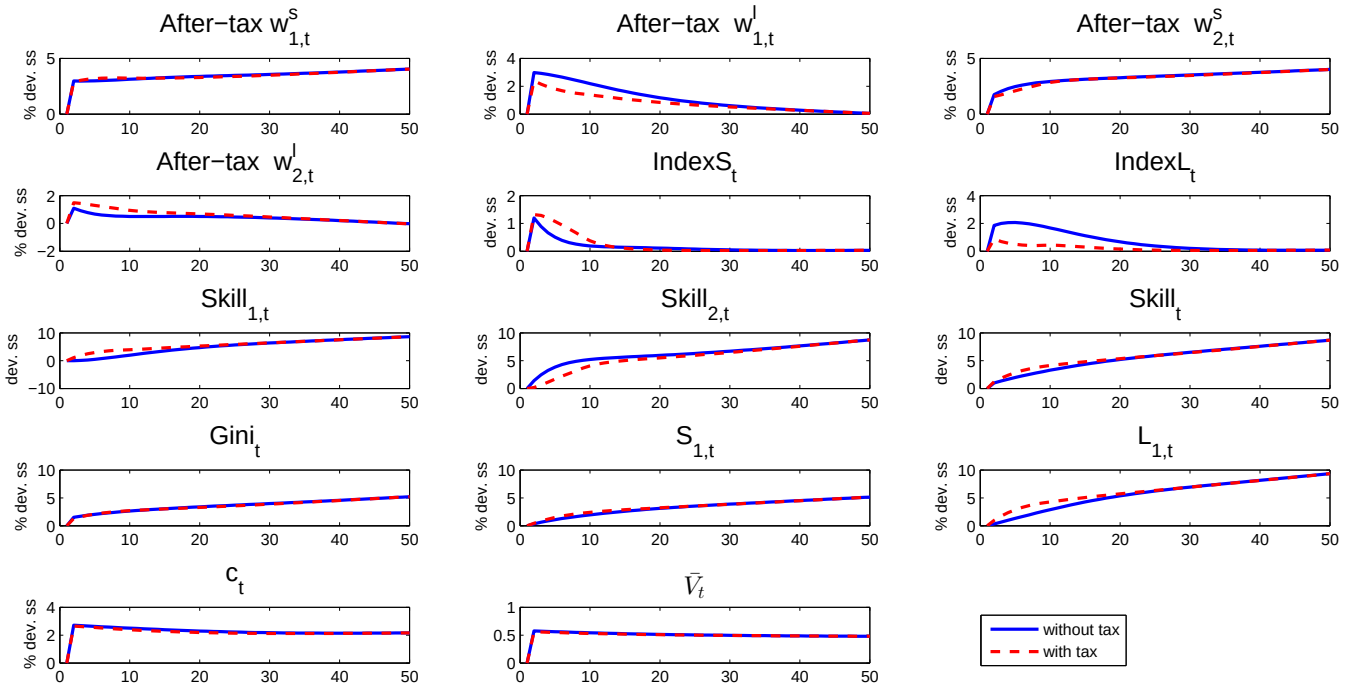

Figure 8:
Temporary migration subsidy to unskilled labor financed by wage tax
Subsidy rises by 75 percentage points for 20 periods

Although the policy speeds up the reallocation of workers and helps the unskilled workers in the import-competing sector, which is the group of workers which benefits the least from trade liberalization, the aggregate effects on welfare are rather minor. It is important to note that the migration decision without policy intervention is actually efficient. So by inducing unskilled workers to migrate more quickly, efficiency in the economy is actually reduced. However, this effect appears to be only minor.

5.3 Endogenous share of skilled workers

5.3.1 Benchmark: no policy change

In this section we discuss policy in the model with endogenous skill formation. We again start with a description of how the most important variables evolve after a permanent and immediate reduction in the Iceberg trade costs when tax policy does not change. Figure 9 illustrates this case.

The first result that strikes the eye is the much smaller increase in the long-run skill premium and in long-run wage inequality. This difference is explained by the opportunity of workers to train. In the previous section the supply of skilled workers was fixed exogenously and could not react to the increased demand for skilled workers. Therefore, all the increase in the demand for skilled workers had to go into higher relative wages. In this scenario, the supply of skilled workers can also adjust, with the implication that less of the adjustment needs to go into higher wages. The skill premium still increases but by a much smaller amount.

This development has also important consequences for the development of unskilled wages. The decrease in the number of unskilled workers counteracts the downwards pressure on unskilled wages so that they increase by approximately 1% in the long run, while they dropped in the no-training scenario.

Another notable result is the higher path of consumption in this scenario. The endogeneity of skilled workers implies that the economy can react more efficiently to the decrease in trade costs. By increasing the number of skilled workers the opportunities of trade can be better exploited, countries can specialize more in their comparative advantage and output and consumption go up.

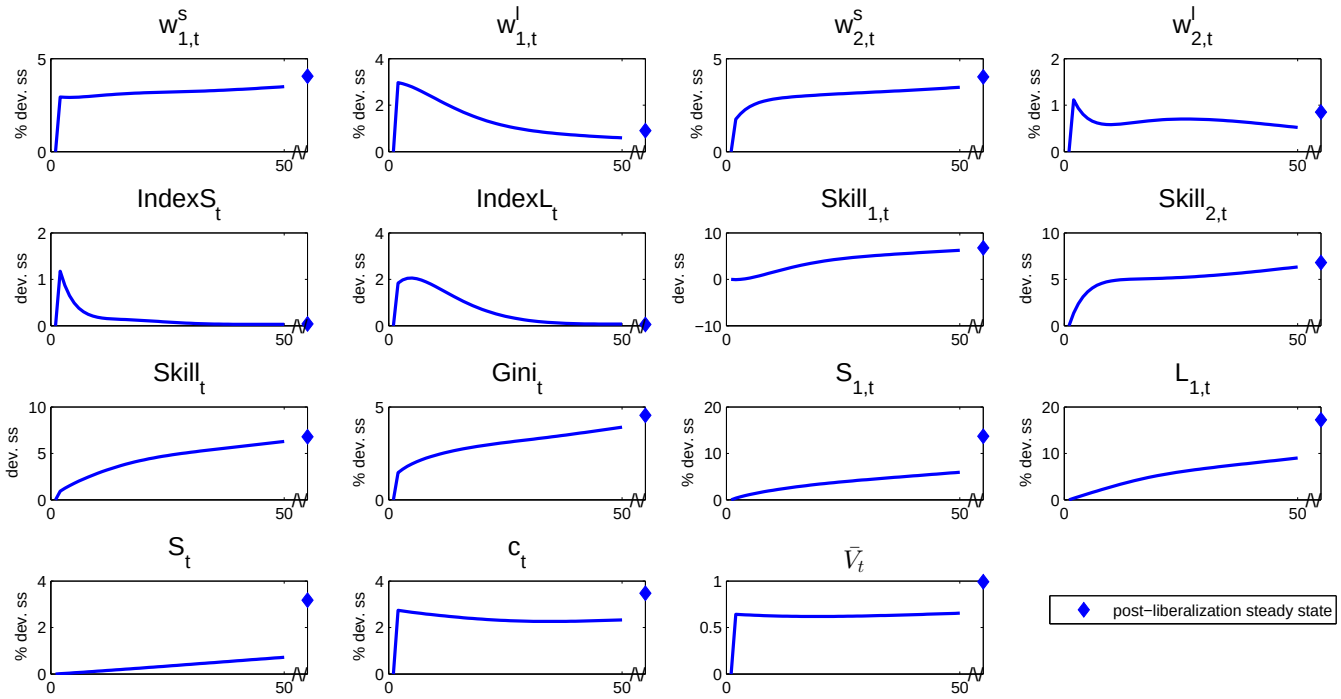

Figure 9:
Benchmark scenario with training
Iceberg trade costs fall from 1.3 to 1.2

Just like the reallocation of workers across sectors, the reallocation of workers across skill classes takes time. This implies that the differences between the training and the no-training scenarios are most pronounced in the long run, while they are very small in the short run.

In the following we will not repeat all the policy experiments we did for the no-training scenario but rather concentrate and the most important redistribution instrument, wage taxes, and add a policy instrument that only makes sense in a setting with endogenous training, training subsidies.

5.3.2 Wage tax

Remember that in the no-training scenario, a tax on wage income that does not differentiate between the two sectors does not distort the economy. The migration/entry decisions are not affected and therefore aggregate output is the same with

and without tax. As demonstrated in figure 10, this changes in the training scenario because an increase in the skilled wage reduces the incentives to train. The policy we consider in this graph is equivalent to scenario 2 in section 5.2.2, a permanent increase in the tax on skilled workers' wages that is used to subsidize the unskilled workers' wages. The size of the tax increase is the same as in scenario 2 of that section, 0.63%.

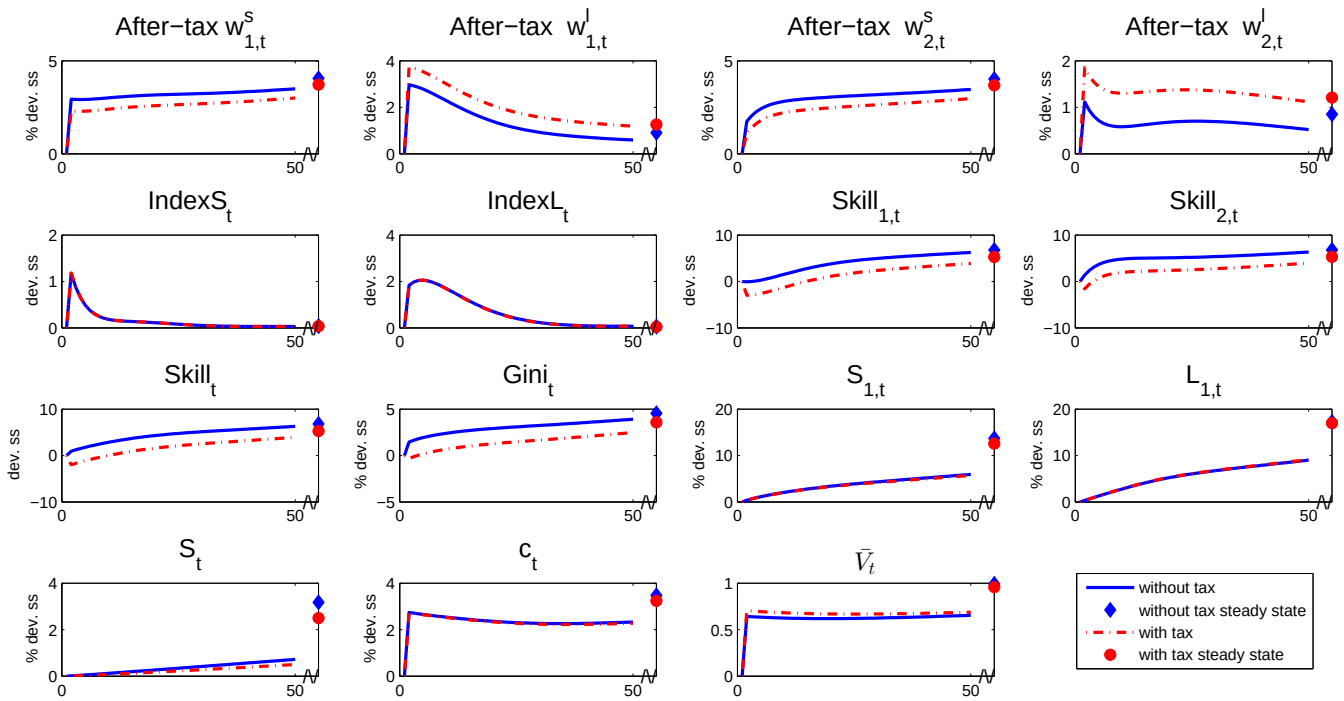

Figure 10:
Permanent wage tax on skilled labor financing wage subsidy on unskilled labor
Tax on skilled rises by 0.63 percentage points.

In short run the effect of the policy change is very similar to the no-training scenario. The skill premium is considerably reduced and with it overall wage inequality. The distortion of the policy is negligible, while income is more evenly distributed and so welfare goes up.

However, the policy reduces the incentives to invest in training and slows down the increase in the number of skilled workers. This effect compounds over time so that in the new steady state the number of skilled workers is considerably reduced. This implies an inefficient allocation of workers and lower consumption in the long run. This effect is so strong that it dominates the more equal distribution of income and welfare goes down.

Figure 11 considers a temporary change in the wage tax for twenty periods. Knowing that a permanent tax change is harmful, politicians might want to opt for a temporary change in the wage tax to smooth the adjustment after trade liberalization. This kind of policy is short-lived and does not change considerably the forward looking training and migration decisions of workers. The tax policy reduces overall wage inequality in the short run by considerably reducing the skill premium. It also has a mild positive impact on welfare.

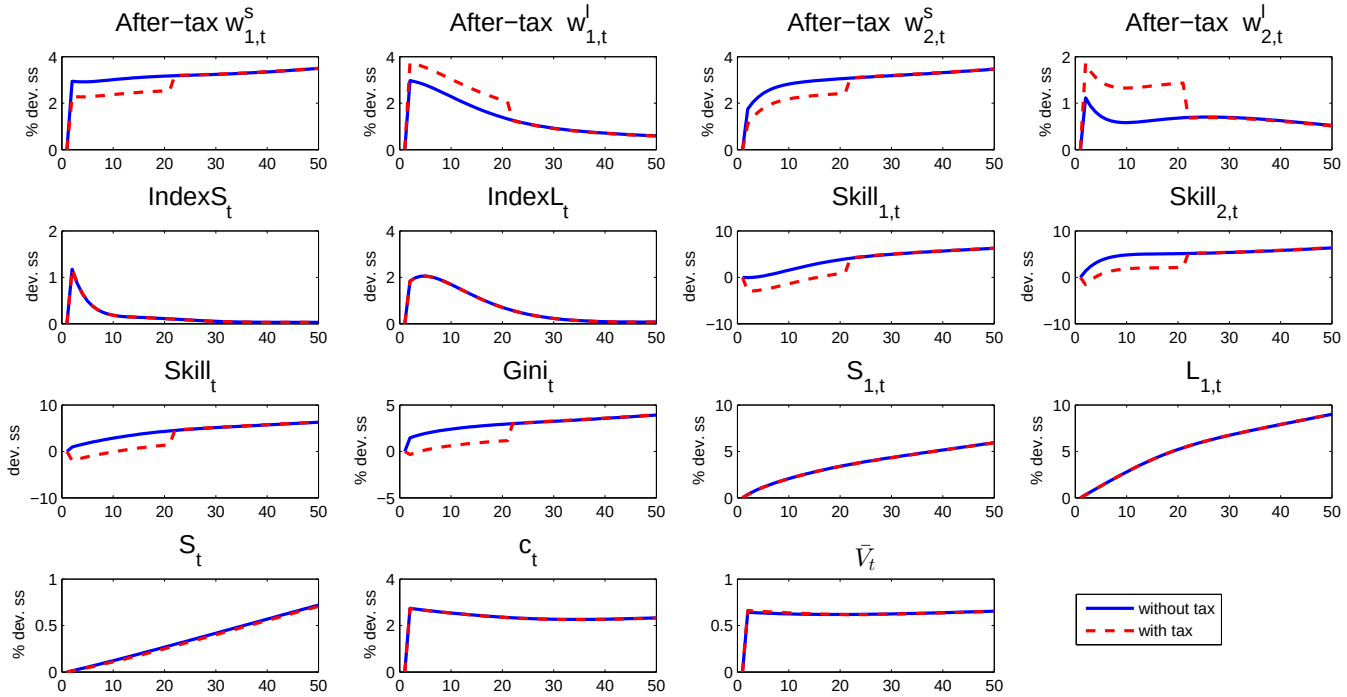

Figure 11:
Temporary wage tax on skilled labor financing wage subsidy on unskilled labor
Tax on skilled rises by 0.63 percentage points for 20 periods

5.3.3 Training subsidy

The endogeneity of the training decision opens up the opportunity to analyze an instrument that could not be analyzed in the no-training scenario: training subsidies, which seem to be a popular instrument during the adjustment periods after trade liberalization (see Boix [2011]). We again look at both, temporary and permanent policy changes.

Figure 12 illustrates the effects of a permanent increase in the training subsidy by 15%, that is financed by a tax on all wages. The implied budget constraint for the government is $\frac{\chi_t^t \int_{\varepsilon_{\min}^T}^{\bar{\varepsilon}_t^T} \varepsilon_t^T d\Gamma(\varepsilon_t^T)}{(1-G(\overline{\varepsilon_t^{Se}}))(C_{1t}^s)^{-1}+G(\overline{\varepsilon_t^{Se}})(C_{2t}^s)^{-1}} (Se_{1t} + Se_{2t} + Le_{1t} + Le_{2t}) = \chi_t \left(w_{1t}^s S_{1t} + w_{2t}^s S_{2t} + w_{1t}^l L_{1t} + w_{2t}^l L_{2t}\right)$ where $\bar{\varepsilon}_t^T = max(\varepsilon_{\min}^T, (v_t^s - v_t^l)/(1-\chi_t^t))$.

Not surprisingly the policy induces a permanent increase in the number of skilled workers. This makes skilled workers more abundant and unskilled workers scarcer so that the skilled wage drops and the unskilled wage rises relative to the no-policy scenario**.** Thus, the skill premium is permanently reduced and with it overall wage inequality.

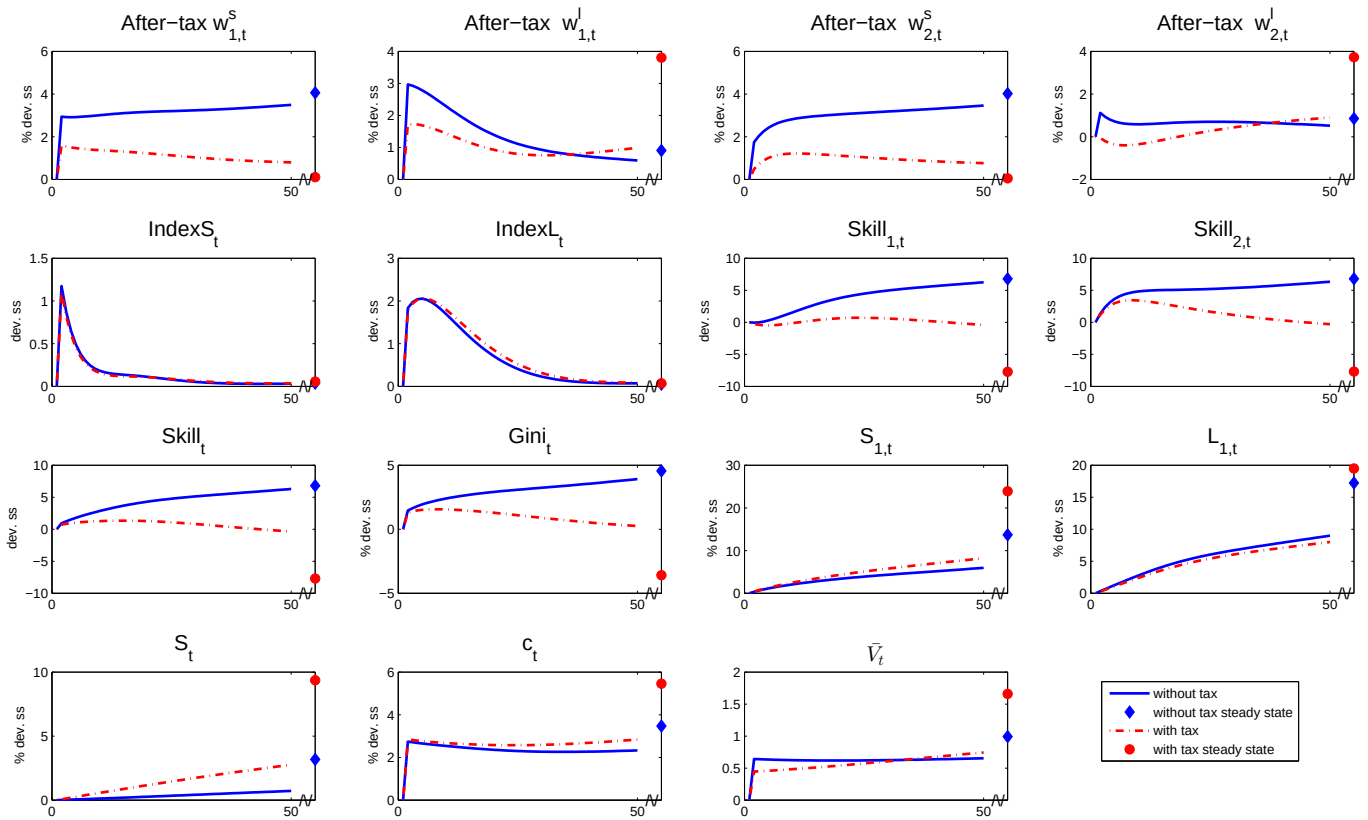

Figure 12:
Training subsidy financed by a wage tax
Subsidy rises permanently by 15 percentage points.

Concerning welfare this policy has two counteracting effects. On the one hand, the training subsidy leads to inefficiently high investments in training. On the other hand, it reduces wage inequality which tends to increase welfare. It can be seen that in the short run the first effect dominates, while in the long run the second effect dominates. Thus the training subsidy leads to long run increase in welfare.

Finally, figure 13 illustrates the effects of a temporary increase in the training subsidy that lasts for 20 periods. The training subsidy considerably and persistently increases the number of skilled workers even beyond its period of implementation. The acceleration in the reallocation of skilled workers also speeds up the reallocation of firms. Because of the large and persistent increase in the number of skilled workers, the skill premium and overall wage inequality go down very persistently.

Thus, training subsidies continue to have an impact much beyond their period of implementation. The reason is that the training decision is a costly, forward looking decision and therefore the process of skilled workers is very persistent. The persistence in the process of skilled workers transmits into persistence for the other variables.

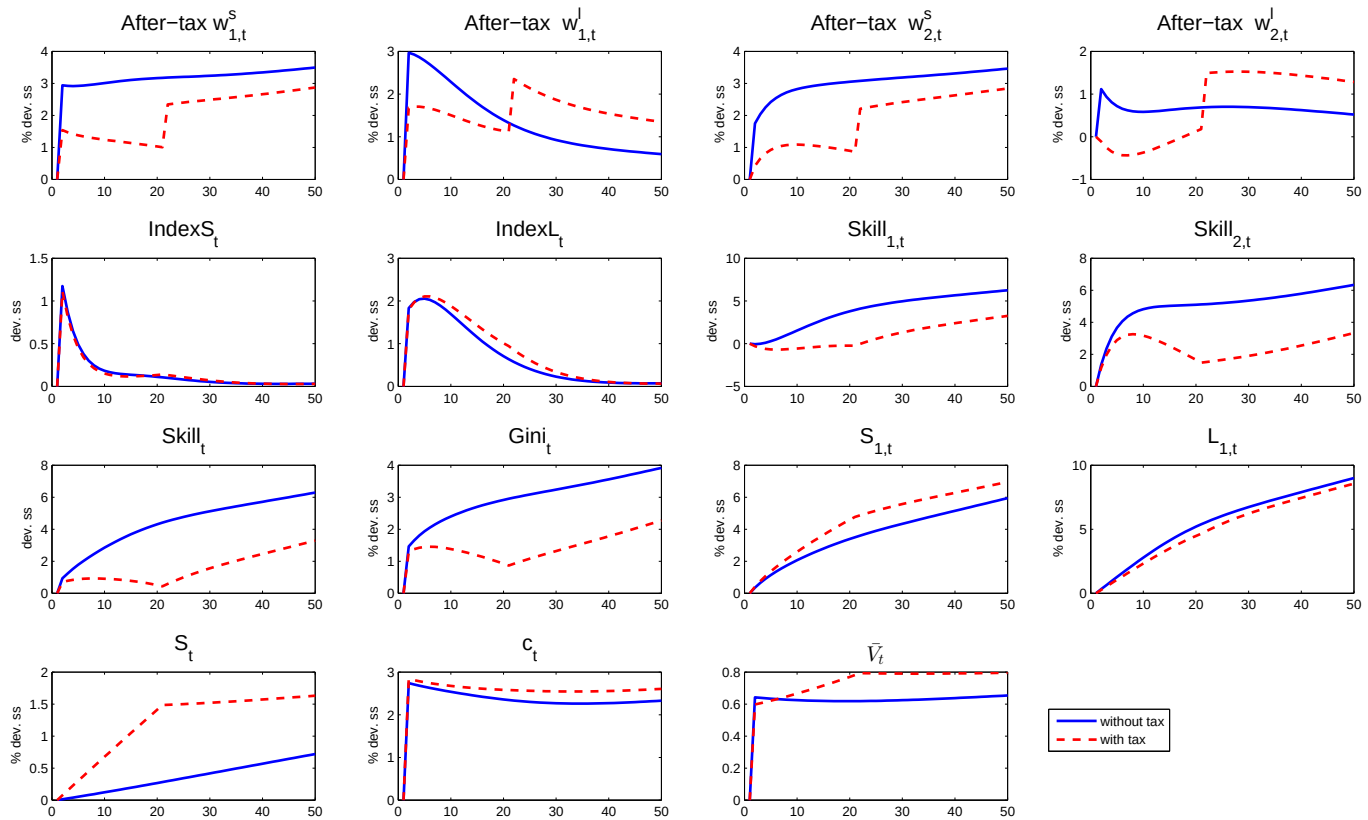

Figure 13:
Training subsidy financed by a wage tax
Subsidy rises by 15 percentage points for 20 periods

5.4 Summary

Table 2 summarizes the results of our policy experiments in a compact manner. It can be seen that, as a broadly general rule, instruments that speed up reallocation do so at the cost of generating wage inequality, while those instruments that reduce wage inequality, slow down reallocation. One exception to this rule are profit taxes, which reduce inter-sectoral wage inequality without having a large impact on the reallocation of workers. The more important exception are training subsidies, which increase the incentives to train, slightly speed up reallocation and considerably reduce wage inequality. The evaluation of wage taxes depends crucially on the endogeneity of training. If training is exogenous, wage taxes do not distort the allocation of workers. But because they have a large impact on the skill premium they increase welfare considerably. If training is endogenous this is still true in the short run, but in the long run wage taxes distort the incentives to train and thus lead to lower welfare.

	No training										Training			
	WT		CT		PT		ES		MS		WT		TS	
	SR	LR	SR	MR	SR	MR	SR	MR	SR	MR	SR	LR	SR	LR
Skill premium	−−	−−	−	−	−	*o*	+	−	+	*o*	−−	−−	−−	−−
IndexL	*o*	*o*	−	*o*	−	*o*	+	−	−	−	*o*	*o*	*o*	*o*
IndexS	*o*	*o*	−	*o*	−	*o*	+	−	+	−	*o*	*o*	*o*	*o*
Gini	−−	−−	−	−	−	*o*	+	−	*o*	*o*	−−	−−	−−	−−
Reallocation S	*o*	*o*	−	−	−	*o*	+	−	++	*o*	*o*	−	+	*o*
Reallocation L	*o*	*o*	−	−	−	*o*	+	−	++	*o*	*o*	*o*	*o*	*o*
Utility	++	++	−	*o*	*o*	*o*	*o*	−	−	*o*	+	−−	*o*	+
Welfare	++	++	−	*o*	*o*	*o*	*o*	*o*	*o*	*o*	+	−−	+	+

WT: wage tax, CT: consumption tax, PT: profit tax, ES: firm entry subsidy, MS: worker migration subsidy, TS: training subsidy, SR: short run, LR: long run

Table 2: Summary of policy effects

6 Conclusion

This paper has analyzed economic policy in a model of international trade that incorporates comparative advantage, skilled and unskilled workers, firm heterogeneity and endogenous firm entry into a dynamic setting. Our model has the advantage that it allows to track the adjustment process after trade liberalization and that it allows for a rich picture of wage inequality.

In our model, trade liberalization that is not accompanied by other policy interventions leads to a short-run increase in inter-sectoral wage inequality that stems from the low mobility of workers across sectors, but recedes as more and more workers reallocate to the expanding exporting sector. The skill premium increases considerably in the long run but reacts little in the short run.

Economic policy in this context can have various goals. It can aim to reduce the skill premium, to reduce inter-sectoral wage inequality or to speed up the adjustment process. The policy instruments that we have considered to reach these goals are wage taxes, consumption taxes, profit taxes, firm entry subsidies, migration subsidies and training subsidies.

We have shown that wage taxes can be a powerful instrument to reduce the skill premium, but they have the disadvantage of overly hurting the skilled workers in the import-competing sector and they can be quite harmful from an aggregate perspective if they distort the incentives to invest in training.

Consumption taxes and profit taxes are a potent instrument to reduce inter-sectoral wage inequality and they lead to a smoother adjustment in wage inequality after trade liberalization. Firm entry subsidies speed up the adjustment process, but at the cost of considerably increased wage inequality. Migration subsidies can help unskilled workers who are stuck in the import-competing sector, but hurt unskilled workers in the exporting sector and therefore have only a minor effect on overall wage inequality.

Probably the most potent instrument to fight wage inequality is the subsidization of worker training. By increasing the number of skilled workers this policy raises output in the long run and in the short run and it reduces the skill premium and with it overall wage inequality in the short run. The policy comes at the cost of over-investment in worker training but the ensued inefficiency is rather minor.

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Appendix

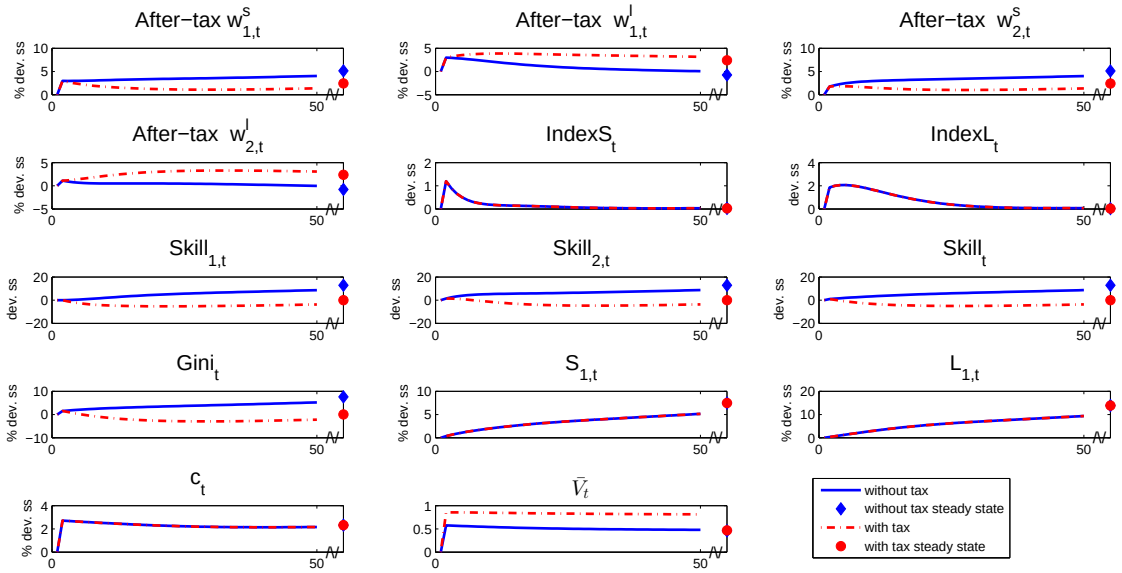

Figure 14:
Permanent wage tax on skilled labor financing wage subsidy on unskilled labor
Exogenous tax in period t : $tax_t = -0.9^t tax_0 + 0.0258$with $tax_0 = 0.0258$

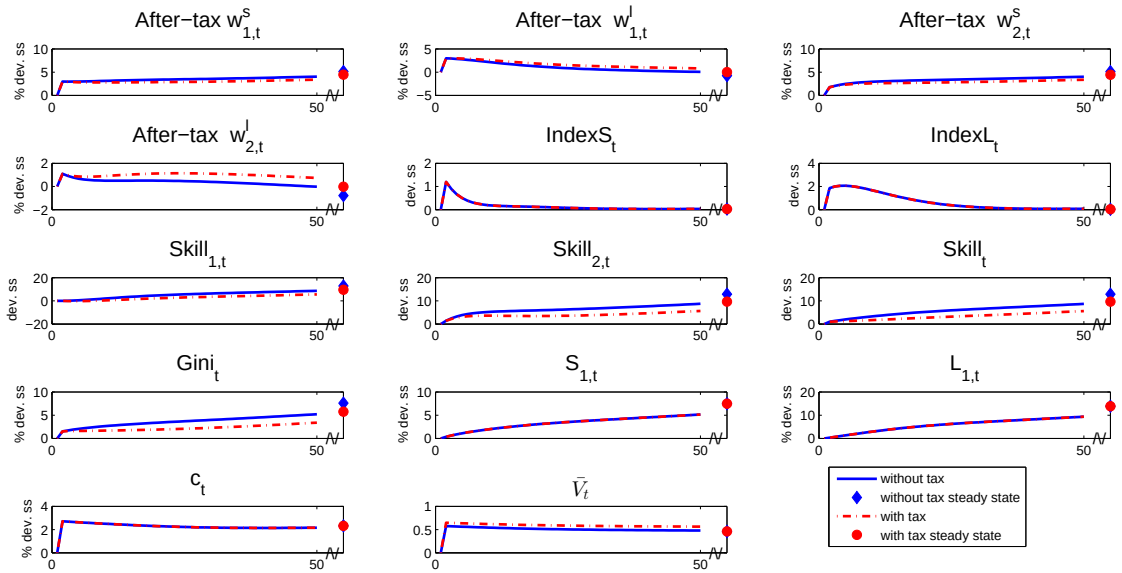

Figure 15:
Permanent wage tax on skilled labor financing wage subsidy on unskilled labor
Exogenous tax in period t: $tax_t = -0.9^t tax_0 + 0.0063$ with $tax_0 = 0.0063$