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

by Wolfgang Lechthaler† and Mariya Mileva ‡,

Abstract:

We develop a dynamic general equilibrium trade model with comparative advantage, heterogeneous firms, heterogeneous workers and endogenous firm entry to study wage inequality during the adjustment after trade liberalization. We find that trade liberalization increases wage inequality both in the short run and in the long run. In the short run, wage inequality is mainly driven by an increase in inter-sectoral wage inequality, while in the medium to long run, wage inequality is driven by an increase in the skill premium. Incorporating worker training in the model considerably reduces the effects of trade liberalization on wage inequality. The effects on wage inequality are much more adverse when trade liberalization is unilateral instead of bilateral or restricted to specific sectors instead of including all sectors.

Keywords: trade liberalization; wage inequality; adjustment dynamics

JEL classification: E24, F11, F16, J62

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1 Introduction

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

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

And indeed, Autor et al. [2013a] show that in the United States (U.S.) increased trade with China goes hand in hand with a decrease in the share of manufacturing employment and that local labor markets that are exposed to Chinese imports suffer higher unemployment and lower wages. In a similar vein, Ebenstein et al. [2009] find that U.S. wages grow more slowly in sectors that are exposed to more import penetration, giving rise to increased wage inequality. Pierce and Schott [2012] identify a direct causal link between the sharp drop in U.S. manufacturing employment after 2001 and the elimination of trade policy uncertainty that resulted from the granting of permanent normal trade relations to China in late 2000. Industries that experienced the sharpest reduction in tariff threats experienced greater employment loss due to suppressed job creation, exaggerated job destruction and a substitution away from unskilled workers. Figure 1 shows that for the European Union (E.U.), too, trade with China has increased enormously, while manufacturing employment has decreased.[1]

A comprehensive study of the effects of trade liberalization on wage inequality should, in our view, contain the following features: i) comparative advantage to study the tension between shrinking, comparative disadvantage sectors and expanding, comparative advantage sectors; ii) skilled and unskilled labor to study changes in the skill premium; iii) adjustment dynamics, because the structure of the economy is unlikely to change over night iv) adjustment costs of labor,

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

because it takes time and resources to switch sectors or to train; v) firm heterogeneity, endogenous firm entry and selection into export markets, because these features have been shown to be important ingredients of international trade.

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

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

In our model, newly entering firms need to pay a sunk entry cost in order to enter either of two sectors (one skill-intensive, one unskilled-intensive). Upon entering they draw their productivity from a Pareto distribution. In contrast to Melitz [2003], but in line with GM, firms do not have to pay fixed production costs, and therefore all newly entering firms take up production. However, firms have to pay a fixed cost of exporting if they want to serve the foreign market. This results in selection into export markets, as in Melitz [2003], i.e., only the most productive firms take up exporting. As part of our robustness analysis we show that firm heterogeneity and selection into export markets imply an additional adjustment margin. This simplifies the adjustment of the economy to trade liberalization and therefore leads to lower wage inequality in the medium and long run. However, it does not qualitatively affect our results.

Each firm is subject to an exogenous rate of exit. This gives rise to non-trivial but tractable adjustment dynamics after trade liberalization, because existing firms keep operating and are stuck in their sector, while newly entering firms are more flexible.[2] Thus, the reallocation of firms from one sector to the other takes place via the exit of old firms. They are replaced by newly entering firms which tend to prefer the expanding sector over the shrinking sector.

Workers can be either skilled or unskilled and can be employed in either of the two sectors. Concerning the mobility of workers we distinguish various adjustment mechanisms: i) workers retire at an exogenous rate and get replaced by newly entering workers who are more flexible in their occupational choices; ii) workers might or might not be allowed to switch sectors after paying a randomly distributed sector migration cost; iii) unskilled workers might or might not be allowed to

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

become skilled after paying a randomly distributed training cost. By simulating various combinations of these mobility assumptions we are able to highlight the role of labor adjustment costs.

In our analysis we focus on the effects of trade liberalization on wage inequality in the rich country.[3] We mainly concentrate on two measures of wage inequality: i) inter-sectoral wage inequality, i.e., the wage differential between workers who are in the same skill class but in different sectors and ii) the skill premium, i.e., the wage differential between skilled and unskilled workers. The effects of trade liberalization on wage inequality depend importantly on the assumption whether unskilled workers can train to become skilled workers or not. If we follow the standard practice in the trade literature and assume fixed endowments with skilled and unskilled workers (as, e.g., in BRS), we find that income inequality strongly increases after trade liberalization. In the short run, this is driven by a rise in the inter-sectoral wage inequality. In the medium to long run, inequality rises due to a rising skill premium.

The two inequality measures have starkly different dynamics: the skill premium reacts only slowly while inter-sectoral wage inequality jumps up on impact and then slowly recedes. Consider the extreme scenario where workers are completely immobile in the short run. Then, the supply of workers cannot respond to the changes in relative labor demand. In the short run wages in the skill-intensive sector have to go up relative to the wages in the unskilled-intensive sector. The skill premium, however, does not change in the short run, because the marginal productivity of skilled and unskilled labor cannot change as their composition in production does not change. In the long run, when labor is fully mobile across sectors, the wage differential between the two sectors must disappear, while the skill premium increases due to higher demand for the skill-intensive good, which translates into higher demand for skilled workers.

This discussion demonstrates that it is crucial to use a dynamic model in order to be able to distinguish between short run and long run effects. In the long run wage differentials between sectors must vanish but in the short run they are the more important source of wage inequality. This short run effect is completely ignored when analyzing steady state outcomes only, while the effect of the increased skill premium is exaggerated since it takes a long time to manifest.

The effects of trade liberalization on wage inequality are considerably different, when we relax the assumption of fixed endowments with skilled and unskilled workers by allowing unskilled workers to train and become skilled workers. Under fixed endowments with skilled and unskilled workers, the overall supply of skilled workers cannot react to the increased demand for skilled workers that comes along with trade liberalization. Thus, the wage of skilled workers has to go up relative to the wage of unskilled workers. However, when we allow for worker training, this is no longer the case. With worker training the supply of skilled workers increases in response to trade liberalization. This not only leads to quicker adjustment of the economy but also reduces the long run effects of trade liberalization on wage inequality because the skill

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

premium does not increase. This suggests that the common assumption of fixed endowments with skilled and unskilled workers is not an innocuous assumption, but instead crucial for the effects of trade liberalization on wage inequality.

The literature on the effects of trade liberalization on labor markets is vast. In the next section we provide a brief overview of this literature and outline our contribution in detail. Here we want to mention the three papers that are most closely related to our analysis, because they also analyze labor market adjustments after trade liberalization: Artuç et al. [2010], Dix-Carneiro [2010] and Coşar [2013]. All of these papers use small open economy models. This implies two shortcomings: i) The terms-of-trade are exogenous; ii) Their analysis is restricted to scenarios where trade liberalization leads to a decrease in the price of imports in one specific sector, ignoring the fact that trade liberalization might also affect the price of exports.

This is a limited view of trade liberalization. When a country opens its borders to foreign imports it typically expects something in return. In fact, most countries sign trade liberalization agreements because they anticipate an increase in exports in the comparative advantage sector which would lead to an increase in labor demand and, thus, higher wages and more jobs in that sector. After trade liberalization we usually observe the co-existence of expanding exporting sectors (the comparative advantage sectors) and shrinking import-competing sectors (the comparative disadvantage sector). When analyzing the effect of trade liberalization on labor markets, we must consider the expanding comparative advantage sectors because they offer attractive alternatives to the workers who suffer in the shrinking comparative disadvantage sectors. The gains and losses from trade due to expanding and shrinking sectors is at the heart of the ongoing debate about the effect of trade liberalization on labor markets, but it is an issue ignored in the papers cited above.

In our general-equilibrium, multi-sector approach the terms-of-trade are endogenous. It also allows us to analyze a broader scope of trade liberalization scenarios. We show that the effects of trade liberalization depend crucially on the exact design of trade liberalization. The effects of trade liberalization on wage inequality are much more adverse when it is unilateral instead of bilateral or restricted to specific sectors instead of including all sectors.

The rest of the paper is structured as follows. Section 2 provides a brief overview over the other related literature. Section 3 describes the theoretical model. Section 4 describes the parametrization. In section 5 we describe our simulations of the symmetric trade liberalization scenarios, while section 6 shows the asymmetric trade liberalization scenarios. Section 7 provides some robustness checks and discusses some of the channels in more detail. Finally, section 8 concludes.

2 Literature review

The literature on the relationship between international trade and wage inequality is extensive. We contribute to two main strands of it.

After the introduction of models examining the role of firm heterogeneity in international trade (Melitz [2003]), an innovative literature has analyzed the labor market implications of trade liberalization in the context of heterogeneous firms, heterogeneous workers, and a variety of labor market frictions. With heterogeneous firms and heterogeneous workers in an industry, labor market equilibria and the labor adjustment process following trade liberalization depend on the mechanisms that match workers and firms. With heterogeneous firms trade liberalization leads to a change in the distribution of firms serving the domestic and foreign market. With labor market frictions, ex ante identical workers may earn different wages and experience differential wage changes after trade liberalization because the change in the distribution of firms might also change the distribution of the wages that they pay. Studies with this type of models focus on the relationship between trade and within-group wage inequality. Some recent examples include Coşar et al. [2011], Krishna et al. [2011], Krishna et al. [2012], Almeida and Poole [2013] and Helpman et al. [2012]. However, these papers ignore that after trade liberalization between-group inequality could increase from shrinking import-competing sectors and expanding exporting sectors. A number of empirical papers already cited above have documented the importance of this channel through which trade can affect inequality. Burstein and Vogel [2011] show that both sources of inequality are important but have relatively little to say about the adjustment following trade liberalization. We contribute to this strand of the literature by highlighting that trade liberalization can lead to significant increases in between-sector inequality and that the persistence of these increases depends on assumptions about labor mobility.

We also contribute to a large literature that extends traditional theories of international trade, such as the Heckscher–Ohlin models, to analyze dynamic adjustment after trade liberalization. More recently, Baxter [1992], Chen [1992], Backus et al. [1994], Stokey [1996], Ventura [1997], Jensen and Wang [1997], Mountford [1998], Acemoglu et al. [2002], Atkeson and Kehoe [2000], Bond et al. [2003], Ferreira and Trejos [2006], Gaitan and Roe [2007] and Caliendo [2010] have combined versions of the standard Heckscher–Ohlin model with the standard Neoclassical growth model or an overlapping generations model. However, the focus of these papers is mostly on growth issues.

There are some papers that show that inter-industry reallocation entails labor market costs. Kambourov [2009] contends that in the presence of regulated labor markets with high firing costs, the inter-sectoral reallocation of labor after a trade reform is slowed down. He builds a dynamic general-equilibrium multi-sector model of a small open economy with sector-specific human capital, firing costs, and tariffs in order to understand the effect of labor market regulations on the effectiveness of trade reforms. Calibrating his model to Chile, Kambourov [2009] makes counter-factual simulations and finds that if Chile had not liberalized its labor market at the outset of its trade reform, then the inter-sectoral reallocation of workers would have been 30 percent slower and as much as 30 percent of the gains in real output and labor productivity in the years following the trade reform would have been lost.

In terms of distributional effects, Helpman and Itskhoki [2009] develop a dynamic version of the two-country, two-sector

model of international trade of Helpman and Itskhoki [2010] in which one sector produces homogeneous products, "outside sector", and the other produces differentiated products. The main finding is that when the two sectors are symmetric in terms of their labor markets trade unambiguously raises welfare in both countries.

In a similar vein, Ishimaru et al. [2012] analyze the welfare and unemployment consequences of trade liberalization by incorporating search and matching frictions into a two-factor, two-sector, two-country Heckscher–Ohlin framework, and developing a dynamic general equilibrium model with comparative advantage to study the entire dynamic path from the original steady state to the new steady state after trade reform. Their numerical simulations reveal a U-shaped steady state unemployment locus along the trade tariff rates. In the presence of labor market frictions, the flow of workers within sectors and across sectors generates wage fluctuations. When more workers are employed at the comparative advantage sector, the aggregate income is higher. Unless the fluctuation in the aggregate supply is large enough, the employment effect is absorbed through prices. In the long run, prices are also U-shaped, so that income inequality increases, with the unemployed consuming less after the trade reform.

However, these papers, except for Helpman and Itskhoki [2009], ignore the effects of intra-industry trade, firm dynamics, selection into export markets and firm heterogeneity on wage inequality. Even in Helpman and Itskhoki [2009] firm heterogeneity is limited to one sector while our model incorporates heterogeneous firms in both sectors which allows us to analyze the importance of each channel for adjustment in each sector and study the interactions between these mechanisms. Our results indicate that firm heterogeneity and slow adjustment of firms matter for the dynamics of labor market adjustment after trade liberalization, particularly for the import-competing sector. The second sector in Helpman and Itskhoki [2009] is a numeraire sector of a homogeneous good which implies that there is no specialization in their model and the role of comparative advantage on wage inequality cannot be analyzed. Furthermore, they use a quasi-linear utility function so that income effects are absorbed in the numeraire sector. Finally, none of these papers incorporates both skilled and unskilled workers which is a key feature of our model that allows us to analyze how skill premia evolve after trade liberalization.

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

3.1 Households

Each country consists of one large representative household which maximizes the present discounted value of utility derived from consumption:

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

where γ is the subjective discount factor and the term $Cost_{t+i}$ summarizes the (potential) disutility from migration and training (see, e.g., Dix-Carneiro [2010]). We assume that all workers in H are members of this large household which pools their labor income. This implies that the distribution of labor income can be ignored for the consumption decision. This is a standard assumption in the macroeconomic literature (see, e.g., Andolfatto [1996]). Then, the household faces the following intertemporal budget constraint:

$$\begin{aligned} &B_{t+1} + Q_t B_{*,t+1} + \frac{\eta}{2}\left(B_{t+1}\right)^2 + \frac{\eta}{2} Q_t \left(B_{*,t+1}\right)^2 + \widetilde{v}_{1t} N_{h,1t} x_{1t+1} + \widetilde{v}_{2t} N_{h,2t} x_{2t+1} + C_t = \\ &(1+r_t)B_t + (1+r_t^*)Q_t B_{*,t} + (\tilde{d}_{1t} + \tilde{v}_{1t}) N_{d,1t} x_{1t} + (\tilde{d}_{2t} + \tilde{v}_{2t}) N_{d,2t} x_{2t} + w_{1t}^s S_{1t} + w_{2t}^s S_{2t} + w_{1t}^l L_{1t} + w_{2t}^l L_{2t} + \tau_{h,t} \end{aligned} \tag{2}$$

The household spends its income on purchases of international risk-free real bonds denominated in the home currency (B_{t+1}) and in the foreign currency ($B_{*,t+1}$), where the foreign bond holdings are adjusted for the consumption-based real exchange rate Q_t. The real exchange rate is defined in terms of units of home consumption per unit of foreign consumption adjusted for the nominal exchange rate e_t, i.e., $Q_t \equiv e_t P_t^* / P_t$. The household also pays fees for adjusting its holdings of international bonds $\frac{\eta}{2}\left(B_{t+1}\right)^2 + \frac{\eta}{2} Q_t \left(B_{*,t+1}\right)^2$. We assume convex fees for international portfolio adjustment in order to

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

ensure that our model has a unique steady state and is stationary (see, e.g., GM). The household also purchases shares x_{it+1} of ownership in all domestic firms that operate at time t, $N_{h,it}$, at price $\widetilde{v}_{it}$. Note that the household can hold shares simultaneously in both sectors $i = 1, 2$. When deciding how many shares to purchase, the household considers all operating firms including incumbents $N_{d,it}$ and new entrants $N_{e,it}$, which implies that $N_{h,it} = N_{d,it} + N_{e,it}$. However, each period a fraction δ of all firms dies. Thus, only $N_{d,it+1} = (1-\delta)N_{h,it}$ will actually produce and generate profits to pay dividends $\tilde{d}_{it}$. The remainder of the household income is spent on the aggregate consumption good C_t.

The household obtains income from interest on its holdings of home bonds $(1+r_t)B_t$ and foreign bonds $(1+r_t^*)Q_tB_{*,t}$, dividend income $\tilde{d}_{it}$ from owning shares in $N_{d,it}$ firms, capital income from selling the shares in $N_{d,it}$ firms, wage income w_{it}^s and w_{it}^l from supplying skilled S_{it} and unskilled labor L_{it} and an international bond fee rebate $\tau_{h,t} = \frac{\eta}{2}\left(B_{t+1}\right)^2 + \frac{\eta}{2}Q_t\left(B_{*,t+1}\right)^2$. The budget constraint is written in aggregate consumption units.

The household chooses C_t ,B_{t+1}, $B_{*,t+1}$, x_{1t+1}, and x_{2t+1}. The corresponding Euler equations for bond and share holdings are:

$$\left(C_t\right)^{-1}\left(1+\eta B_{t+1}\right) = \gamma E_t\left[\left(C_{t+1}\right)^{-1}\left(1+r_t\right)\right] \tag{3}$$

$$\left(C_t\right)^{-1}\left(1+\eta B_{*,t+1}\right) = \gamma E_t\left[\left(1+r_t^*\right)\left(C_{t+1}\right)^{-1}\left(\frac{Q_{t+1}}{Q_t}\right)\right] \tag{4}$$

$$\widetilde{v}_{1t} = \gamma(1-\delta)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(\widetilde{v}_{1t+1}+\tilde{d}_{1t+1}\right)\right] \tag{5}$$

$$\widetilde{v}_{2t} = \gamma(1-\delta)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(\widetilde{v}_{2t+1}+\tilde{d}_{2t+1}\right)\right]. \tag{6}$$

The aggregate consumption good C is a Cobb-Douglas composite of the goods produced in the two sectors:

$$C_t = C_{1t}^{\alpha}C_{2t}^{1-\alpha}, \tag{7}$$

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

$$C_{1t} = \alpha\frac{P_t}{P_{1t}}C_t \;\; and \;\; C_{2t} = (1-\alpha)\frac{P_t}{P_{2t}}C_t, \tag{8}$$

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.

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

$$C_{it} = \left[\int_{\omega \epsilon \Omega_i} c_{it}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right]^{\frac{\theta}{\theta-1}}, \tag{9}$$

where $\theta > 1$ is the elasticity of substitution between varieties. Varieties are internationally traded. Thus a variety can either be produced at home or imported. At any given time, only a subset of varieties $\Omega_{it} \epsilon \Omega_i$ is available in each sector. 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 $c_{it} = \left(\frac{p_{it}}{P_{it}} \right)^{-\theta} C_{it}$. It is useful to redefine these in terms of aggregate consumption units. Let us define $\rho_{it} \equiv \frac{p_{it}}{P_t}$ and $\psi_{it} \equiv \frac{P_{it}}{P_t}$ as the relative prices for individual varieties and for the sector baskets, respectively. Then, we can rewrite the demand functions for varieties and sector baskets as $c_{it} = \rho_{it}^{-\theta} C_{it}$ and $C_{it} = \alpha \psi_{it}^{-1} C_t$, 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 BRS. In the second version, 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 non of the incumbents would decide to switch the sector, 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 positive idiosyncratic sector migration cost, measured in disutility,[5] which is represented by an idiosyncratic $\varepsilon_t^s \geq 1$, drawn each period from a random distribution $F(\varepsilon^s)$. 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.

[5] As in Dix-Carneiro [2010] 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.

We interpret the sector migration cost in a similar way as Iceberg trade costs. When workers move, a certain share of their value V_{jt}^s in the other sector 'melts away', so that only $1/\varepsilon_t^s$ is left. Put differently, workers who switch sectors have to forgo $(\varepsilon_t^s - 1)\%$ of the present value of their future wage income, in terms of utility, in order to buy into the new sector. The advantage of modelling migration costs in this way is that migration costs depend positively on the wage income of the worker, i.e., workers with a higher income suffer higher migration costs. Thus, a worker will move from sector j to sector i if:

$$\frac{V_{it}^s}{\varepsilon_t^s} > V_{jt}^s. \tag{10}$$

Vice versa, a worker in sector i will move to sector j if $\frac{V_{jt}^s}{\varepsilon_t^s} > V_{it}^s$. Equation 10 defines a threshold, $\bar{\varepsilon}_t^s$, for which a worker is indifferent between switching and not switching the sector

$$\overline{\varepsilon_t^s} = \frac{V_{it}^s}{V_{jt}^s} \tag{11}$$

and the probability of switching sectors is

$$\begin{aligned} \eta_{jit}^s &= F(\max(\overline{\varepsilon_t}^s, \varepsilon_{\min}^s)) \\ \eta_{ijt}^s &= F\left(\max\left(\frac{1}{\overline{\varepsilon_t}^s}, \varepsilon_{\min}^s\right)\right) \end{aligned}$$

where η_{jit}^s is the probability to switch from sector j to sector i and vice versa for η_{ijt}^s. $\varepsilon_{\min}^s$ is the minimum moving cost that the worker has to pay in order to switch sectors. We assume that $\varepsilon_{\min}^s \geq 1$ so that only one of the two rates can be positive, the other has to be zero.

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

$$V_{it}^s = w_{it}^s + \gamma(1-s)\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left[(1-\eta_{ijt+1}^s)V_{it+1}^s + \int_{\varepsilon_{\min}^s}^{1/\bar{\varepsilon}_{t+1}^s} \frac{V_{jt+1}^s}{\varepsilon_{t+1}^s}\partial F\left(\varepsilon_{t+1}^s\right)\right], \tag{12}$$

where s is the probability of retiring. The worker's value is a function of the real wage that the worker earns and the expected discounted future value,[6] adjusted for the probability of survival, and averaged over the cases where the worker will choose to stay in the same sector or switch to the other sector, taking account of eventual sector migration costs.

In order to keep the working population constant, we assume that each period the retiring workers are replaced by newly entering workers, Se_{it}. The newly entering workers have to choose the sector in which they want to be employed.

[6]The appropriate discount factor is $\gamma\left(\frac{C_{t+1}}{C_t}\right)^{-1}$, taking account of changes in marginal utility.

We assume that this decision is based on the relative payoffs in sectors 1 and 2. If the value in sector 1 is higher than the value in sector 2, then relatively more workers will enter sector 1, but we avoid the extreme assumption that all entering workers flock to one sector. To assure stationarity in the steady state, we have to 'weigh' the payoffs of each sector with the number of workers in that sector, so that the ratio of workers entering each sector is given by:[7]

$$\frac{Se_{1t}/S_{1t}}{Se_{2t}/S_{2t}} = \frac{V^s_{1t}}{V^s_{2t}}.$$

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

$$S_{it} = (1-s)\left[(1-\eta^s_{ijt})S_{it-1} + \eta^s_{jit}S_{jt-1} + Se_{it-1}\right].$$

In this version of the model, the country 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 that survive:

$$sS = (1-s)(Se_{1t} + Se_{2t}).$$

Remember that in the long run workers are fully mobile between sectors.[8] Then, for each skill class the values in both sectors need to be the same, which implies that there is full wage equalization across sectors in the steady state. Thus, in the long run skill premia are equal across sectors ($\frac{w^s_1}{w^l_1} = \frac{w^s_2}{w^l_2}$). Skill premia differ across countries because we assume that country H has a higher relative endowment with skilled labor than country F, so that the skill premium in country H is lower in the long run.

3.2.2 Worker mobility with training

[7] If we did not weigh the payoffs, then equalization of payoffs and wages across sectors would only be possible if workers were split equally across sectors.

[8] Even when sector migration costs were prohibitively high so that no worker would want to pay the sector migration costs, the constant flow of retiring workers assures full mobility in the long run.

In this section, we relax the assumption of perfect immobility between skill classes, by allowing unskilled workers of each sector to train to become skilled workers in their sector. We model the training decision analogously to the sector migration decision of the previous section. Unskilled workers who want to become skilled have to pay a positive training cost, measured in disutility, which is represented by an idiosyncratic ε_t^i drawn each period from a random distribution $\Gamma(\varepsilon^i)$. Unskilled workers in sector i train if the value of being skilled is high enough to justify the training cost, i.e., if

$$\frac{V_{it}^s}{\varepsilon_t^i} > V_{it}^l. \tag{13}$$

Equation 13 defines a threshold $\bar{\varepsilon}_t^i$ for which a worker is indifferent between training and not training

$$\bar{\varepsilon}_t^i = \frac{V_{it}^s}{V_{it}^l}, \tag{14}$$

so that the probability of training is

$$\eta_{it} = \Gamma\left[\max(\bar{\varepsilon}_t^i, \varepsilon_{\min}^i)\right],$$

where $\varepsilon_{\min}^i$ is the minimum training cost that unskilled workers have to pay in order to become skilled. Note that these minima are equal across sectors ($\varepsilon_{\min}^1 = \varepsilon_{\min}^2$) and that they correspond to the steady state skill premium ($\varepsilon_{\min}^i = \frac{w_i^s}{w_i^l}$).

While the value function for skilled workers remains the same as in the model with fixed labor endowments, the value function for unskilled workers must be re-defined to take account of the possibility of training such that,

$$V_{it}^l = w_{it}^l + \gamma(1-s)\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left[(1-\eta_{ijt+1}^l - \eta_{it+1})V_{it+1}^l + \int_{\varepsilon_{\min}^l}^{1/\bar{\varepsilon}_{t+1}^l} \frac{V_{jt+1}^l}{\varepsilon_{t+1}^l} dH(\varepsilon_{t+1}^l) + \int_{\varepsilon_{\min}^i}^{\bar{\varepsilon}_{t+1}^i} \frac{V_{it+1}^s}{\varepsilon_{t+1}^i} \partial\Gamma(\varepsilon_{t+1}^i)\right].$$

Since training is now endogenous, newly entering workers not only have to decide about their sector but also about their training. We model this decision analogously to the decision about switching sectors, taking account of the cost of training. Assuming that the minimum cost of training applies to newly entering workers implies:[9]

$$\frac{Se_{it}/S_{it}}{Le_{it}/L_{it}} = \frac{V_{it}^s}{V_{it}^l}\frac{1}{\varepsilon_{\min}^i}.$$

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 moved from sector j to sector i, the newly trained unskilled workers and the new

[9] Again, this is the simplest assumption that assures a stationary steady state.

entrants, taking account of the retirement rate, such that

$$S_{it} = (1-s)\left[(1-\eta^s_{ijt})S_{it-1} + \eta^s_{jit}S_{jt-1} + Se_{it-1} + \eta_{it}L_{it-1}\right].$$

The number of unskilled workers in sector i at the end of period t equals the number of incumbents who neither switched sectors nor trained, the number of unskilled workers who moved from sector j to sector i and the new entrants, taking account of the retirement rate, such that

$$L_{it} = (1-s)\left[(1-\eta^l_{ijt} - \eta_{it})L_{it-1} + \eta_{jit}L_{jt-1} + Le_{it-1}\right].$$

Finally, in equilibrium the total number of workers that retire has to equal the number of new entrants that survive:

$$sENDOW = (1-s)(Se_{1t} + Le_{1t} + Se_{2t} + Le_{2t}),$$

where $ENDOW = S_t + L_t$ is the total endowment with labor for country H.

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. First, we define two measures of wage inequality across sectors. They measure the relative percentage difference across sectoral wages for skilled and unskilled workers

$$\begin{aligned} IndexS_t &= \left(\frac{w^s_{1t}}{w^s_{2t}} - 1\right)100, \\ IndexL_t &= \left(\frac{w^l_{1t}}{w^l_{2t}} - 1\right)100. \end{aligned}$$

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

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

$$Skill_{it} = \left(\frac{w^s_{it}}{w^l_{it}} - 1\right)100.$$

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

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

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. Defining the average wage for country H as $w_t = \frac{S_{1t}}{S_t+L_t} w_{1t}^s + \frac{S_{2t}}{S_t+L_t} w_{2t}^s + \frac{L_{1t}}{S_t+L_t} w_{1t}^l + \frac{L_{2t}}{S_t+L_t} w_{2t}^l$, the Gini coefficient for country H is

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

The term in parentheses is a measure of dispersion in which we calculate the absolute deviations from the average income and weigh those by the population shares.

3.3 Production

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

$$Y_{it} = z_i S_{it}^{\beta_i} L_{it}^{(1-\beta_i)}, \tag{15}$$

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 firms which implies that all firms pay the same wage. Consequently, relative

labor demand can be described by the following condition:

$$\frac{w_{it}^s}{w_{it}^l} = \frac{\beta_i}{(1-\beta_i)} \frac{L_{it}}{S_{it}}, \tag{16}$$

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 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 16 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 GM there are no fixed costs of production, so that all firms produce each period until they are hit by an exit shock, which occurs with probability $\delta \epsilon (0,1)$ 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. Prices in real terms, relative to the price index in the destination market are then given by:

$$\rho_{d,it}(z) = \frac{p_{d,it}(z)}{P_t} = \frac{\theta}{\theta-1}\frac{\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}}{z}, \rho_{x,it}(z) = \frac{p_{x,it}(z)}{P_t^*} = \frac{1}{Q_t}\tau_t \rho_{d,it}(z). \tag{17}$$

[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.

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

$$d_{d,it}(z) = \frac{1}{\theta}\left(\frac{\rho_{d,it}(z)}{\psi_{it}}\right)^{1-\theta}\alpha_i C_t \tag{18}$$

$$d_{x,it}(z) = \begin{array}{ll} \frac{Q_t}{\theta}\left(\frac{\rho_{x,it}(z)}{\psi_{it}}\right)^{1-\theta}\alpha_i C_t^* - f_{xt}\left(w_{it}^s\right)^{\beta_i}\left(w_{it}^l\right)^{1-\beta_i}, & \text{if firm z exports} \\ 0 & \text{otherwise.} \end{array} \tag{19}$$

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

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 $\tilde{z}_{d,it}$ for all producing firms in sector i of country H and an average $\tilde{z}_{x,it}$ for all exporters in sector i of country H:

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

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

We can redefine all the prices and profits in terms of these average productivity levels. The average nominal price of H firms in the domestic market is $\tilde{p}_{d,it} = p_{d,it}(\tilde{z}_{d,it})$ and in the foreign market is $\tilde{p}_{x,it} = p_{x,it}(\tilde{z}_{x,it})$. The price index for sector i in H reflects prices for the $N_{d,it}$ home firms and F's exporters to H. Then, the price index for sector i in H can be written as $P_{it} = \left[N_{d,it}\left(\tilde{p}_{d,it}\right)^{1-\theta} + N_{x,it}^*\left(\tilde{p}_{x,it}^*\right)^{1-\theta}\right]$. Written in real terms of aggregate consumption units this becomes $\psi_{it} = \left[N_{d,it}\left(\tilde{\rho}_{d,it}\right)^{1-\theta} + N_{x,it}^*\left(\tilde{\rho}_{x,it}^*\right)^{1-\theta}\right]$, 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 $\{\tilde{d}_{is}\}_{s=t+1}^{\infty}$,

$$\tilde{v}_{it} = E_t \sum_{s=t+1}^{\infty} \left[\gamma^{s-t} (1-\delta)^{s-t} \left(\frac{C_s}{C_t} \right)^{-1} \tilde{d}_{is} \right]. \tag{20}$$

This also corresponds to the average value of incumbent firms after production has occurred. 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

$$\tilde{v}_{it} = f_{et} \left(w_{it}^{s} \right)^{\beta_i} \left(w_{it}^{l} \right)^{1-\beta_i}. \tag{21}$$

Finally, the number of firms evolves according to

$$N_{d,it} = (1-\delta)(N_{d,it-1} + N_{e,t-1}). \tag{22}$$

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 conductivities are

$$\tilde{z}_{d,it} = \nu z_{min} \text{ and } \tilde{z}_{x,it} = \nu z_{x,it}. \tag{23}$$

The share of exporting firms in sector i in H is

$$\frac{N_{x,it}}{N_{d,it}} = 1 - G(z_{x,it}) = 1 - \left(\frac{\nu z_{min}}{\tilde{z}_{x,it}} \right)^k. \tag{24}$$

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

profits must satisfy

$$\tilde{d}_{x,it} = (\theta - 1)\left(\frac{\nu^{\theta-1}}{k}\right) f_{xt} \left(w_{it}^{s}\right)^{\beta_i} \left(w_{it}^{l}\right)^{1-\beta_i}. \tag{25}$$

3.4 Market Clearing Conditions, Aggregate Accounting and Trade

Equilibrium requires that the net supply of home and foreign bonds equals zero worldwide, so that $B_{t+1} + B_{t+1}^{*} = 0$ and $B_{*,t+1} + B_{*,t+1}^{*} = 0$. Shares in firms cannot be traded internationally, which implies that $x_{it+1} = x_{it} = 1$. Imposing these equilibrium conditions and aggregating the home and foreign household budget constraints, implies that the accumulation of net foreign assets follows

$$\begin{aligned} &B_{t+1} + Q_t B_{*,t+1} + C_t = (1 + r_t)B_t + (1 + r_t^{*})Q_t B_{*t} + \frac{1}{2}\left(\widetilde{d}_{1t} N_{1t}^{d} + -Q_t \widetilde{d}_{1t}^{*} N_{1t}^{*d}\right) + \frac{1}{2}\left(\widetilde{d}_{2t} N_{2t}^{d} - Q_t \widetilde{d}_{2t}^{*} N_{2t}^{*d}\right) \\ &+\frac{1}{2}(w_{1t}^{s} S_{1t} - Q_t w_{1t}^{*s} S_{1t}^{*}) + \frac{1}{2}(w_{2t}^{s} S_{2t} - Q_t w_{2t}^{*s} S_{2t}^{*}) + \frac{1}{2}(w_{1t}^{l} L_{1t} - Q_t w_{1t}^{*l} L_{1t}^{*}) + \frac{1}{2}(w_{2t}^{l} L_{2t} - Q_t w_{2t}^{*l} L_{2t}^{*}) \\ &-\frac{1}{2}\left(\widetilde{v}_{1t} N_{1t}^{e} + -Q_t \widetilde{v}_{1t}^{*} N_{1t}^{*e}\right) - \frac{1}{2}\left(\widetilde{v}_{2t} N_{2t}^{e} - Q_t \widetilde{v}_{2t}^{*} N_{2t}^{*e}\right) - \frac{1}{2}(C_t - Q_t C_t^{*}). \end{aligned} \tag{26}$$

The current account of H is defined as

$$CA_t \equiv B_{t+1} - B_t + Q_t(B_{*,t+1} - B_{*,t}).$$

Total revenue in each sector must equal total expenditure on labor:

$$N_{d,it}\left(\frac{\tilde{\rho}_{d,it}}{\tilde{\psi}_{it}}\right)^{1-\theta} \alpha_i C_t + Q_t N_{x,it}\left(\frac{\tilde{\rho}_{x,it}}{\tilde{\psi}_{it}}\right)^{1-\theta} \alpha_i C_t^{*} + \tilde{v}_{it} N_{e,it} - \tilde{d}_{it} N_{d,it} = w_i^{s} S_{it} + w_{it}^{l} L_{it}. \tag{27}$$

4 Parametrization

This section describes the parameterization of the model that we use for the numerical simulations. In most aspects we follow GM and BRS. 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 also set the parameter for adjustment costs of international bond portfolios

to $\eta = 0.0025$, in line with GM. 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 GM.

To focus on comparative advantage, we assume that all industry parameters are the same across industries and countries except factor intensity (β_i). We consider symmetric differences in factor intensities ($\beta_1 = 0.6, \beta_2 = 0.4$). To assure a positive skill premium in both countries, we assume that unskilled labor is more abundant in both countries. The richer country, H, is endowed with more skilled labor than the poorer country, F. Specifically, we assume that $S = 700$ and $L = 1300$ for H and that $S^* = 300$ and $L^* = 1700$ for F. These numbers imply that the share of skilled workers in the whole workforce is 35% for the rich country and 15% 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]). In the scenario where we allow for training, only the total endowment with labor is fixed at $ENDOW = S_t + L_t = 2000$ and $ENDOW^* = S_t^* + L_t^* = 2000$, while the share of skilled and unskilled workers is determined endogenously. In that scenario we assume that the training cost is Pareto distributed and set the minimum training cost in such a way, that the share of skilled and unskilled workers matches the numbers above, which implies $\varepsilon^i_{\min} = 2.03$ and $\varepsilon^{*i}_{\min} = 5.19$. The shape parameter of the training cost distribution is set to $\kappa^{train} = 2$.

Artuç et al. [2010] find that average sector migration costs are large and very dispersed. We assume that the sector migration costs are Pareto distributed and use the same parameters for both countries to assure that our results are not driven by asymmetric parameter choices. We consider three different scenarios with varying degrees of sector migration costs. In the first scenario we shut-off active migration across sectors by choosing $\varepsilon^s_{\min} = \varepsilon^l_{\min} = 5$. This implies that no worker is willing to pay the sector migration cost to switch sectors.[11]

For the second scenario, we assume that unskilled workers are more mobile than skilled workers by choosing $\varepsilon^s_{\min} = 5$ and $\varepsilon^l_{\min} = 1$. We consider this the most realistic scenario since it is in line with a number of empirical studies: Artuç et al. [2010] find that US workers with a college degree face on average higher mobility costs than workers without a college degree; Greenaway et al. [2000] as well as Elliott and Lindley [2006b] find that unskilled workers in the UK are much more mobile across sectors than skilled workers; Elliott and Lindley [2006a] confirm this result and argue that this

[11] Remember that there is still the potential for worker reallocation via the replacement of retired workers with newly entering workers.

is due to their significant investments in specific human capital. Recent empirical studies on human capital specificity indicate that sector-specific skills are not industry- or occupation-specific but are defined over broader categories of tasks or skills. Poletaev and Robinson [2008] and Gathmann and Schonberg [2010] show that the pattern of individual wage growth is more closely associated with switching over these broadly defined categories than switching between occupations or industries. Gathmann and Schonberg [2010] show that in Germany 19% of the unskilled switch occupations each year as compared to 10% of the skilled. In addition, skilled workers tend to switch to occupations that require a very similar set of skills as their previous occupation while unskilled workers tend to switch to occupations with dissimilar skills. This suggests that on average skilled workers tend to be less mobile due to sector-specific human capital that is not easily transferable across occupations. However, there is also evidence pointing in the opposite direction. Autor et al. [2013b] find that skilled workers in the US are more mobile across sectors, but sectors in their analysis are much more narrowly defined than in our model. Nevertheless, in the robustness section we include a scenario where skilled workers are more mobile than unskilled workers, i.e., $\varepsilon^s_{\min} = 1$ and $\varepsilon^l_{\min} = 5$.

Finally, we analyze a third scenario where the sector migration costs are low for both skilled and unskilled workers, such that $\varepsilon^s_{\min} = \varepsilon^l_{\min} = 1$. The scale parameter for the sector migration cost distributions is identical across countries and industries and is set to $\kappa = 2$, which implies a highly dispersed distribution. We provide robustness checks with respect to both parameters of the sector migration cost distribution.

5 Symmetric trade liberalization scenarios

In this section we describe the dynamic adjustment after a symmetric trade liberalization shock. We assume that the Iceberg trade costs decrease for both sectors and for both countries from 1.3 to 1.2.[12] Naturally, the length of adjustment depends on the ability of workers to move between sectors. In the long run workers are fully mobile so that they have to earn the same wage in both sectors. In the short run, however, adjustment costs can lead to wage differentials between sectors. This effect can only be captured by using a dynamic model that can distinguish between the short run and the long run.

To highlight the role of worker mobility, we will distinguish four different scenarios: i) the first scenario features the slowest adjustment. Here we make the extreme assumption that incumbent workers cannot switch sectors due to sector-specific skills. In other words, the minimum of the cost function for moving between sectors is assumed to be so high that nobody chooses to switch sectors. However, there are still workers who retire and get replaced by newly entering workers. These workers are more flexible because they have not invested in their skills yet. ii) In the second scenario we assume

[12] In section 7 we provide robustness with respect to larger decreases in trade costs.

that unskilled workers can switch sectors. We restrict this ability to unskilled workers, because unskilled workers are less likely to have invested in sector-specific skills.[13] iii) In the third scenario we assume that skilled workers can also switch sectors. Although the speed of adjustment is different, all of these scenarios imply the convergence to the same steady state as a static model with perfectly mobile labor between sectors but with perfect immobility between skill classes as in BRS. iv) In the fourth scenario we relax this assumption by assuming that unskilled workers can invest in training to become skilled workers. In our view scenarios ii) and iv) are the most realistic but the comparison with the other scenarios is useful to understand the role of the mobility assumptions. In the robustness section we will also discuss the cases where skilled workers are more mobile across sectors than unskilled workers. In the following we concentrate on the analysis of the effects of trade liberalization on H, the country with the higher endowment with skilled labor.

5.1 Scenario 1: No active switching

Figure 2 shows the dynamic adjustment of selected variables for the first scenario, where only newly entering workers can choose in which sector to work. The decrease in trade costs implies that it is more beneficial for both countries to specialize more in the production of the good in which they have their comparative advantage. Country H is endowed with relatively more skilled labor and thus has a comparative advantage in the production of the skill-intensive good. When trade costs are reduced, it specializes more in the production of that good so that the demand in the import-competing sector (which produces the unskilled-intensive good) goes down, while the demand in the exporting sector (which produces the skill-intensive good) goes up.

This increases the wages of both skilled and unskilled workers in the exporting sector relative to their wages in the import-competing sector. This in turn induces an increase in the number of workers in the exporting sector at the cost of employment in the import-competing sector, but the adjustment is very slow because all active workers are stuck in the sector where they have acquired their skills (only newly entering workers can choose their sector of occupation).

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

[13] See the evidence discussed in the parametrization section, which favors this assumption.

an exogenous exit shock. This explains why the number of firms in the import-competing sector decreases only slowly.[14]

Surprisingly, however, the number of firms in the exporting sector also decreases in the short run, although it increases in the long run. The reason is that the slow movement of workers makes production very inefficient. There are too many workers in the import-competing sector and too few workers in the exporting sector. Consequently wages in the exporting sector are very high, depressing market entry in the early phases of the transition. In general the transition period appears very long. Note, however, that this scenario yields the longest transition since the assumed mobility of workers is the lowest. Recent results from structural estimations (see, e.g., Dix-Carneiro [2010] and Coşar [2013]) also point towards slow adjustment after trade liberalization shocks.

The focus of our analysis is on wage inequality. Due to restricted mobility in the short run, our model allows for wage inequality along two dimensions: i) a wage differential between the two sectors (see $IndexS$ and $IndexL$); ii) a wage differential between skilled and unskilled workers (the skill premium, see $Skill$). The first of the two wage differentials is due to mobility restrictions in the short run and will go away in the long run. The second exists even in the long run because otherwise workers would not have an incentive to invest in skills.

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

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

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

for skilled labor and, thus, increases the skill premium. In the process of moving workers from the import-competing sector to the exporting sector, the ratio of unskilled to skilled workers rises in both sectors, and with it the relative marginal product of skilled workers.[15]

Thus, in the short run the measure of overall wage inequality, the Gini coefficient, increases mainly through the first effect, the increase in inter-sectoral wage dispersion for each skill-class. With the movement of workers from the import-competing sector to the exporting sector, the wage inequality from this source decreases, but the skill premium increases. Thus, in the transition we have two counteracting effects on overall wage inequality. It turns out that the second effect dominates the first effect, so that overall wage inequality increases over time.

Another interesting feature can be found in the disaggregated data of wages. The wage of unskilled workers is overshooting quite substantially. This implies that for the most part of the transition real wages of unskilled workers are actually falling. Compared to the old pre-liberalization steady state an unskilled worker always earns a higher wage after trade liberalization. But after the initial adjustment (the big jump in the wage on impact), the workers suffer a prolonged period of real wage losses. Assuming that in reality workers and labor unions have a shorter time horizon when evaluating their gains from trade, it is understandable why unskilled workers tend to perceive themselves as losers of globalization. As time progresses, the initial jump in the real wage is 'forgotten' and the prolonged period of wage declines leads unskilled workers to suffer a perceived loss of wage income due to trade liberalization.

It might seem surprising that there are not any 'real' losers from trade liberalization, i.e., workers who suffer lower wages after trade liberalization than before.[16] After all, as described above, demand for labor in the import-competing sector falls. Why does that not lead to wage drops, at least in the short run? The reason is that there are two counteracting effects. The effect just described is a substitution effect, shifting labor demand from the import-competing sector to the exporting sector. This effect indeed tends to decrease wages in the import-competing sector. Note, however, that there is also an income effect. Trade liberalization reduces the costs of trade, makes global production more efficient, and thus increases total wealth. This effect tends to increase the real wage of all workers, by lowering the price level.

A note of caution is expedient here. Being a 'real' model, our model can only be used to make inference about real wages. Thus, our model mixes the effects of trade liberalization on nominal wages and on nominal prices. The real wage can rise because the nominal wage rises or because the nominal price drops. The real wage can rise even when the nominal wage drops, if the ensuing drop in nominal prices is even larger. In terms of the income and substitution effects discussed in the paragraph above, the substitution effect tends to lower nominal wages in the import-competing sector, while the income effect tends to decrease the overall price level. In the current scenario the income effect is dominant and so real

[15] This is not necessarily so, but depends on the relative movement of both types of workers. Depending on the calibration and the scenario the skill premium might decrease in the import-competing sector.

[16] This will change in some of the following scenarios.

wages go up in each sector, but we will also see scenarios where this is not necessarily the case. Let us stress that from a welfare point of view, real wages are the appropriate measure to use. Even if some workers would suffer nominal wage cuts, if their real wage goes up, their welfare goes up, because they can afford to buy more products.

Remember that our model allows for unbalanced trade in the short run. In this scenario with symmetric cuts in trade costs and low mobility of workers, this, however, does not play a role. Trade liberalization does not lead to unbalanced trade, not even in the short run.

5.2 Scenario 2: Active switching of unskilled workers

So far we have assumed that only workers newly entering the labor market can choose in which sector they want to work. We will now relax this assumption by lowering the minimum of the sector migration cost distribution to 1. For the moment, we restrict this possibility to unskilled workers, because their sector mobility is less likely to be restricted by sector-specific investments in human capital. For a discussion of the empirical evidence supporting this assumption see section 4.

Figure 3 shows the results. Similarly to scenario 1 workers in the comparative advantage sector benefit relative to the workers in the comparative disadvantage sector. Both measures of sectoral wage inequality rise. Note, however, that there are important differences between the skill classes: the wage differential between sectors increases strongly and persistently for high-skilled workers, while it jumps up but then recedes very fast for low-skilled workers. The reason is that unskilled workers are more mobile and thus react more strongly to sectoral wage differentials. As the demand in the exporting sector goes up, unskilled workers quickly move from the import-competing sector to the exporting sector. This increases the supply of unskilled workers in the exporting sector, reducing the upward pressure on wages. At the same time, the supply of unskilled workers in the import-competing sector goes down, reducing the downward pressure on wages in that sector. In contrast, skilled workers are stuck in the sector where they have acquired their skills. Consequently, the supply of skilled workers cannot adjust so quickly and wage differentials for skilled workers are much more persistent.

Furthermore, the faster (between-sector) migration of unskilled workers relative to skilled workers implies a stronger shift in their respective shares in the production process. This benefits skilled workers in the exporting sector: as skilled and unskilled workers are complements, the increase in the number of unskilled workers increases the productivity of skilled workers. But it further hurts the skilled workers in the import-competing sector because the decrease in the number of unskilled workers there reduces the productivity of skilled labor. Thus, skilled workers in the import-competing sector are hit twice by trade liberalization. First, the demand for their skills decreases. Second, their productivity goes down because so many unskilled workers leave the sector. However, these are only transitory effects. In the long run, the number of skilled workers goes up in the exporting sector because newly entering skilled workers prefer the exporting

sectors. Therefore, in the very long run the sectoral wage differential vanishes even for skilled workers.

The asymmetric speed of adjustment has also important implications for the skill premium, which, in the short run, now goes in opposite directions in the two sectors. In the exporting sector the skill premium still goes up, and even more so and more quickly than in scenario 1, due to the described movement of unskilled workers, which benefits the skilled workers in the exporting sector. In contrast, the skill premium in the import-competing sector now goes down, although in the long run the skill premium in both sectors must be the same because inter-sectoral wage differentials must vanish.

The Gini coefficient, our measure of overall wage inequality, jumps up on impact and then slowly increases further due to the rising skill premium. Ten years after the reduction in trade costs, the Gini coefficient has increased by 2%. To put this number into perspective, ten years after China's WTO accession, the Gini coefficient for the US had increased by 6.5%, while for the UK the Gini coefficient had increased by 3.3%. According to our model this is, however, only a relatively small part of the total effect: in the new steady state the Gini coefficient is 5.6% higher than in the old steady state.[17]

The faster inter-sectoral migration of unskilled workers has also implications for firm dynamics. Due to the smaller increase in the unskilled wage in the exporting sector it pays off more to invest into new firms. The total number of firms in the exporting sector still goes down initially but recovers very quickly. After about 20 periods the number of active firms is higher then in the old steady state, while this took almost 80 periods in scenario 1.

In scenarios 1 and 2 we used assumptions on two opposite extremes: in scenario 1 sector migration costs are so high that none of the incumbent workers would want to switch sectors, while in scenario 2 sector migration costs are zero for unskilled workers. The most realistic case is probably somewhere in between, with sector migration costs lower than in scenario 1 and higher than in scenario 2. In the robustness section we will show such an intermediate case, which basically implies that the impulse responses lie in between the impulse responses of scenarios 1 and 2.

5.3 Scenario 3: Active switching of skilled and unskilled workers

This scenario reduces the minimum of the sector migration cost distribution for both unskilled and skilled workers to 1. Results are illustrated in figure 4. The results resemble those of scenario 1, but the adjustment is much quicker. The inter-sectoral wage differential is receding much faster and the skill premium is rising much faster. Our measure of overall wage inequality is lower than in scenario 1 in the first periods but then rises much faster.

Due to the faster movement of workers, the adjustment of firms also takes place much faster. The number of firms in the import-competing sector goes down much faster. The number of firms in the exporting sector drops only very briefly

[17] Note, however, that this strongly depends on the assumption of fixed endowments with skilled and unskilled worker, as will become clear further below.

and quickly gets on a rising path.

5.4 Scenario 4: Training

In BRS and in our scenarios 1-3 it is assumed that the endowments of skilled and unskilled workers are fixed. Although workers are mobile between the two sectors, they are not mobile between skill classes. In this section we relax this assumption by allowing unskilled workers to invest in training to become skilled workers, as described in section 3.2.2. We consider two alternative scenarios. In the first scenario we assume that the training cost of new entrants as well as the minimum of the training cost distribution of incumbents are both equal to the long run skill premium. In the second we assume that the minimum of the training cost distribution of incumbents is higher than the training cost of new entrants which is still equal to the long run skill premium. The assumptions concerning inter-sectoral migration we are using in this scenario are equivalent to scenario 2: unskilled workers can switch sectors, while skilled workers cannot, because of sector-specific skills.

The solid line in figure 5 illustrates the first scenario. The availability of flexible opportunities to train has dramatic consequences for the transitional dynamics. The increased demand in the exporting sector induces some unskilled workers in the exporting sector to invest in their skills, speeding up the increase in the number of skilled workers in the exporting sector. The possibility to train and become skilled in the exporting sector also enhances incentives for unskilled workers in the import-competing sector to switch to the exporting sector. This reduces the productivity of skilled workers in the import-competing sector by even more than in the second scenario, with the consequence that their wage drops sharply after the initial upward jump and even falls below the pre-liberalization steady state level.

As a result, the skill premium decreases strongly and very persistently in the import-competing sector, while it sharply but only briefly increases in the exporting sector. This implies that some of the skilled workers in the import-competing sector would not have invested in skills before trade liberalization, had they anticipated the development of wages. Note, however, that due to the way we have modeled the training decision, in the long run the skill premium must go back the old pre-liberalization steady state level in both sectors. In contrast to the earlier scenarios, in the long run the higher demand for skills due to trade liberalization results in a higher number of skilled workers instead of a higher skill premium. Ignoring training possibilities leads to exaggerated estimates of the skill premium effect of trade liberalization.

Inter-sectoral wage inequality among skilled workers moves as expected, the wage in the exporting sector increases strongly and persistently relative to the wage in the import-competing sector. The development of inter-sectoral wage inequality among unskilled workers also moves as expected. It increases sharply on impact and quickly recedes.

The consequences for overall wage inequality are also in stark contrast with the results we had so far. On impact overall wage inequality increases because of the increase in inter-sectoral wage inequality as well as the rise in the skill premium in

the exporting sector. However, these trends quickly recede and the decrease in the skill-premium in the import-competing sector begins to dominate, so that in the medium run total wage inequality actually drops below the old steady state level. Note, however, that this drop in wage inequality is not due to higher unskilled wages but due to the bad performance of skilled workers in the import-competing sector. In the long run overall wage inequality does not change much, because the skill premium is fixed and inter-sectoral wage inequality vanishes. The Gini coefficient still increases a little bit in the long run, because the composition of the workforce changes. The number of skilled workers goes up, and thus more workers receive the skill premium. This increases wage inequality if the number of skilled workers is small to begin with, which is the case with our parameterization.

Overall, this scenario delivers much more polarizing labor market developments than the previous scenarios, with the skilled workers in the import-competing sector being the biggest losers, due to their investments in the 'wrong' sector.[18]

Note, however, that the assumptions concerning the opportunities to train are quite extreme. Incumbent workers can react without any delay to the changing wage-signals so that the reallocation of workers is very quick with the exception of the skilled workers in the import-competing sector. Therefore, we consider a second scenario, which is an intermediate case between the extremely flexible training possibilities considered in this section so far and the complete omission of training in the previous sections. We assume that newly entering workers face the same training cost as before, but that the minimum of the training cost distribution of incumbents is higher. This has the consequence that the steady state does not change at all, but that the convergence to the new steady state is slowed down.

The dashed line in figure 5 illustrates the results in this scenario. The main difference is that the rise in the skill premium in the exporting sector is much more persistent. Fewer workers have the possibility to upgrade their skills and, therefore, the number of skilled workers in the exporting sector increases much more slowly. This suffices to turn the drop in the Gini coefficient experienced in the first scenario of this section into an increase in the Gini. In fact, the Gini overshoots its long run value and then slowly converges to it from above.

Thus, this scenario reconciles the results of our model with the empirical finding that trade liberalization increases wage inequality. But it is still the case that the long run effects on wage inequality are much lower, because more of the adjustment goes into quantities (more skilled workers) and less into wages. We learn from the analysis in this section that training plays an extremely important role. Having good and flexible training opportunities available not only dampens the long run increase in overall wage inequality but also eases the transition to the new steady state, even to such an extent that wage inequality could go down.

[18] Much of this resembles the effects discussed in Larch and Lechthaler [2011], who analyze the effects of trade liberalization on unemployment in the BRS model. However, they use a static model and thus the dynamic perspective, which is at the heart of this paper, is missing.

6 Asymmetric trade liberalization scenarios

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

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

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

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

iii) Finally, we analyze a unilateral reduction in the trade costs for exporting the unskilled-intensive good from the poor country to the rich country (scenario 7). Although it appears unlikely that a country reduces the trade costs for one of its sectors without any concessions from its trading partners, we include this scenario to make our results more comparable to the other recent papers studying the transitional dynamics of trade liberalization (Artuç et al. [2010], Dix-Carneiro [2010] and Coşar [2013])

In all three scenarios, we restrict our analysis to the mobility assumption that we, in line with empirical results from other papers, consider the most realistic, namely assuming that unskilled workers are more mobile across sectors than skilled workers. We will consider both the case with exogenous endowments with skilled workers (analogous to scenario 2 of the previous section), to be comparable to BRS, and the case with sector specific training where incumbent and entering workers face the same training costs (analogous to scenario 4).

6.1 Scenario 5: Liberalization of the skill-intensive sector

In this scenario the rich country manages to push through the liberalization of trade in the sector where it has its comparative advantage, i.e., τ_1 and τ_1^* are both reduced from 1.3 to 1.2, while τ_2 and τ_2^* remain unchanged at 1.3. With

this strategy the rich country might hope to gain from increased exports in its comparative advantage sector, while at the same time avoiding stronger competition in its import-competing sector. We show that this reasoning is flawed.

The results are illustrated in figures 6 and 7. Let us first concentrate on the case without training, figure 6. It is immediately evident that unskilled workers are hard hit in this scenario. Although the wage of unskilled workers in the import-competing sector increases a bit on impact, it soon drops and then stays below the old steady state value. The unskilled wage in the exporting sector immediately drops and stays below its pre-liberalization level.

The wages of skilled workers in the exporting sector drop on impact but increase in the long run. The wages of skilled workers in the import-competing sector also fall below the old steady state value for some time but must rise eventually to catch up with the skilled wage in the exporting sector (remember that in the long run wages have to be equalized across sectors). Note, however, that the wage gains for the skilled workers are much smaller than in the scenario where both sectors were liberalized (compare figure 3). The development of exporting firms is also interesting. While the number of exporting firms in the liberalized sector goes up, the number of exporting firms in the not liberalized sector goes down.

Thus, leaving out the import-competing sector from trade liberalization fails to protect the wages of unskilled workers and the wages of skilled workers in the import-competing sector. The skill-intensive sector in F is exposed to higher competition, and thus F specializes more in the production of the unskilled-intensive good. This implies that H's import-competing sector is exposed to higher competition from abroad, even though the trade costs in that sector have not decreased. Thus, the substitution effect (away from the import-competing sector) is still in place. But the partial liberalization of trade implies lower efficiency gains in global production and thus the income effect, which is beneficial to all workers, is lower than when trade is liberalized in both sectors. This explains why real wages of unskilled workers go down permanently in this scenario.

Allowing for endogenous training, as illustrated in figure 7, has qualitatively similar implications. Trade liberalization increases the demand for skilled workers. This induces more unskilled workers to pay the training cost to become skilled workers. Relative to the scenario without training, the total supply of unskilled workers is thus lower, while the total supply of skilled workers is higher. Consequently, the wages of unskilled workers are pushed up relative to the scenario without training, while the wages of skilled workers are pushed down. This implies that skilled workers in the import-competing sector have to endure a prolonged period of wages below the pre-liberalization steady state. In contrast, the push-up in the unskilled wage is large enough so that the initial wage losses are turned into wage gains rather quickly. But again, the wage increases are much lower than in the scenarios where both sectors are liberalized.

6.2 Scenario 6: Liberalization of comparative-advantage sectors

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

The results for exogenous endowments with skilled and unskilled workers are illustrated in figure 8. This scenario yields the most dramatic effects so far. While the wage increases of skilled workers in the exporting sector are higher than in all previous scenarios, the wages of skilled workers in the import competing sector and the wages of unskilled workers in both sectors go down. Even though the wage of unskilled workers in the exporting sector jumps up on impact, it becomes negative very quickly. The drop in wages of skilled workers in the import-competing sector is very large and persistent. The drop in unskilled wages is permanent and large (almost 2%). Note that the average wage of skilled workers still exhibits a strong increase, so looking only at the aggregates ignores the huge differentials revealed at a more disaggregated level. In line with these developments all our measures of wage inequality increase more sharply than before. For example, the skill premium increases by almost 20%. In scenario 2 it increased by only half of that amount.

In this scenario the import-competing sector is hit double. The sector cannot gain from lower trade barriers but at the same time it is still exposed to higher competition from abroad.

Figure 9 shows the results under the assumption that unskilled workers can invest in training. Again partial trade liberalization hurts the income of skilled workers in the import-competing sector severely and persistently, even more severely than in the scenario without training. The wage of unskilled workers in the import-competing sector drops only temporarily and then increases.

Again we conclude that the partial liberalization of trade in specific sectors is not better than full liberalization. This strategy cannot protect the profits of firms in vulnerable sectors. Furthermore, it not only can reduce the wage gains from trade for all groups of workers but can also lead to lower incomes for some groups of workers such as unskilled workers and skilled workers in the exporting sector.

6.3 Scenario 7: Unilateral Liberalization

This is the scenario that is most comparable to other recent studies of the dynamic adjustment to trade liberalization (Artuç et al. [2010], Dix-Carneiro [2010] and Coşar [2013]). These papers use small open economy models, which implies that world market prices are given exogenously and that bilateral trade liberalization scenarios are hard to model. Therefore, these papers restrict themselves to the analysis of a unilateral reduction in the costs of imports in one specific sector,

typically the import-competing sector. Therefore, we assume in this scenario that the trade costs for exporting the unskilled-intensive good from the poor country to the rich country are reduced (τ_2^* goes down from 1.3 to 1.2).[19]

The results for exogenous endowments with skilled and unskilled workers are illustrated in figure 10. Not surprisingly, the implications of a unilateral reduction in trade costs are very different from the bilateral reduction in trade costs in our baseline scenario 2. The wage of skilled workers in the exporting sector increases much more, while the wage of skilled workers in the import-competing sector goes down much more and much more persistently after its initial jump. It is also notable that in this scenario almost all of the long run benefits of trade liberalization go the skilled workers. The long run increase in the wage of unskilled workers is almost indistinguishable.

Wage inequality measured by the Gini index rises much more in the scenario with unilateral trade liberalization, both in the short run and in the long run. In the short run this development is driven by a sharp and persistent increase in the inter-sectoral wage inequality for skilled workers, which is more than twice as strong as in scenario 2. In the long run this development is driven by a higher skill premium. It is also notable that the effects on wage inequality are less extreme than in the previous asymmetric trade liberalization scenarios. The reason is that lower barriers to exports of the exporting sector additionally benefited the skilled workers in that sector.

Figure 11 shows the same trade liberalization scenario allowing for worker training. The short run effects on wage inequality are again much stronger under unilateral trade liberalization than under full liberalization. Of course, in the long run wage inequality still does not change significantly because both the inter-sectoral inequality and the skill premium converge to zero at the new steady state.

We can conclude that the effects of unilateral and bilateral trade liberalization are very different. This is hardly surprising but underscores the value of having a general equilibrium model with two large economies, which allows for a meaningful simulation of both types of trade liberalization.

7 Robustness

In this section we perform robustness checks and try to investigate more closely the importance of various channels for the dynamic adjustment after trade liberalization. First, we shut off firm dynamics. Second, we analyze the role of selection into export markets and of firm heterogeneity. Third, we simulate a scenario with higher trade costs. Fourth, we change the distributional parameters of the sector migration costs. Finally, we analyze a scenario where the skilled workers are more mobile than the unskilled workers. We restrict ourselves to the symmetric liberalization scenarios 2 (with active switching of unskilled workers only) and 4 (with training where incumbents and new entrants face the same training costs)

[19] There is still a difference to the other papers because we still allow for general equilibrium effects.

because we consider them the most realistic. Results for the other scenarios are available upon request.

7.1 Firm dynamics

In GM all the dynamics arise from the slow adjustment of firms. As noted in Burstein and Melitz [2012], the model would not yield any transitional dynamics if domestic firms had to pay fixed costs as well, because unproductive firms would drop out of the market immediately. This is different in our model, because sector migration costs and training costs give rise to slow labor market adjustment. Thus, even without the slow adjustment of firms, our model yields transitional dynamics.

To demonstrate this we shut off firm dynamics completely, by making the number of domestic firms ($N_{d,i}$), the number of newly entering firms ($N_{e,i}$) and the number of exporting firms ($N_{x,i}$) exogenous variables during the transition. We assume that these variables immediately jump to their new steady state levels. The result is demonstrated by the dash-dot black line in figures 12 and 13. Since none of the parameters are changed, the initial and final steady states are the same as in our baseline simulations; only the transition is affected.

For most variables shutting-off of firm dynamics only implies quantitative changes but not qualitative changes. There is a notable exception: the wage of unskilled workers in the import-competing sector drops on impact, whereas it increased in our baseline scenario. The wage of skilled workers in the import-competing sector goes down more persistently than in the baseline scenario 2.

Due to the instantaneous adjustment of firms, the number of firms in the import-competing sector drops much faster than in our baseline scenarios. This implies that the demand for labor in the import competing sector falls much faster. The unskilled workers are more mobile, migrate more quickly to the exporting sector and, therefore, the effect is very short-lived. The skilled workers are more immobile and, therefore, endure lower wages for a much longer period. Note, however, that ultimately the wage of skilled workers in the import-competing sector catches up with the wage of skilled workers in the exporting sector.

This has also implications for wage inequality. The figures illustrate that all our measures of wage inequality react much more strongly in the short run, especially the inter-sectoral wage inequality among skilled workers. Thus, slow firm adjustment dampens the effects of trade liberalization on wage inequality.

7.2 Selection into export markets and firm heterogeneity

In this section we analyze the role of selection into export markets and of firm heterogeneity. In contrast to Melitz [2003], in our model the two are indistinguishable because we do not have selection into the domestic market. Shutting off selection

into export markets in our model implies that both the average productivity of domestic firms and the average productivity of exporting firms are fixed. This makes firm heterogeneity irrelevant because the model is isomorphic to one in which only one firm exists with its productivity equal to the average of the productivity distribution of the heterogeneous firms model.

To study the role of selection into export markets and firm heterogeneity we set the fixed cost of exporting equal to zero. This implies that all active firms take up exporting, i.e., the share of exporting firms is always equal to one. It further implies that the average productivity of exporting firms is equal to the average productivity of domestic firms (in fact, the two sets are identical). The results are illustrated in figures 14 and 15.

In general, wages tend to react by less in the model with selection into export markets. Selection into export markets provides an additional margin of adjustment. In response to the increase in demand that follows from trade liberalization, the share of exporting firms increases, especially in the exporting sector. Since exporting firms are more productive than domestic firms, the increase in the share of exporting firms makes production generally more efficient. This implies that less reallocation between sectors is needed to increase production, both in terms of firms and in terms of workers. In the model where all firms export, this adjustment mechanism is missing and therefore more reallocation of factors between the two sectors is necessary.

Due to the lower reallocation that is necessary in the model with selection into export markets, wage differentials need to rise by less. In the end these wage differentials drive the reallocation of workers and if less reallocation is needed, wage differentials tend to be lower. Note that the differences are quite sizable, not so much in the short run as in the long run. E.g., in scenario 2 the decrease in the number of both skilled and unskilled workers in the import-competing sector is about twice as large as in the model without selection into export markets, while the increase in the skill premium is about 50% higher. Thus, it can be concluded that selection into export markets and firm heterogeneity are dampening the effects of trade liberalization on wage inequality.

7.3 Trade costs

In our baseline scenario we have used the standard approach of reducing trade costs from 1.3 to 1.2. This is arguably quite low, given that we want to capture the trade between a rich, developed country and a poor, developing country. As demonstrated in Larch and Lechthaler [2011] the magnitude of trade costs matters for the type of trade: for high trade costs inter-industry is dominant, while for low trade costs intra-industry becomes more and more important. Therefore, we check how robust our results are to the type of trade (intra- versus inter-industry) by simulating a scenario with higher trade costs.

Figures 16 and 17 compare scenarios 2 and 4 of our baseline with the same scenarios under a trade shock that decreases

τ and τ^* from 2.5 to 2, so that the trade costs decrease from 150% to 100%. In relative terms this is the same reduction as in our baseline simulations where we decreased the trade costs from 30% to 20%.

The results from the higher transport cost simulation are qualitatively similar to our baseline scenarios: all variables move in the same direction and the shape of most impulse response functions is also very similar. The magnitude of the reactions is harder to compare because the experiments are so different, including different steady states before and after trade liberalization. Most variables move relatively less in the scenario with higher trade costs, even though the absolute reduction in trade costs is higher. This is also true for all our measures of wage inequality, suggesting that trade liberalization has a larger impact on wage inequality when trade costs are already low to begin with. One exception is again the number of exporting firms which is much more responsive if trade costs are higher. This is not surprising, given that the number of exporting firms is much lower when trade costs are high.

7.4 Sector migration costs

This section discusses robustness with respect to both distributional parameters of the sector migration cost. We selected the shape parameters of the sector migration cost distribution and the training cost distribution in order to generate very dispersed distributions. Now we use $\kappa = \kappa_{train} = 6$ instead of $\kappa = \kappa_{train} = 2$, which implies much lower dispersion. Our results remain unchanged even quantitatively.[20]

Figure 18 compares our baseline scenario 2, where $\varepsilon^l_{\min}$ was assumed to be 1 with a scenario where it is 1.01. This implies that some workers decide to switch from the import-competing sector to the exporting sector, but the number of switching workers is lower then in scenario 2. Thus, this is an intermediate case between scenarios 1 and 2. The figure shows that the results do not change qualitatively but only quantitatively. We thus can conclude that our qualitative results do not depend on the distributional parameters.

7.5 More mobile skilled workers

In the simulations so far we have assumed that skilled workers are less mobile than unskilled workers. In this section we demonstrate what happens when this assumption is reversed, i.e., when skilled workers are mobile across sectors ($\varepsilon^s_{\min} = 1$), while unskilled workers are immobile across sectors ($\varepsilon^l_{\min} = 5$). We assume that the total number of skilled and unskilled workers is fixed, so that there is no training.

The results are illustrated in figure 19. Not surprisingly, the results look very different in this scenario. The wage of skilled workers in the import-competing sector no longer goes down in the short run as in scenario 2 (where skilled

[20] The simulation results are virtually identical. For brevity they are not included in the paper but are available upon request.

workers were immobile) but instead shoots up very quickly. The reason is that skilled workers are quick to leave the import-competing sector, which drives up the productivity of the remaining workers. Due to the fast movement of skilled workers, the inter-sectoral wage inequality among skilled workers recedes very quickly.

The losers of globalization are now the unskilled workers in the import-competing sector. The demand for the products they are producing goes down and due to the quick outflow of skilled workers their productivity also goes down. This leads to a short run decrease in their wage. Unskilled workers in the exporting sector are actually experiencing larger wage gains than in scenario 2, because their productivity is higher. As a result the inter-sectoral wage inequality among unskilled workers is larger and much more persistent.

The development of the skill premium is interesting. In the import-competing sector the skill premium shoots up, while in the exporting sector the skill premium goes down. This seems surprising but is explained by the quick movement of skilled workers, which, in the short run, favors the unskilled workers in the exporting sector because their productivity goes up. In the aggregate these diverse developments wash out, so that overall wage inequality develops similarly to scenario 2.

7.6 Summary

In this section we have explored in more detail the effects of various features of our model on our results regarding wage inequality. We have found that the slow adjustment of firms and the selection of firms into export markets lead to more modest increases in wage inequality after trade liberalization. For the most part, changing the importance of the various features of our model has only quantitative, but no qualitative implications. One notable exception is the development of skilled wages in the import-competing sector when firm dynamics are shut off. The immediate adjustment of firms reduces the demand for skilled workers in the import-competing sector to such an extent that their wage goes down for a prolonged period of time. Another exception is of course the assumption concerning the mobility of skilled workers relative to the mobility of unskilled workers. The results are dramatically changed when skilled workers are assumed to be more mobile than unskilled workers.

8 Conclusion

We build a two-country, two-sector dynamic general equilibrium trade model with labor mobility costs in order analyze the transitional dynamic effects of permanent trade liberalization. Our analysis concentrates on the change of wage inequality that occurs in developed countries from increased trade with developing countries. The advantage of our analysis is that we use a general equilibrium model of two large countries, while other recent dynamic papers use small open economy

models. This implies that we can analyze a broader scope of trade reforms, not just a decrease in the restriction to imports in a specific sector. Our results show that different types of trade reform lead to starkly different transitions. Thus it is essential to be able to capture a broad scope of trade reforms.

We distinguish two potential sources of wage inequality, the wage differential between workers who are in the same skill class but in different sectors (comparative advantage versus comparative disadvantage sectors) and the skill premium, i.e., the wage differential between skilled and unskilled workers. In the short run, wage inequality is dominated by changes in the wage differential across sectors: it rises due to rising relative demand for workers in the exporting sector and due to the slow reallocation of workers. In the medium to long run, when workers are more mobile, wage inequality is dominated by changes in the skill premium.

Another contribution of our paper is that we analyze scenarios in which we allow unskilled workers to train to become skilled workers. This has important implications both for the long run effects of trade liberalization and for the transition to the new steady state. The long run effects of trade liberalization on wage inequality are considerably reduced because more of the adjustment is accomplished via quantities (more skilled workers) and less via wages. Good training opportunities also speed up the transition to the new steady state.

Our results also suggest that full trade liberalization (encompassing both sectors in both countries) is better than partial or unilateral trade liberalization. When trade liberalization is restricted to the skill-intensive sector the gains from trade are considerably reduced, while the effects on wage inequality are minor at best. If both countries restrict their trade liberalization to their respective comparative advantage sectors, the effects are even more striking. Not only are the gains from increased trade reduced but the workers in the import competing sector actually experience wage declines, which does not occur under symmetric trade liberalization. The reduction in trade in the import-competing sector that comes with a liberalization of the exporting sector hurts skilled workers who have invested their skills in the 'wrong' sector. Unilateral liberalization, on the other hand, leads to more polarized income distribution than full liberalization. After a unilateral reduction in the trade costs of exporting the unskilled-intensive good from the poor to the rich country the increase in inequality is much larger than after full trade liberalization.

While a full analysis of policy implications is left for future research, a few conclusions are suggestive. Labor market policies of increasingly globalized developed countries should concentrate on providing moving subsidies to workers so that they can switch their sector of employment more easily. In addition, unskilled workers value the option to train and become skilled in the exporting sector very highly. Our findings suggest that a training subsidy can make this option to train even more valuable and mitigate the increase in inequality after trade liberalization.

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9 Tables and Figures

Table 1		
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
η	cost of international bond trading parameter	0.0025
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	300
L^*	endowment with unskilled labor at Foreign	1700
s	retirement rate of workers	0.02
$\varepsilon^s_{\min}$	minimum sector migration cost for skilled labor	$5(S1, S2, S4, S5, S6, S7), 1(S3)$
$\varepsilon^l_{\min}$	minimum sector migration cost for unskilled labor	$5(S1), 1(S2, S3, S4, S5, S6, S7)$
κ	Pareto shape parameter for sector migration cost distribution	2
$\varepsilon^i_{\min}$	minimum cost of training at Home	2.03
$\varepsilon^{*i}_{\min}$	minimum cost of training at Foreign	5.19
κ^{train}	Pareto shape parameter of training cost distribution	2
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

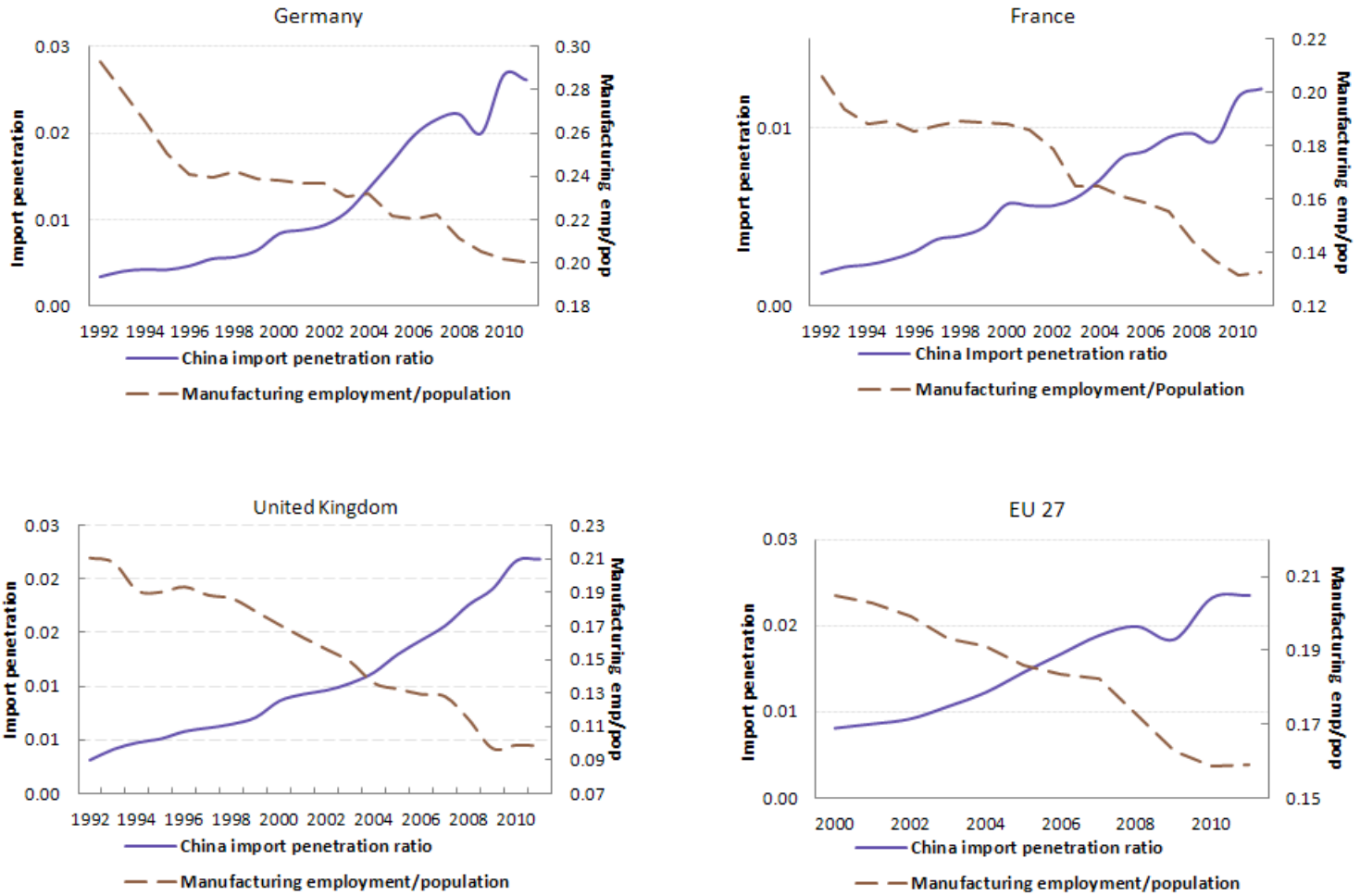

Figure 1: Import Penetration Ratio for Imports from China (left scale), and Share of Working-Age Population Employed in Manufacturing (right scale)

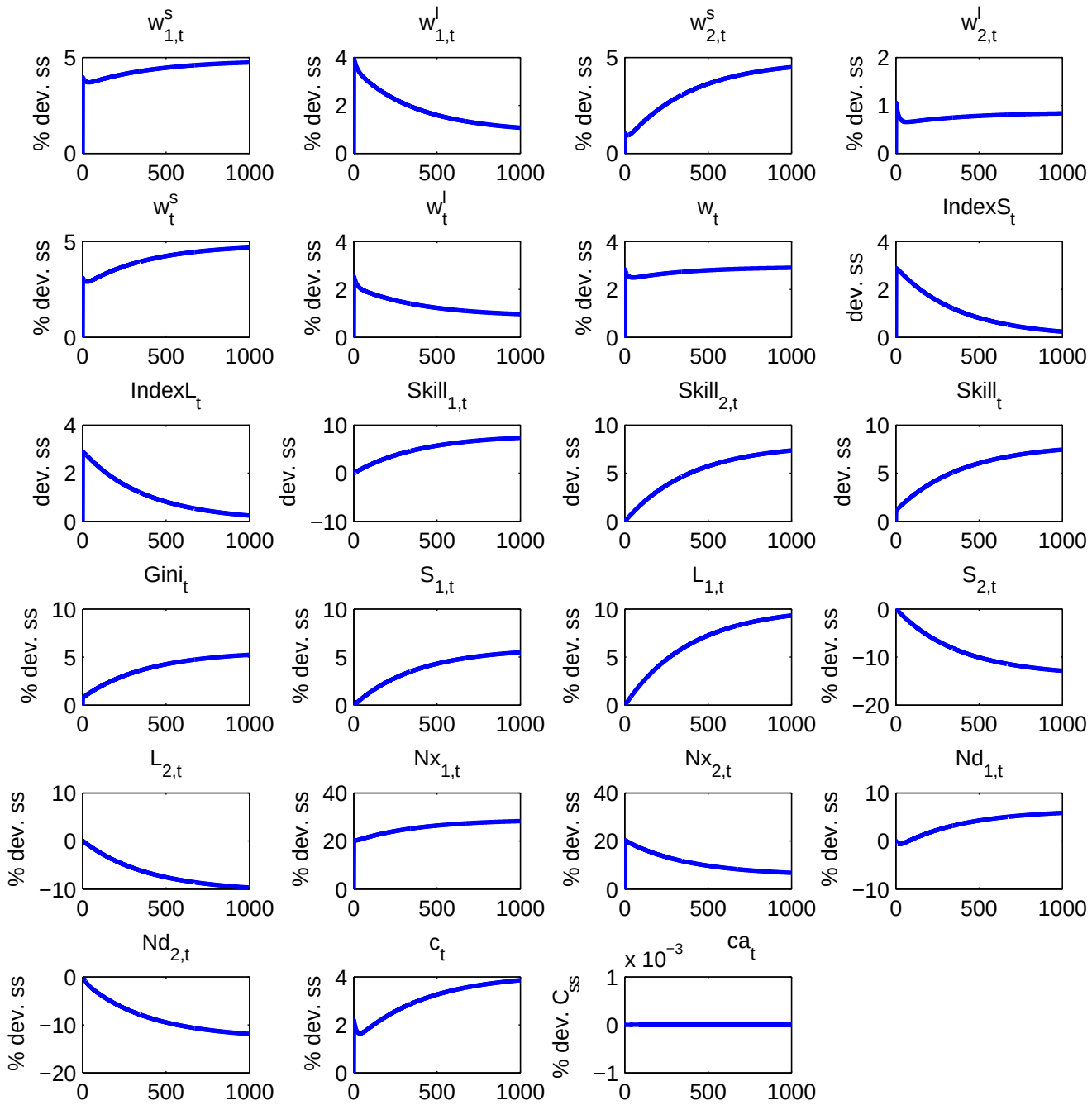

Figure 2: Scenario 1 Symmetric Liberalization With No Active Switching of Workers

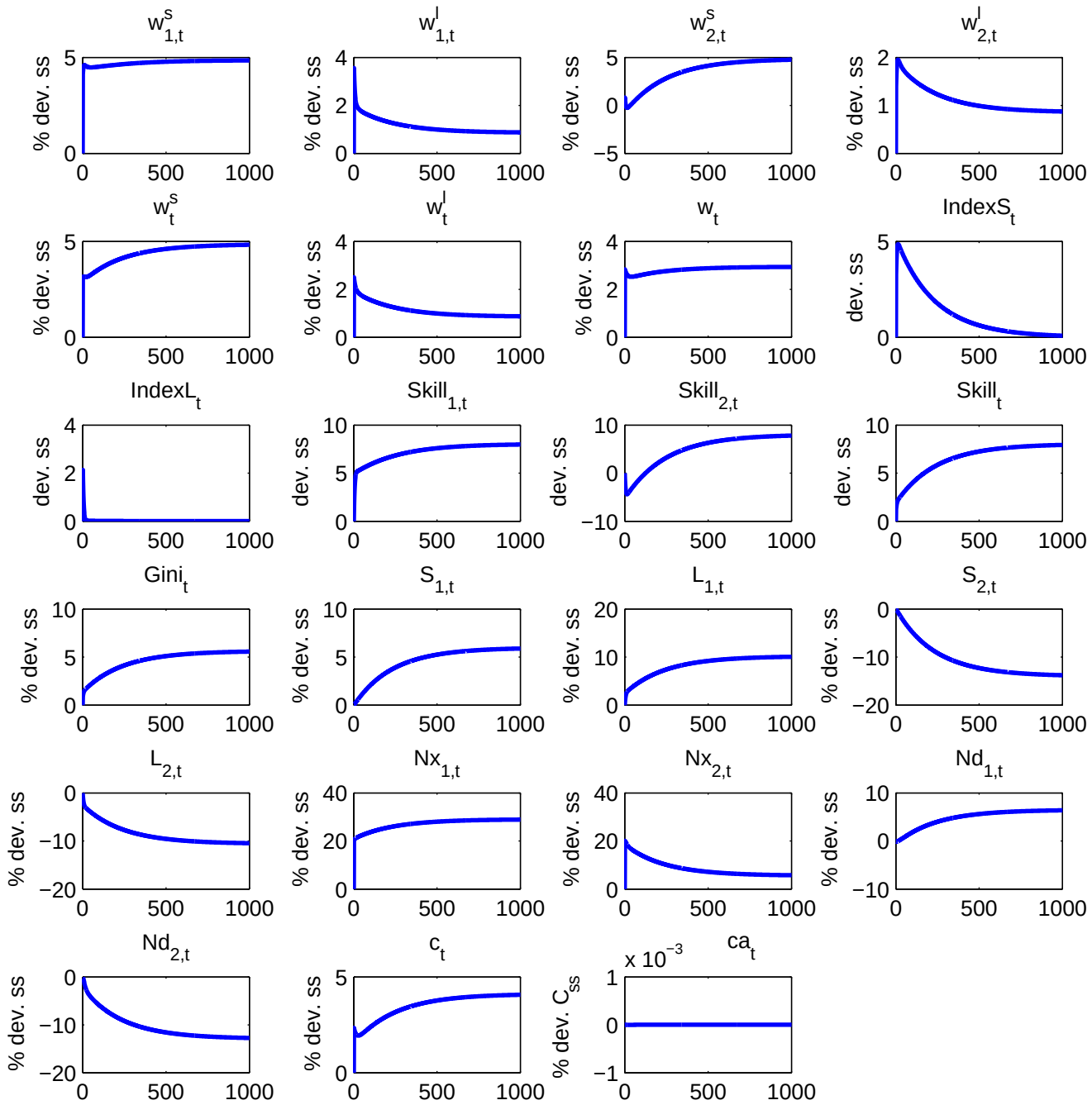

Figure 3: Scenario 2 Symmetric Liberalization With Active Switching of Unskilled Workers Only

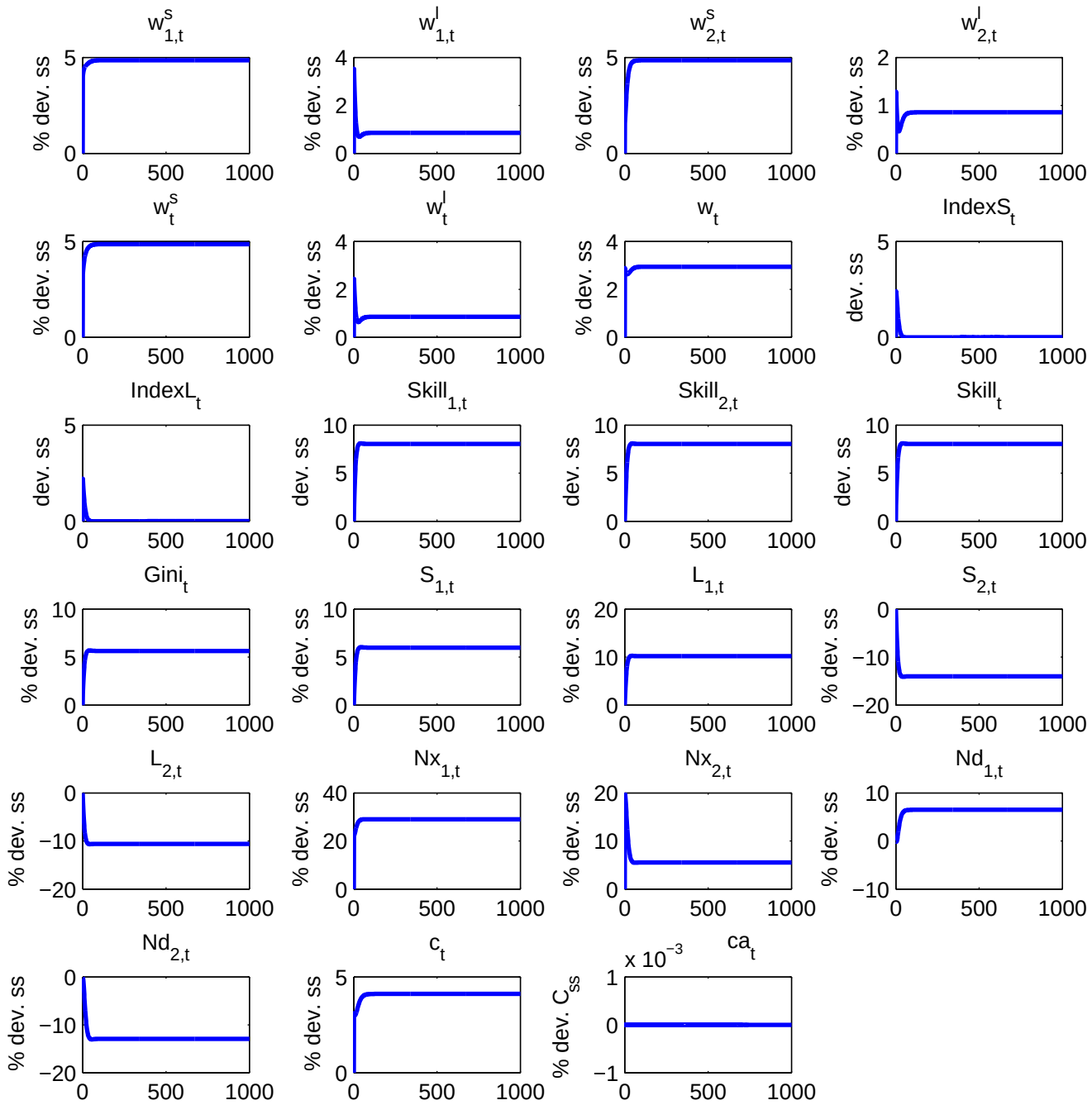

Figure 4: Scenario 3 Symmetric Liberalization With Active Switching of Skilled and Unskilled Workers

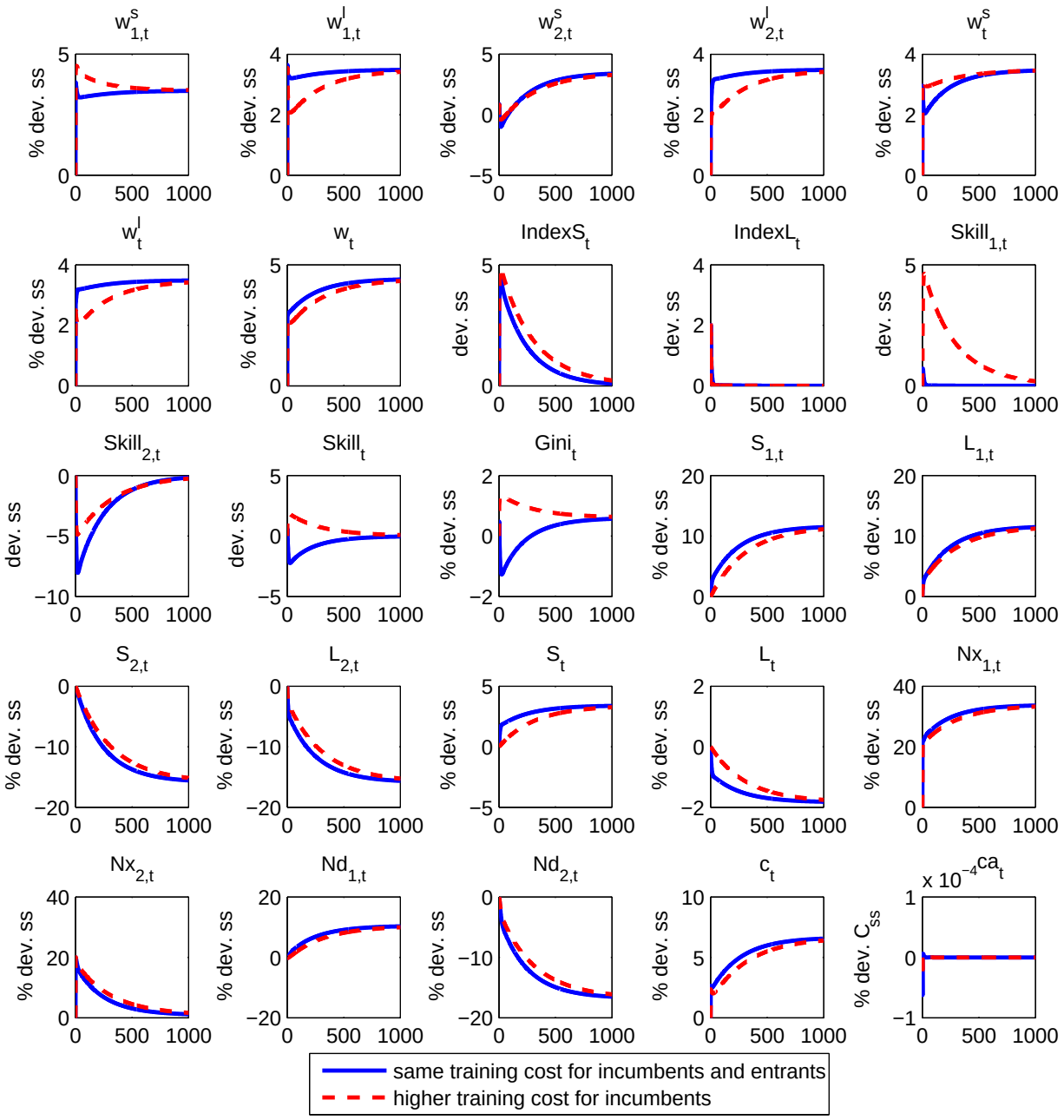

Figure 5: Scenario 4 Symmetric Liberalization With Training

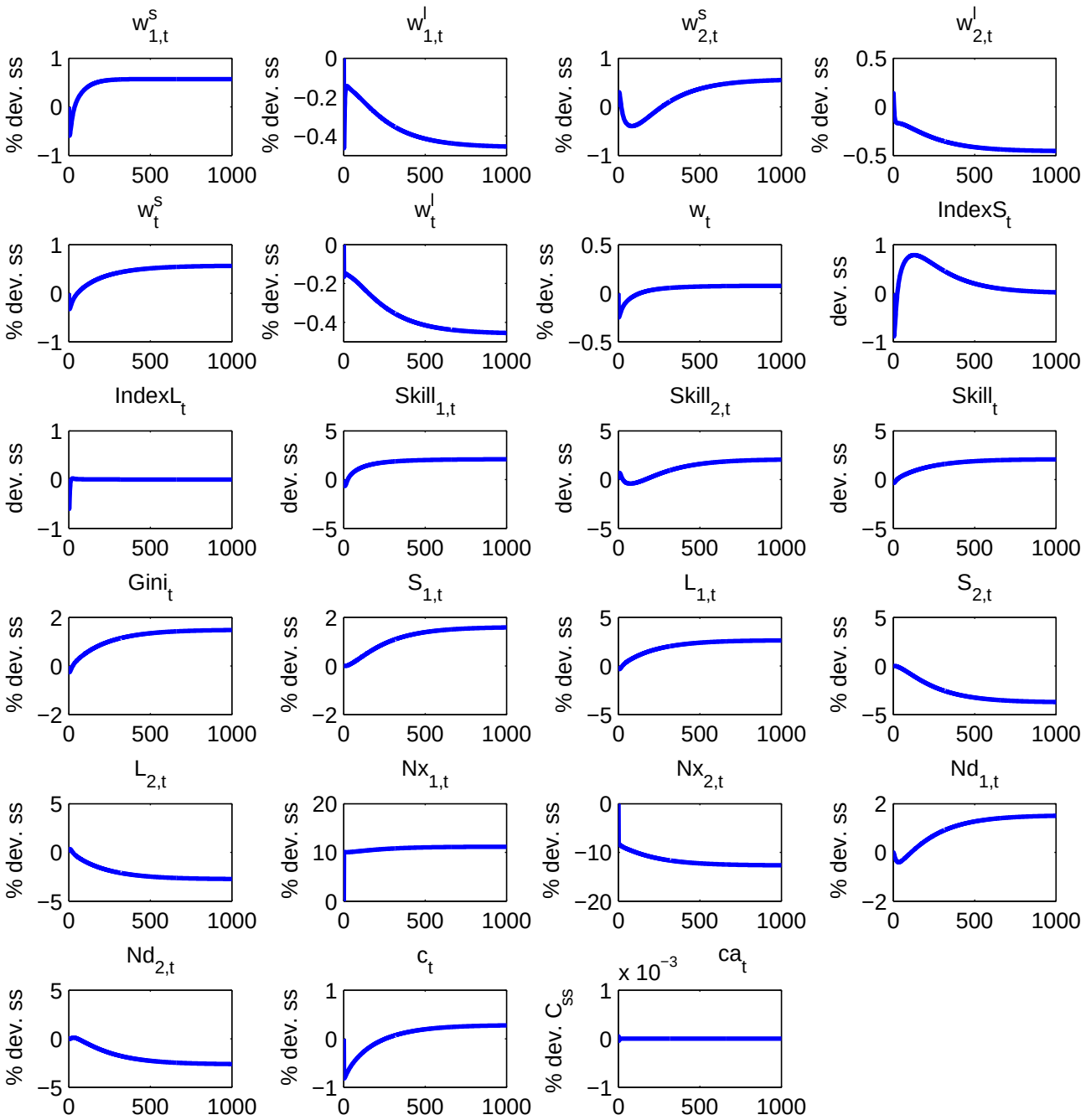

Figure 6: Scenario 5a Liberalization of the Skill-Intensive Sector With Active Switching of Unskilled Workers Only

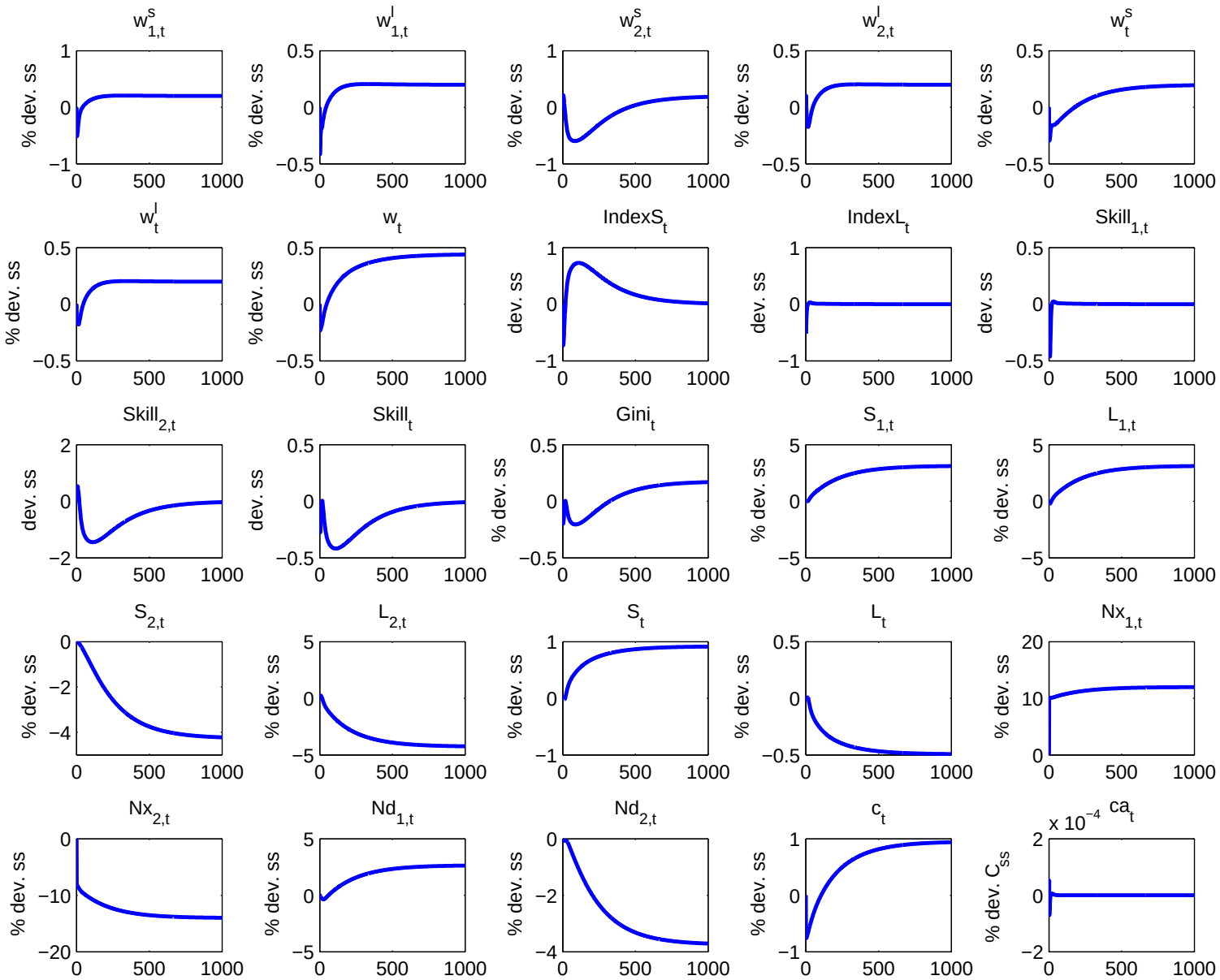

Figure 7: Scenario 5b Liberalization of the Skill-Intensive Sector With Training

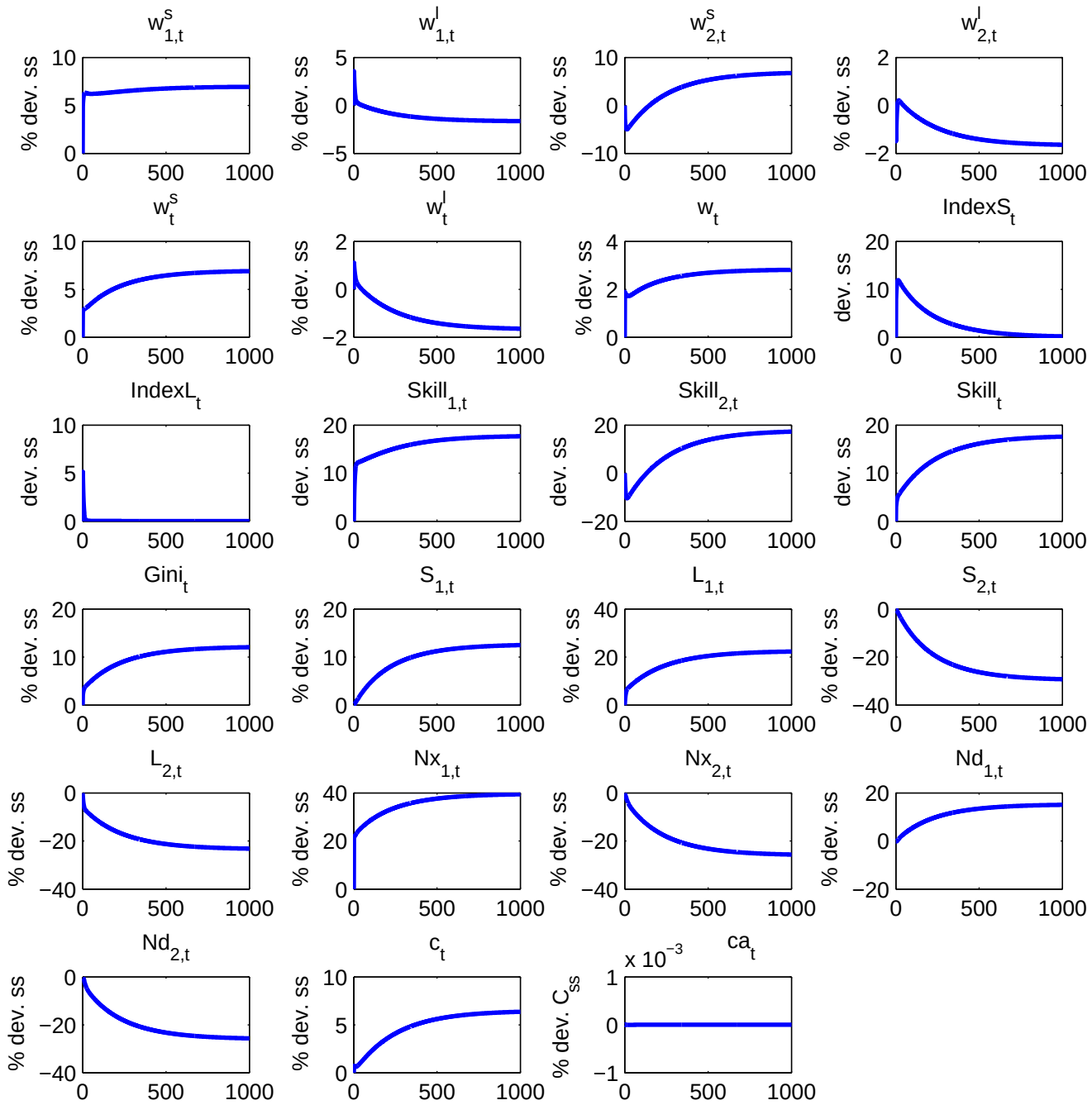

Figure 8: Scenario 6a Liberalization of the Comparative Advantage Sectors With Active Switching of Unskilled Workers Only

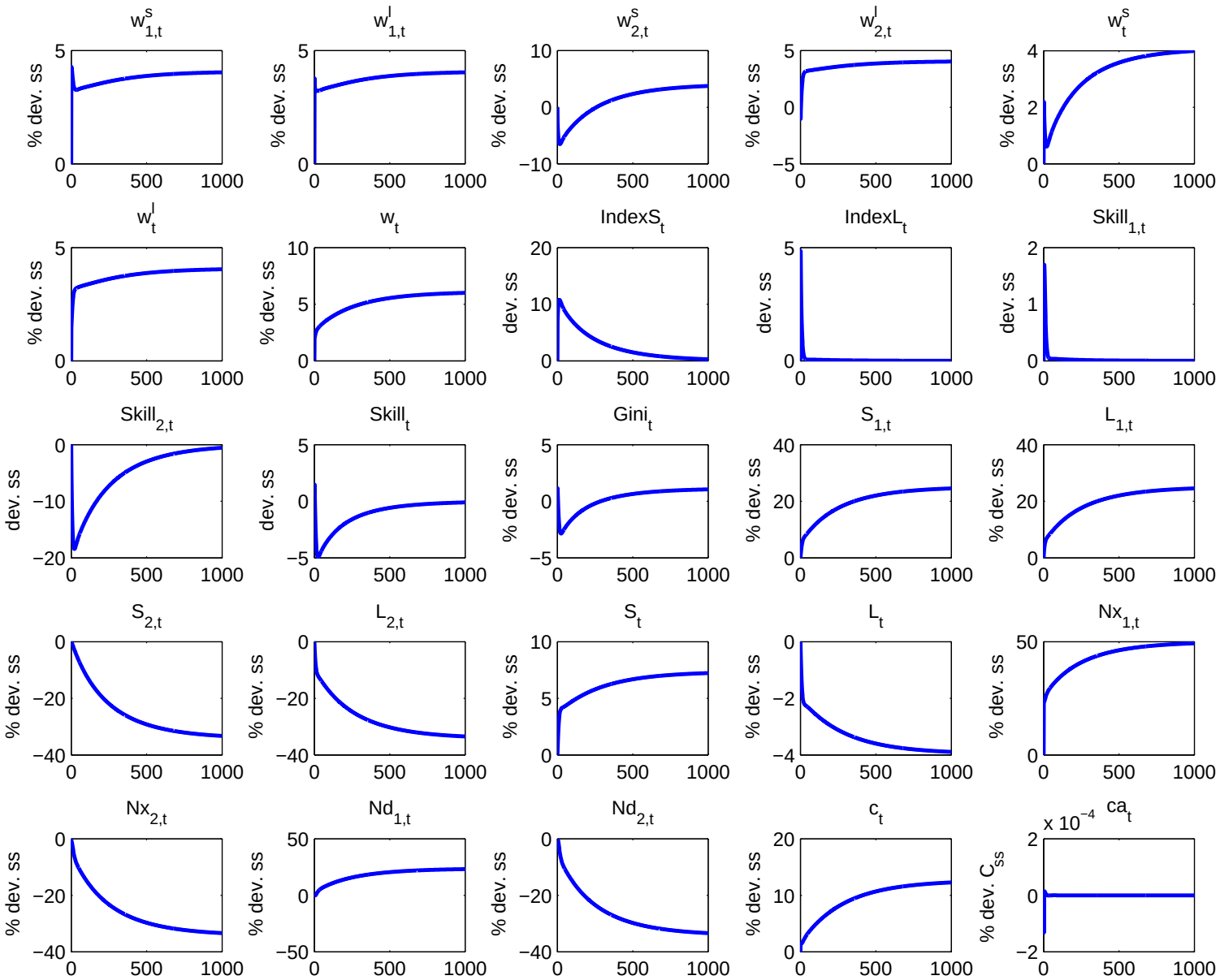

Figure 9: Scenario 6b Liberalization of the Comparative Advantage Sectors With Training

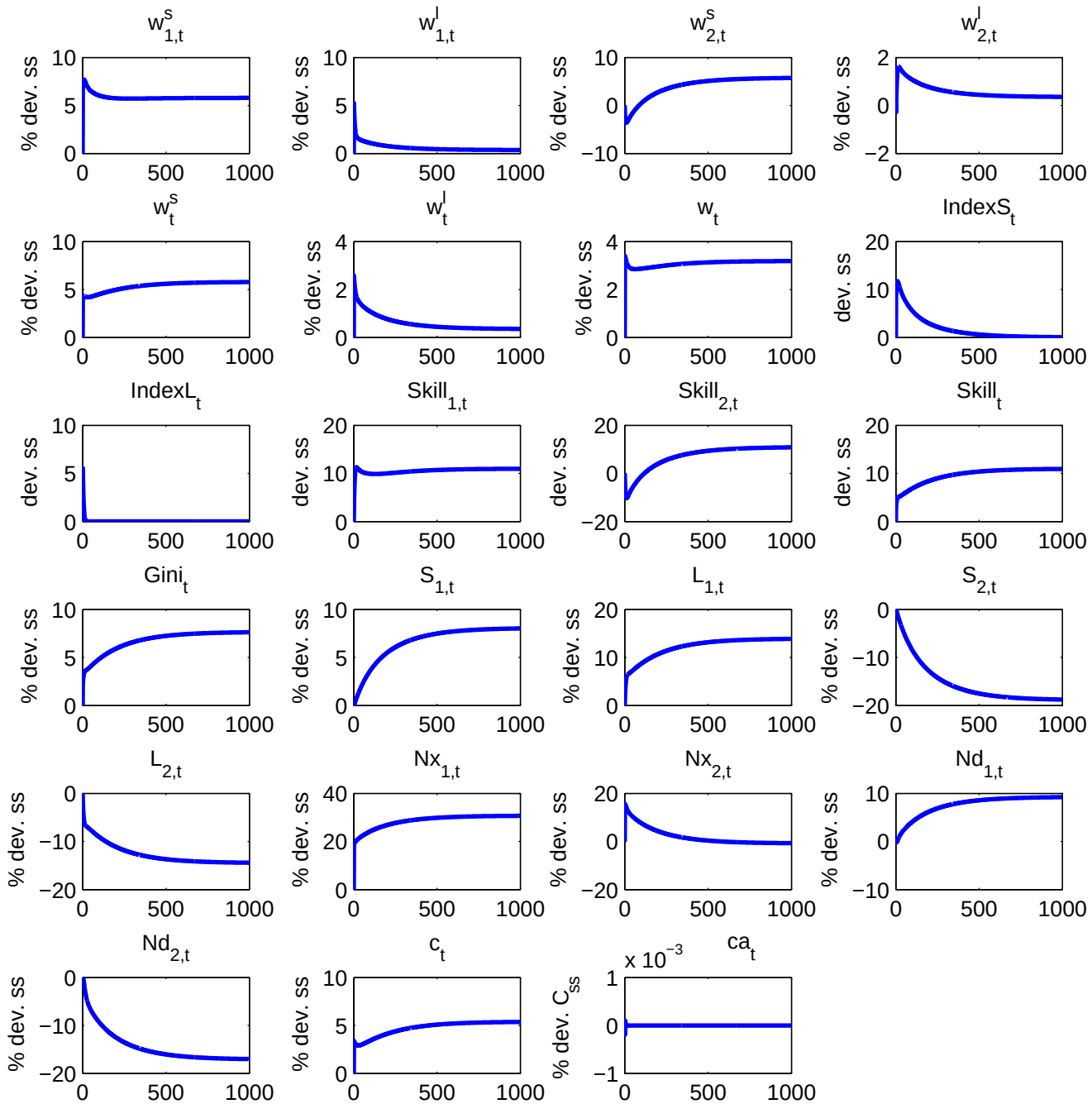

Figure 10: Scenario 7a Unilateral Liberalization of the Comparative Disadvantage Sector Imports With Active Switching of Unskilled Workers Only

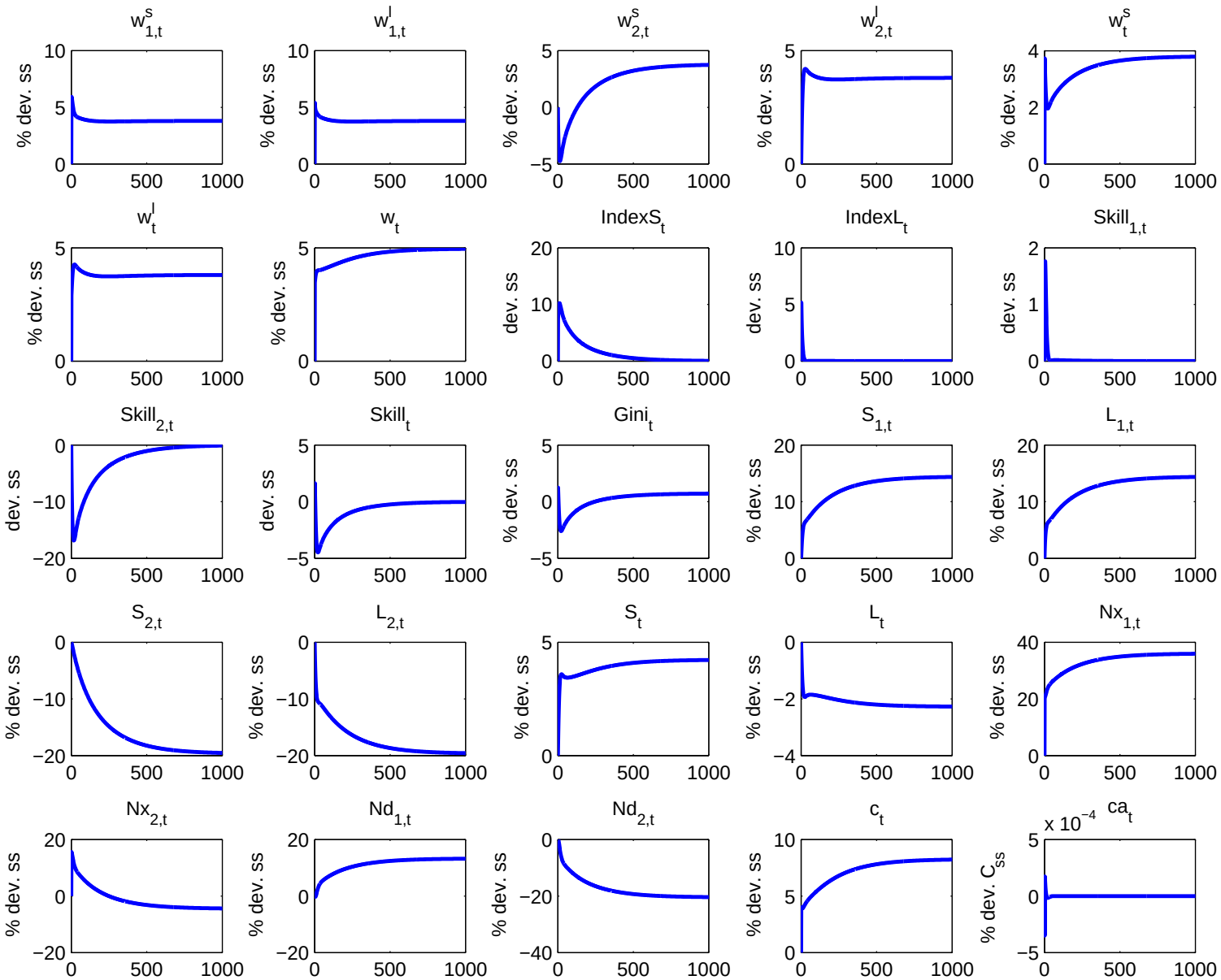

Figure 11: Scenario 7b Unilateral Liberalization of the Comparative Disadvantage Sector Imports With Training

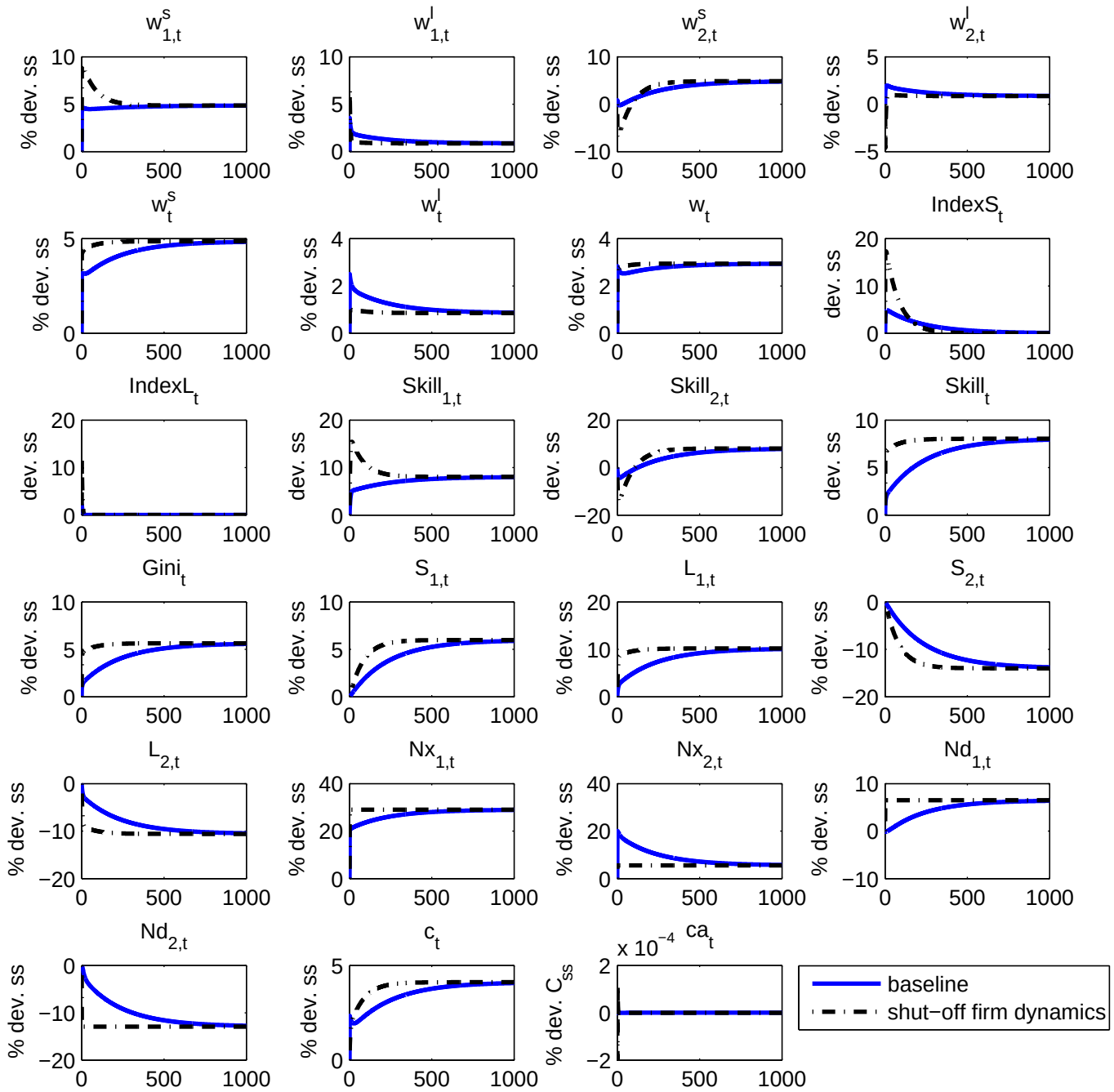

Figure 12: Symmetric Liberalization With Firm Dynamics Shut-Off With Active Switching of Unskilled Workers Only

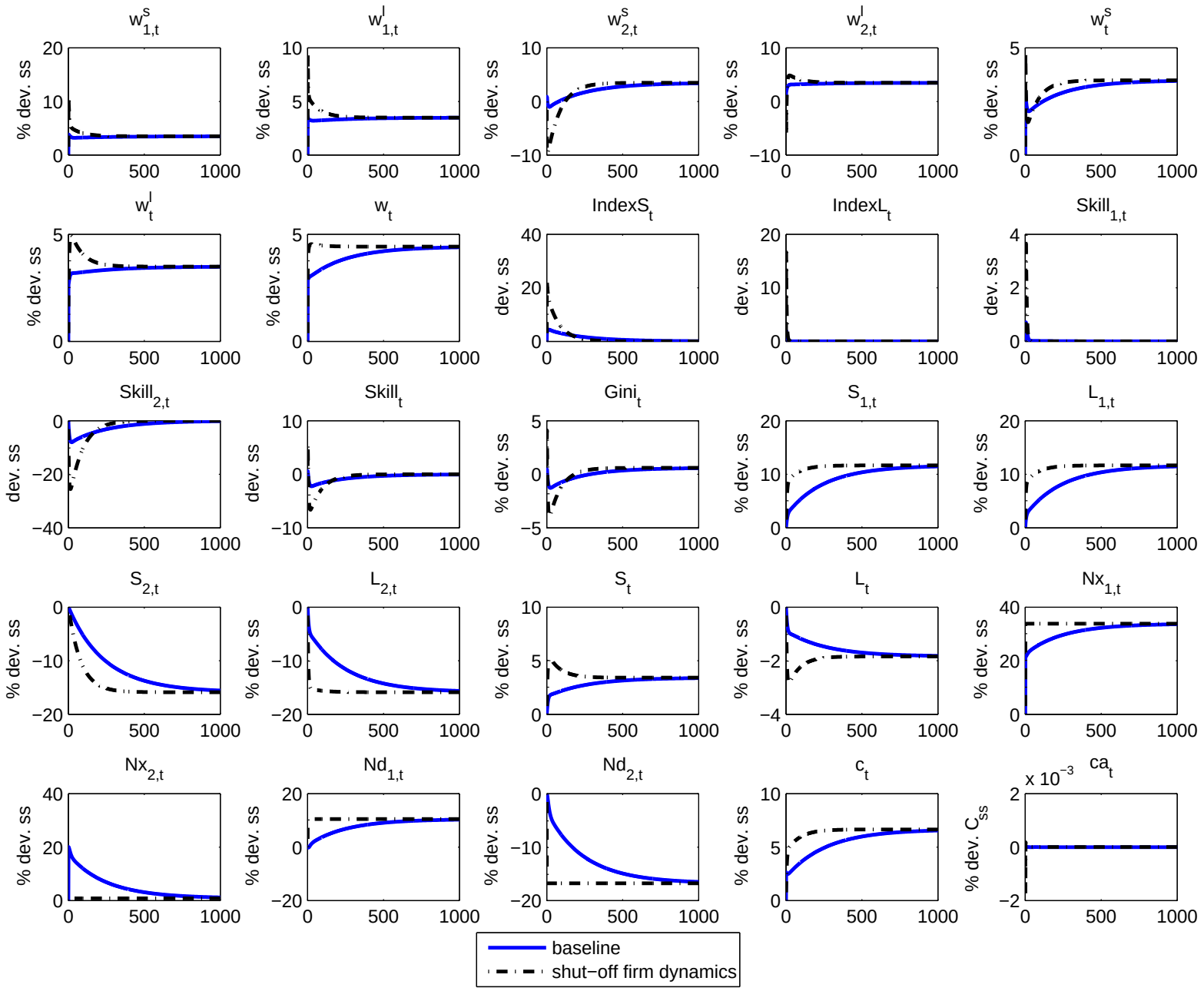

Figure 13: Symmetric Liberalization With Firm Dynamics Shut-Off With Training

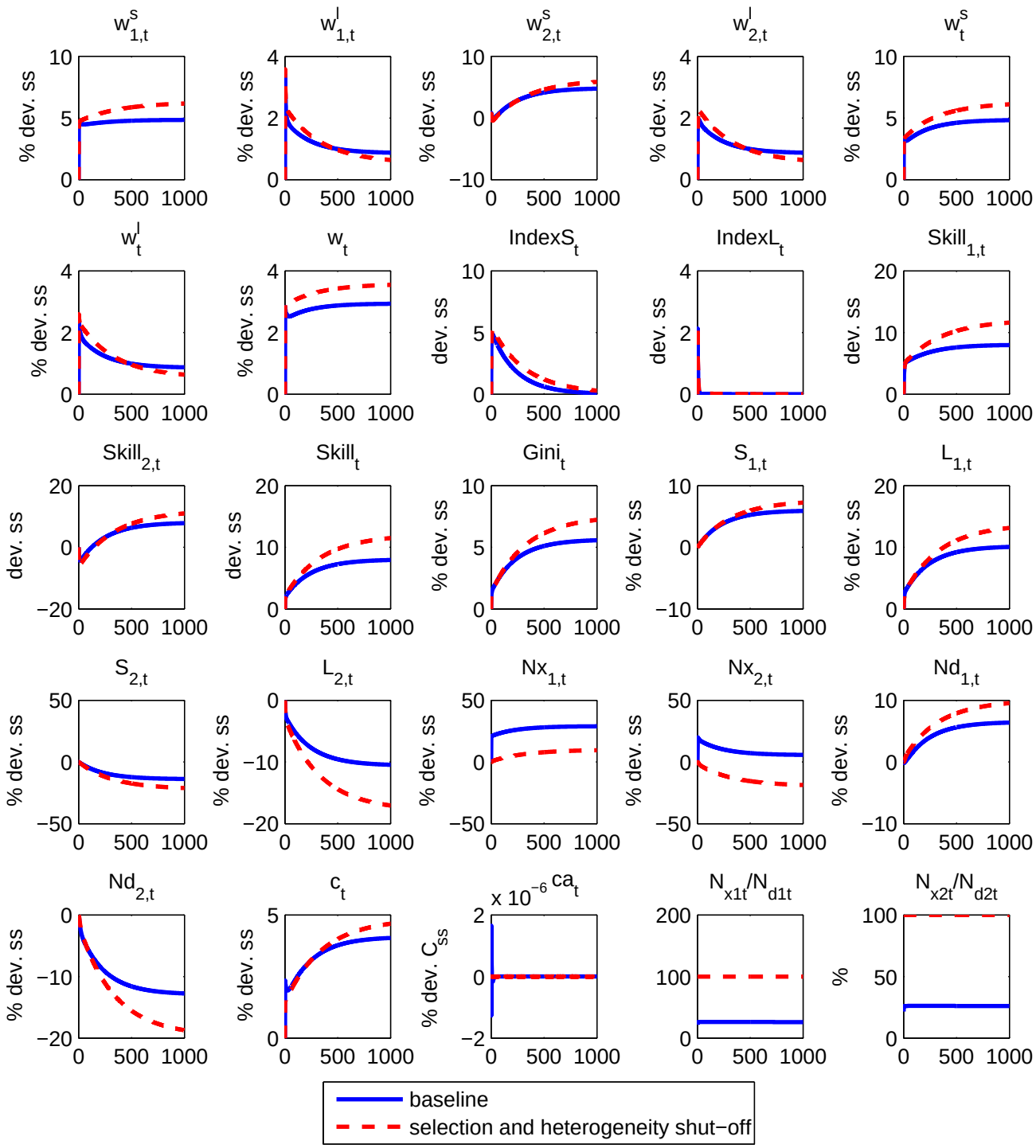

Figure 14: Symmetric Liberalization Without Selection Into Export Markets With Active Switching of Unskilled Workers Only

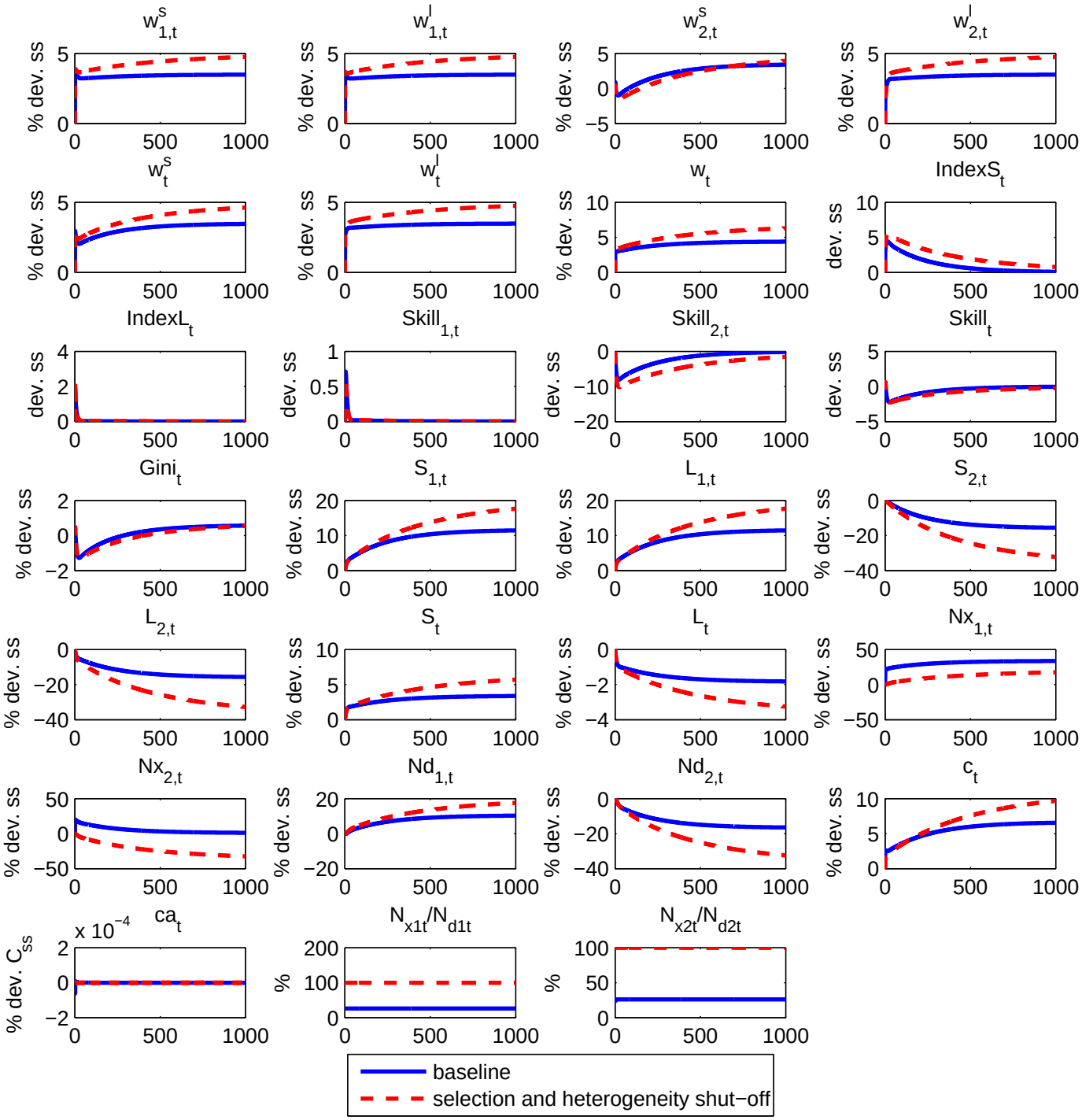

Figure 15: Symmetric Liberalization Without Selection Into Export Markets With Training

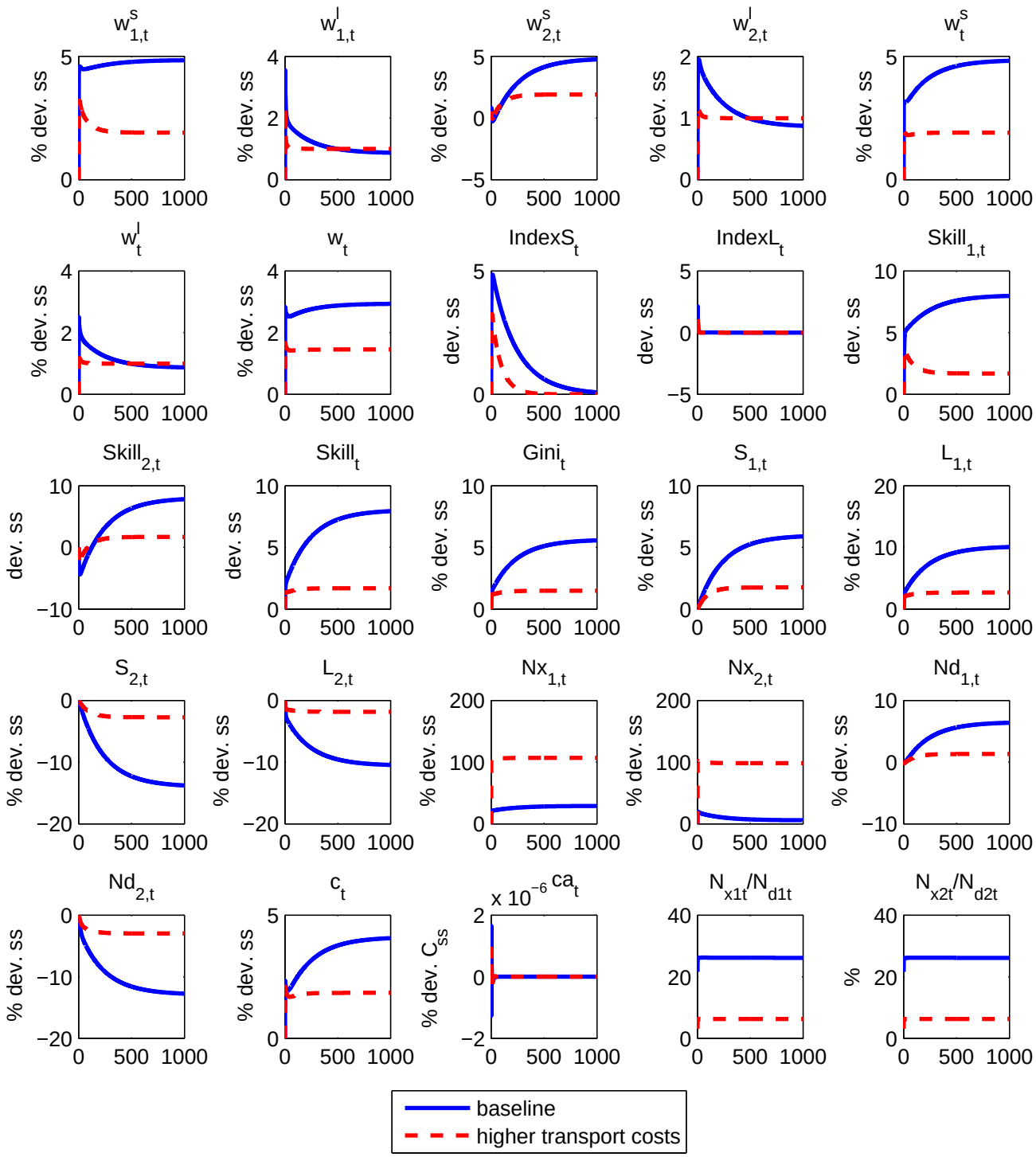

Figure 16: Symmetric Liberalization With Higher Transport Costs With Active Switching of Unskilled Workers Only

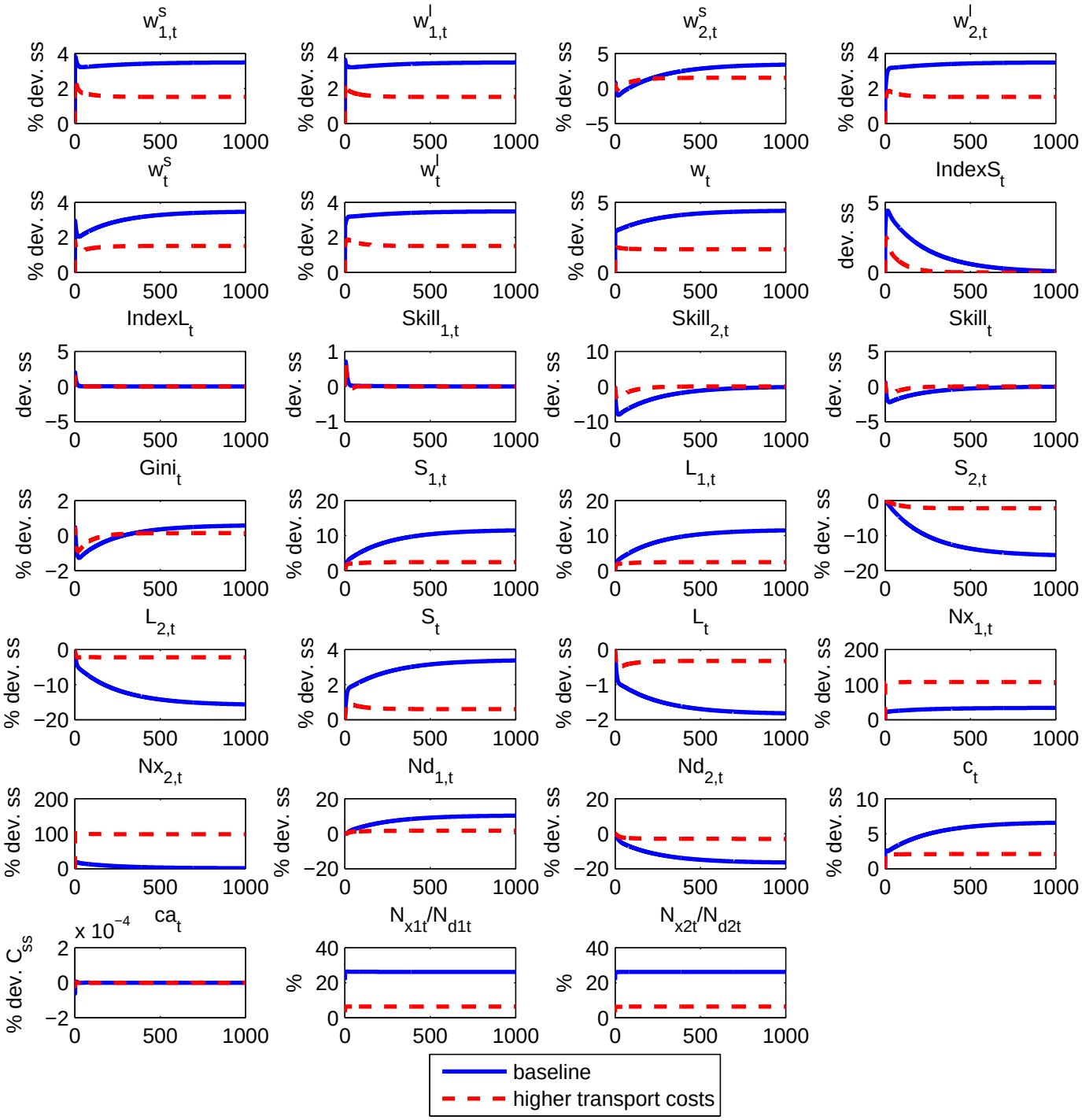

Figure 17: Symmetric Liberalization With Higher Transport Costs With Training

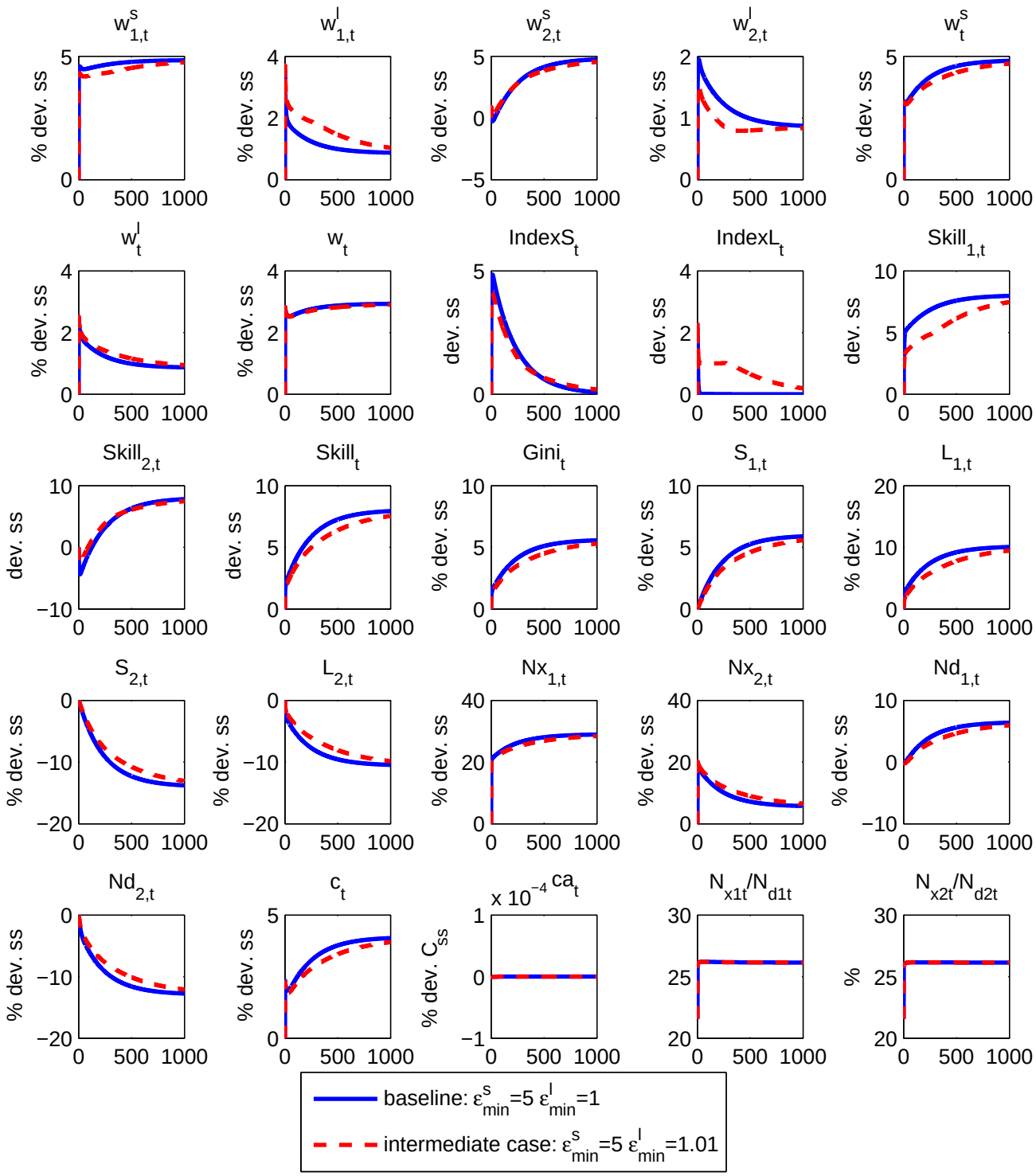

Figure 18: Symmetric Liberalization With Intermediate Labor Mobility Costs

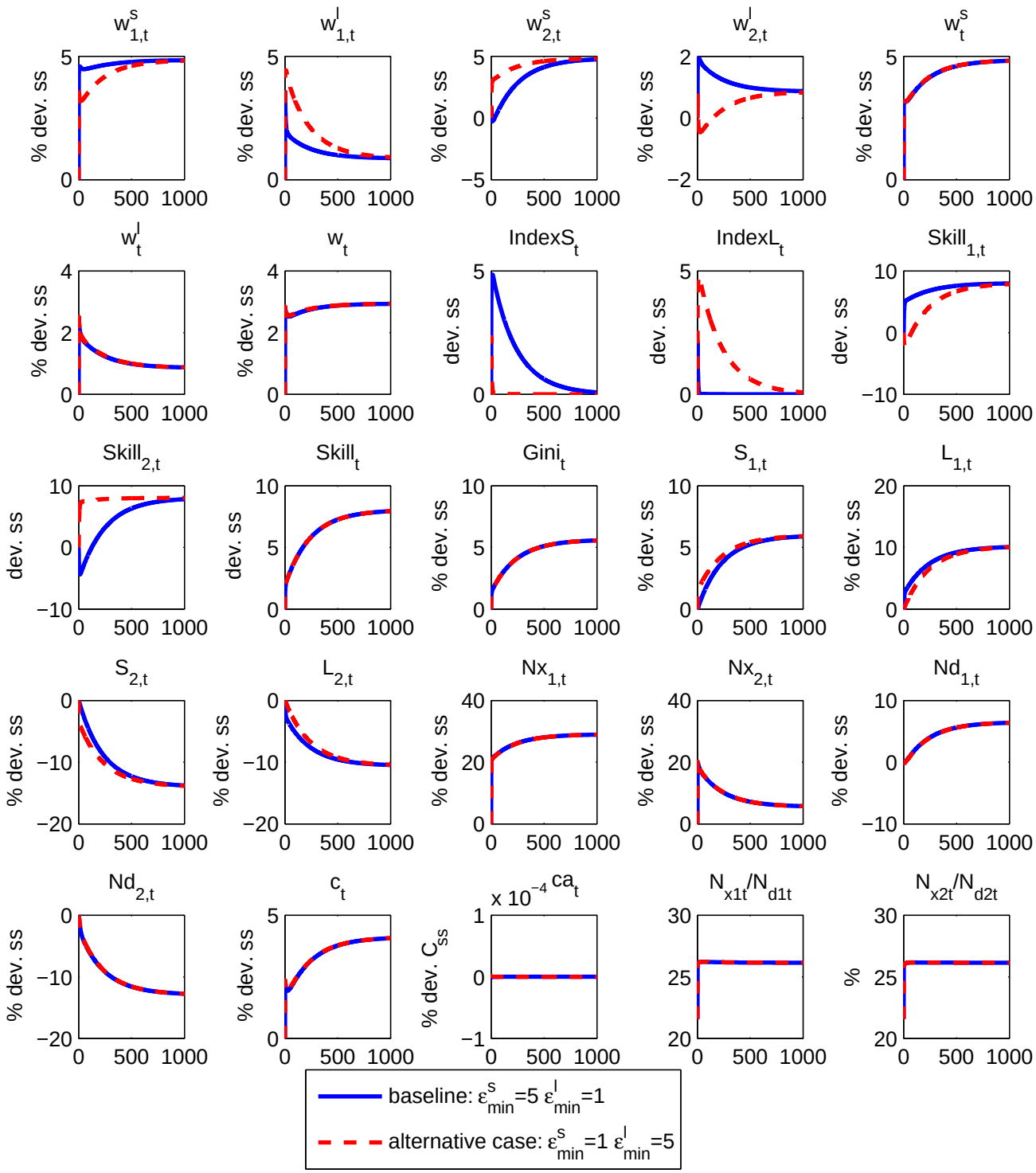

Figure 19: Symmetric Liberalization with More Mobile Skilled Workers