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Offshoring and Labour Market Reforms: Modelling the German Experience

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ABSTRACT

Offshoring and Labour Market Reforms: Modelling the German Experience

A usual interpretation of the high performance of the German economy since 2005 is that the Hartz labour market reforms have boosted German competitiveness, resulting in higher exports, higher production and lower unemployment. This explanation is at odds with the sequence of observed facts. We propose and model an alternative scenario in which offshoring explains the gains in competitiveness but increases unemployment and inequality, and the subsequent labour market reforms lower unemployment by lessening the reservation wage and expanding the non-tradable sector. The model replicates the developments of the German economy since 1995: 1) Germany offshores more intensively than other advanced countries; 2) The increase in competitiveness and in the exports/production ratio occurs before the implementation of the labour market reform, and this comes with both higher inequality and higher unemployment; 3) The implementation of the reform reduces unemployment, but also decreases the exports/production ratio and increases inequality. The model also predicts that the reduction in unemployment in Germany would have occurred without the Hartz reforms, but later and less intensively. We finally discuss the possible extension of this 'strategy' to other Eurozone countries, and alternative policies that activate similar mechanisms without increasing inequality.

JEL Classification: H55, J31, J65

Keywords: Germany, inequality, labour market reform, offshoring, unemployment

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1. Introduction

Since the mid-2000s, Germany has exhibited better economic results than most European countries. Growth has been higher, unemployment has continuously diminished, budget deficits and public debt have decreased and are now significantly lower than the European average levels. Above all, the German performance on external markets has been particularly beneficial since Germany has accumulated substantial trade surpluses and maintained its international market share, in contrast with all advanced economies whose market shares have narrowed because of the increasing weight of emerging countries. Finally, unlike all advanced economies, the decrease in unemployment has been continuous since 2005, with almost no impact of the 2008 financial crisis on this reduction.

The turning point occurred in the mid-2000s. In the late 1990s-early 2000s, Germany was considered as 'the sick man' in Europe (e.g., Economist, 2004), with low growth, high and increasing unemployment, budget deficits and public debt. Most German economic indicators began to improve in 2006, i.e., one year after the final setting of the Hartz reforms. Implemented from 2003 up to 2005, the four stages of the Hartz reform aimed at lowering unemployment and increasing German competitiveness by making labour more flexible and inciting unemployed workers to participate in the labour market.

The coincidence of the German recovery with the implementation of Hartz laws has led most observers to explain the German success by the following sequence. The Hartz reforms have increased labour flexibility, reduced wages and boosted German competitiveness, resulting in both higher exports and higher production, and finally lower unemployment. A virtuous circle has then emerged in which higher exports, production and employment have lessened public deficit and debt, which prevented Germany from setting the restrictive fiscal policy followed by most European countries, which has in turn resulted in higher growth compared to the rest of Europe.[1]

Unfortunately, this interpretation does not coincide with observed facts. The core of the explanation is the impact of Hartz reforms on wage moderation, competitiveness and exports, which would have boosted production and employment. But the increase in competitiveness and exports occurred over the period 1993-2005, i.e., before the setting of Hartz laws. After 2005, German exports in percent of GDP as well as the exports/imports ratio have decreased, in contradiction with the aforementioned interpretation. Moreover, the most striking result of the Hartz reforms is the huge increase in atypical employment.

This paper provides an alternative explanation that combines offshoring and labour market reforms to explain the German experience. The scenario is as follows. Facing higher labour cost than other advanced countries, German firms have relocated the (low skilled) labour-intensive stages of production to low-wage countries, particularly Central European countries, this relocation being much more pronounced in the German case compared to other European countries. This has (i) increased the competitiveness of German products in foreign markets, raising thereby German exports, (ii) increased the unemployment of unskilled workers in Germany, and (iii) increased inequality by driving down the wages of the unskilled. The impact upon growth was negative in a first stage because (i) of growing unemployment and (ii) the increase in exports was to a large extent based on offshoring, i.e., composed of imported parts. Confronted with the offshoring-related increase in unemployment, the German government introduced the Hartz reforms whose key implication was the promotion of low paid jobs in non-tradable services. This policy has reduced unemployment, but this has come with the increase in non-standard employment and with growing inequality and in-work poverty. Finally, the increasing demand for German goods due to higher competitiveness has

[1] Arguments along these lines can, e.g., be found in Kirkegaard (2014) and Rinne & Zimmermann (2013).

subsequently boosted production in the segments located in Germany, implying a further increase in employment.

We develop a general equilibrium framework that replicates the aforementioned scenario and provides a modelling of the German experience (outsourcing + labour market reform). The GE model does not aim at capturing all the dimensions of the German macroeconomic experience since the mid-nineties. Its goal is to analyse the impact on the German economy of the combination of, and interplay between, offshoring and labour market reforms, and to verify that these mechanisms provide a reliable picture of the major characteristics of the German economy over this period. The model comprises three sectors and three countries. The three countries are Germany, other advanced economies (labelled '*North*') and the 'South'. The South displays a comparative advantage in low skill intensive productions. There is one skill-intensive sector which comprises two goods differentiated according to their country of origin ('Armington's hypothesis'), Germany and North, and produced from two segments, one utilising skilled labour and the other unskilled labour. The 'unskilled' segment can be offshored, but offshoring has a cost which decreases with time (globalisation). Another sector is unskilled-intensive and its production is fully located in the South. Finally, a non-tradable unskilled-intensive service is produced in each country. We start from an initial situation in which the offshore production cost is large enough to maintain the whole production of the skill-intensive sectors in Germany and North. The subsequent continuous decrease in this cost results in offshoring to the South of the unskilled-intensive segment of the German skill-intensive good. We analyse the impact of offshoring by assuming a reservation wage in Germany, and then a decrease in this reservation wage due to labour market reforms.

In contrast with the usual explanation based on the impact of wage limitation upon German competitiveness on external markets, the results of our model reproduce the main characteristics of the German experience since the mid-nineties. The fact that Germany outsources before and more intensively than other countries is an endogenous finding of the model. In addition, the model replicates the sequence of observed facts. In particular, it explains the increase in the exports/GDP ratio before the Hartz reforms and its decrease afterwards, as well as the fact that the rise in the skill premium and in the cost of unskilled labour began before the implementation of these reforms. We also find that the decrease in unemployment would have occurred even without the Hartz laws, but later and less intensively. Finally, by showing that the decline in unemployment is essentially based on the development of non-tradables, the model provides a useful starting point to discuss alternative pro-employment policies.

The stylised facts and the related literature are outlined in Section 2. Section 3 presents the general framework of the model, the analysed scenario and the modelling strategy. Section 4 describes the equilibria corresponding to each stage of our scenario. Section 5 exposes the results of the simulations implemented from an extended version of the model. The main findings are discussed in Section 6 and we conclude in Section 7.

2. Facts and literature

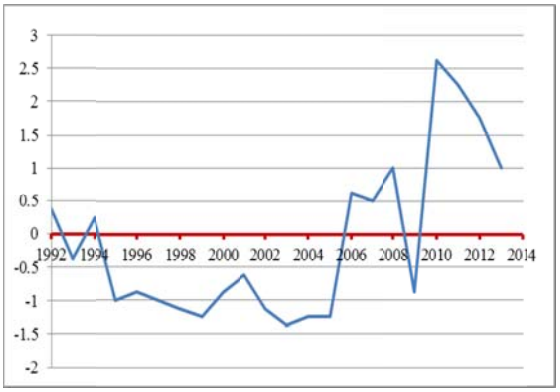
2.1. Economic outcomes in Germany and Eurozone countries

Comparing the German economy with that of other European and advanced countries since 1995 leads to a clear distinction between two phases (Figure 1). From 1995 to 2005, the German economic performance was below those of most advanced countries: growth was lower and unemployment was higher. In contrast, from 2006 onwards, Germany has exhibited

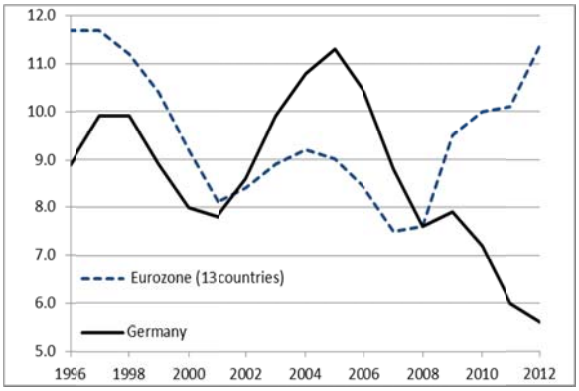
economic results incontestably better than those of its European partners. In particular, the recession that followed the 2008 financial crisis has had a far less damaging impact on unemployment in Germany than in most advanced economies (Fig. 1b).

A noticeable specificity of Germany is its superior performance in terms of external trade (Figure 2). Germany is the only advanced country whose ratio of exports of goods on GDP has substantially increased in the last two decades, passing from 25% in 1996 up to 47% in 2008. In addition, the exports/imports ratio of goods has always been significantly higher than one, attaining 1.25 over the period 2001-2008. It must finally be highlighted that the German export performance measured by the Exports/GDP ratio has improved from 1995 up to 2005, i.e., before the Hartz reforms. In contrast, the implementation of these reforms has come with a decrease in this ratio.

Figure 1. GDP growth and unemployment in Germany and the Eurozone (1992-2012)



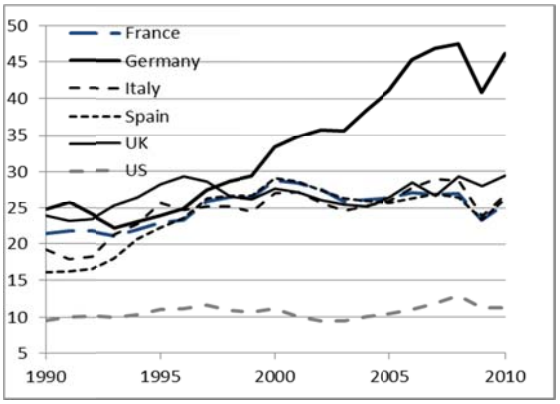
a) GDP growth gap: Germany – Eurozone



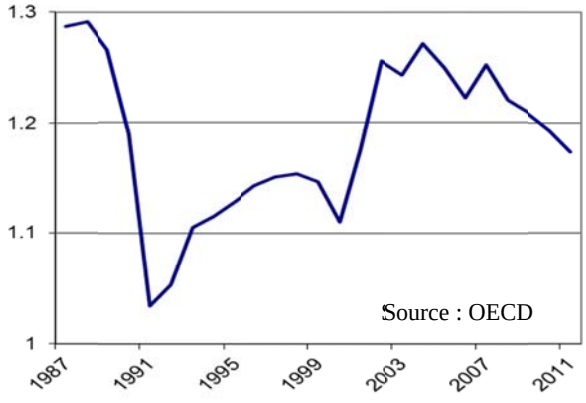
b) Rate of unemployment

Source: Eurostat. *http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database. a)Difference between the German GDP growth rate (volume) and the GDP growth rate of other Eurozone countries (13 countries minus Germany). Calculations by the authors.*

Figure 2: German foreign trade



a) Ratio Exports*(goods & services)*/ GDP (%)



b) Germany: Ratio Exports/Imports, goods

Source: OECD. *http://www.oecd.org/statistics/*.

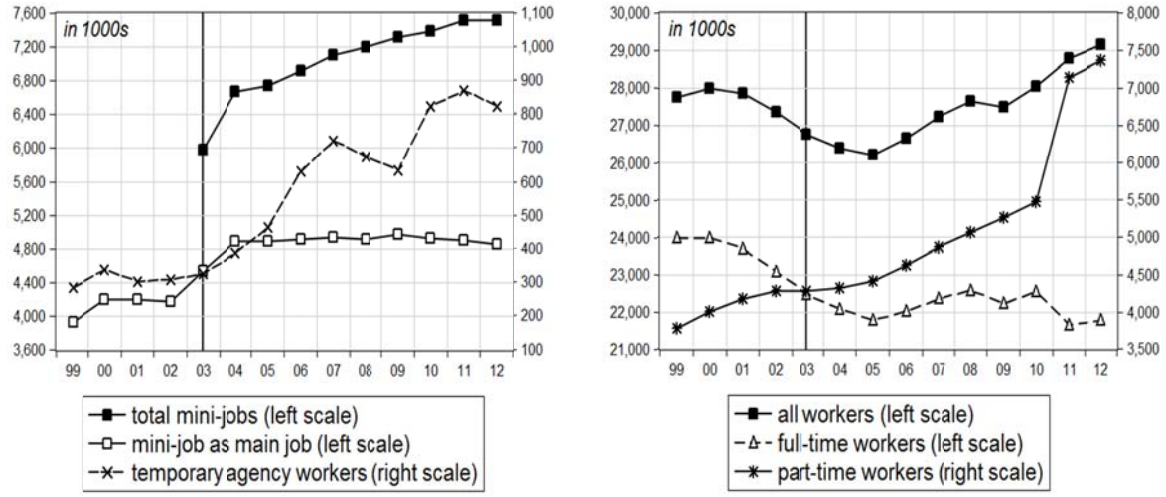
2.2. The Hartz reforms

When unemployment started to rise again in 2000, especially among the unskilled, the German government decided a series of labour market reforms known as the Hartz reforms and implemented in four stages from 2003 to 2005 (Jacobi & Kluve, 2007 and Alber &

Heisig, 2011, for details). We focus here on the measures of the Hartz reforms that have significantly contributed to the increase in low-wage and non-standard employment: (i) deregulation of temporary agency employment (Hartz I in 2003), (ii) reform and facilitation of marginal employment in the form of so-called mini jobs (Hartz II in 2003) and (iii) reform of the unemployment compensation system (Hartz IV in 2005).

Hartz I led to an increase in temporary agency employment by about 150 percent from 2003 to 2012 (Figure 3a). Temporary agency workers accept considerably lower wages. Depending on the econometric model variant, Jahn & Pozzoli (2013) find pay gaps for the majority of temporary agency workers ranging from about 20 to 40 percent.

Figure 3: Standard and non-standard employment in Germany (1999 – 2012)



a) Mini-jobs and temporary agency workers b) Workers covered by social security

Source: Federal Employment Agency (BA). End-of-year values. a) Mini-jobs: Beschäftigungsstatistik: Geringfügig entlohnte Beschäftigte nach ausgewählten Merkmalen; temporary agency workers: Arbeitsmarkt in Zahlen – Arbeitnehmerüberlassung. Leiharbeitnehmer und Verleihbetriebe. b) Beschäftigungsstatistik: Sozialversicherungspflichtig Beschäftigte nach ausgewählten Merkmalen. The vertical line indicates the start of the Hartz reforms in 2003.

Before the Hartz II reform, incomes up to 325 Euro per month were exempt from employees' social security contributions if the weekly working time was less than 15 hours. The Hartz II reform raised this threshold to 400 Euros, eliminated the hour constraint and exempted from social security contributions and income tax the mini-jobs held as secondary jobs (fully taxable since 1999). As a consequence, the number of mini-jobs significantly increased. In 2012, about 7.5 million mini-jobs are reported, with about 4.9 million mini-jobs held as main job and about 2.6 mini-jobs held as secondary job (Figure 3a). According to Eichhorst et al. (2012), nearly one half of the workers with a mini job as main job earned less than 7,50 Euro per hour, and about 75 percent less than 10 Euro. Mini-jobbers are predominantly employed in services, especially in health and social work, hotels and restaurants, wholesale and retail trade and other services (RWI, 2012). There are also indications that regular workers have been substituted by mini-jobbers, especially in smaller firms (Hohendanner & Stegmaier, 2012).

The Hartz IV reform united the formerly separate (earnings-related) unemployment assistance and social assistance schemes into a new flat-rate unemployment assistance benefit, called unemployment benefit-II. For most people, unemployment benefit II is less generous than the former earnings-related assistance benefit. There are indications that this has led to a reduction in reservation wages (Arent & Nagl, 2011). Moreover, the duration of earnings-

related unemployment benefits-I has been reduced (Alber & Heisig, 2011, for details). Unemployment benefit-II can also be used to augment insufficient earnings from work (or insufficient earnings-related unemployment benefit-I). The number of workers receiving both wages and unemployment benefit II amounted to 1.2 million in 2012.[2]

The rise in employment of workers covered by social security observed after the implementation of the Hartz reforms has only derived from the increase in part-time employment (Figure 3b). From 2003 to 2012 the number of part-time workers increased by 72 percent, amounting to 7.4 million part-time workers in 2012. In contrast, the number of full-time workers declined by 3 percent over the same period.

The evidence on whether the decline in German unemployment can be ascribed to the Hartz reforms remains inconclusive. Using calibrated macro models, Launov & Wälde (2013a) only find a negligible effect on unemployment, whereas Krebs & Scheffel (2013) and Krause & Uhlig (2012) diagnose a substantial reduction in equilibrium unemployment. Busl and Seymen (2013) only find weak effects of the Hartz reforms on wage restraint and no effects on the German current account surplus. In empirical studies, the evidence is mixed as well. Fertig et al. (2006) find no significant effects of the Hartz I-III reforms on unemployment in- and outflows. In contrast, several studies on the overall effectiveness of the Hartz reforms, particularly by estimating matching functions, find a positive impact on job creation (Fahr & Sunde, 2009; Klinger & Rothe, 2012; Hertweck & Sigrist, 2013).

All in all, the Hartz reforms are certainly one of the main driving forces of the increase in non-standard employment, especially in services. This can be regarded as an intended effect since the Hartz reforms main objective was the activation of the unemployed who were essentially low skilled workers. The reforms may also have contributed to the decline in aggregate unemployment and may have dampened wage demands. However, wage moderation and the increase in competitiveness started long before the Hartz reforms, as outlined below.

2.3. Offshoring, unemployment and wage inequality in Germany

Since the mid-nineties, German manufacturing industries have experienced a substantial rise in offshoring (Figure 4), particularly towards Central European countries. This has resulted in a huge increase in the unemployment of low skilled workers.

Fig. 4. Increase in offshoring 1995-2008

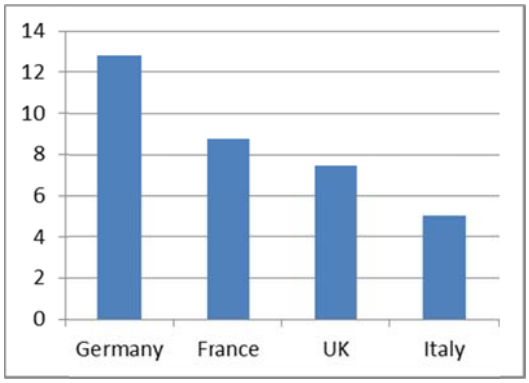
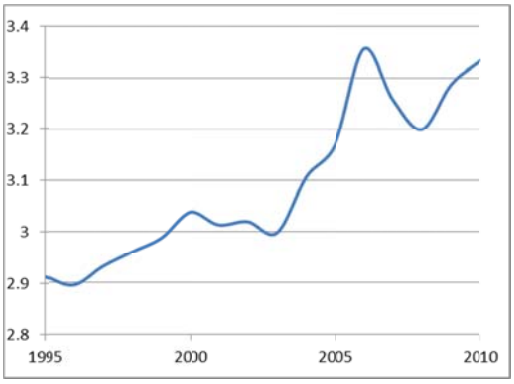


Fig. 5. Inequality (D9/D1, earnings)



Sources and explanations: Fig.4: Timmer et al. (2013). Offshoring is measured by the percentage of imports within intermediate inputs utilised in manufacturing industries (variation in this percentage). Fig.5: OECD Database. http://stats.oecd.org/.

[2] Data taken from: Bundesagentur für Arbeit (2013), Erwerbstätige Arbeitslosengeld II-Bezieher.

The economic analysis of international offshoring has known a critical development since the early nineties. Theoretical and empirical works on the subject are many (reviews by Crino, 2009, Chang, 2012 and Chusseau & Dumont, 2013).

There is now a rather large literature dealing with the impact of offshoring upon wages and labour demand in Germany. The early work by Falk & Koebel (2002) showed no impact on the demand for unskilled workers, but this result is questionable from a methodological point of view (Geishecker & Görg, 2008) and, maybe more important, it concerns the period 1978-1990 in which offshoring to emerging countries was limited. More recent studies typically diagnose a significant negative impact upon both the demand for unskilled workers and their pay (Geishecker, 2006; Becker et al., 2006; Geishecker & Görg, 2008; Braun & Scheffel, 2007).

Dustmann et al. (2014) and Bonin (2012) suggest that the decentralization of wage setting since the early 1990s and the introduction of 'opening clauses' in industry-level collective agreements may be attributed to the credible threat of offshoring to central and eastern European countries. Both works argue that the rising flexibility of the German industrial relations had led to wage moderation and to an increase in competitiveness long before the Hartz reforms. Dustman et al. (2014) also point out that the offshoring intensity in Germany increased far more than that in other European countries. For example, in 2000, imported inputs from Poland, Hungary, the Czech and the Slovak Republics amounted to about 8.5 percent of inputs in Germany, compared to only 2.5 percent in Italy and 1.9 percent in France. Higher German offshoring dynamics compared to other large European economies is confirmed by Timmer et al. (2013).

The growing offshoring of unskilled-intensive stages of production has come with wage moderation, rising flexibility and increasing earnings inequality. The German income distribution remained quite stable from the seventies up to the mid-1990s (Steiner & Wagner, 1998; Biewen, 2000; Prasad, 2004). Since then, Germany has experienced a critical increase in income inequality and poverty (Gernandt & Pfeiffer 2007, Dustmann et al, 2009; Fuchs-Schündeln et al. 2010, Antoncyck et al., 2010; Figure 5).

Gernandt & Pfeiffer (2007) find that the rise in wage inequality in West Germany from 1994 to 2005 is essentially attributable to the bottom side of the wage distribution. Dustmann et al. (2009) find that wage inequality in West Germany increased at the bottom half of the wage distribution from the 1990s onward, but also at the top half from the 1980s. For the period 1999-2006, Biewen & Juhasz (2012) find that about one half of the increase in income inequality is explained by labour incomes, the other half being equally shared by employment changes and changes in the tax system.

2.4. Observed facts and the modelled scenario

Taken together, the stylized facts and empirical literature exposed above show the plausibility of the scenario exposed in the introduction:

1) The increase in competitiveness and exports started early in the mid-1990s and can be explained by the relocation of the labour-intensive stages of production to low-wage countries. This strategy of firms was implemented much more intensively in Germany than in other European countries and led to an increase in unemployment and to wage inequality.

2) Confronted with rising unemployment, the German government introduced the Hartz reforms, thereby promoting the creation of low-paid jobs, especially in non-tradable services.

In the next section, we develop a theoretical model based on these facts and we show that the so-generated mechanisms replicate the main traits of the German experience. We subsequently operate simulations from an extended version of this model. From the mechanisms revealed in this scenario, we discuss the possibility and effectiveness for other

Eurozone countries to imitate this strategy. Based on the diagnosis that the decrease in unemployment essentially derives from the job creation in non-tradable services, we finally discuss alternative pro-employment policies that could prevent the most controversial aspect of the German experience, i.e., the increase in inequality and poverty.

3. The model

We firstly present the general framework of the model and the offshoring decision. We subsequently describe the successive phases of our scenario. We finally expose the modelling strategy.

3.1. General framework

There are three countries: two advanced countries, Germany and North (other advanced countries, depicted by a tilde, ~), and the South, i.e., emerging countries (depicted by a star*).

There are two factors, skilled labour (*H*) and unskilled labour (*L*). Factor endowments are given. The German endowment is $\left(\overline{H},\overline{L}\right)$ and North's endowment $(\tilde{\overline{H}},\tilde{\overline{L}})$. We denote *H* and *L* ($\tilde{H}$ and $\tilde{L}$) the factor utilisation in Germany (North) that can differ from the factor endowment when there is unemployment.

For the sake of simplicity, the South is assumed to be endowed with unskilled labour only.

There are three sectors:

- Sector *l* provides one homogenous unskilled intensive good (*l*) which is fully produced by the South and imported by both Germany and North.
- Sector *nt* utilises unskilled labour only to produce one homogenous non-tradable service in each country.
- The third sector is skill-intensive and produces two tradable goods that are differentiated according to Armington's hypothesis, *h* being the German variety and $\tilde{h}$ North's. Both varieties are produced by combining two segments, one using skilled labour only and the other unskilled labour only.

We suppose that the segments utilising unskilled labour may be relocated to the South depending on the cost of producing abroad relative to the cost of producing domestically. In contrast, the segment utilising skilled labour is always produced in the home country because it encompasses the specificities that differentiate the products according to Armington's hypothesis. We finally assume that labour is immobile, i.e., labour mobility costs are sufficiently high to prevent migration flows.

3.1.1. Production

In all countries, the non-tradable service (*nt*) utilises unskilled labour only with the same linear technology:

$$Y_{nt} = \delta L_{nt} \; ; \qquad \tilde{Y}_{nt} = \delta \tilde{L}_{nt}$$

Assuming perfect competition in the market for goods and services, the zero-profit condition ($p_{nt}Y_{nt} = w_L L_{nt}$ and $\tilde{p}_{nt}\tilde{Y}_{nt} = \tilde{w}_L \tilde{L}_{nt}$) determines the prices of non-tradable services:

$$p_{nt} = w_L / \delta \; ; \quad \tilde{p}_{nt} = \tilde{w}_L / \delta \qquad (1)$$

where w_L ($\tilde{w}_L$) denotes the wage of unskilled labour in Germany (North).

The two skill intensive goods (variety h for Germany and $\tilde{h}$ for North) are produced by the same Cobb-Douglas combination of two segments:

$$Y_h = AS_L{}^{\alpha} S_H{}^{1-\alpha}; \qquad \tilde{Y}_{\tilde{h}} = A\tilde{S}_L{}^{\alpha} \tilde{S}_H{}^{1-\alpha}$$

Segments S_L and $\tilde{S}_L$ display the same technology which utilises unskilled labour only. Symmetrically, S_H and $\tilde{S}_H$ utilise skilled labour only with the same technology:

$$S_L = L_h \qquad \tilde{S}_L = \tilde{L}_{\tilde{h}} \tag{2}$$

$$S_H = H_h = H \qquad \tilde{S}_H = \tilde{H}_{\tilde{h}} = \tilde{H} \tag{3}$$

3.1.2. Demands for goods

In the three countries, households maximise the same utility function subject to the usual income constraint:[3]

$$u = \gamma_l \log c_l + \gamma_h \log\left(ac_h{}^{\beta} + c_{\tilde{h}}{}^{\beta}\right)^{1/\beta} + \gamma_{nt} \log c_{nt}, \qquad \gamma_h + \gamma_l + \gamma_{nt} = 1$$

where c_i is the consumption of good i, $i = l, h, \tilde{h}, nt,$ and $0 < \beta < 1$.

Coefficients γ_l, γ_h and γ_{nt} are respectively the share of the demand for *l*, $h+\tilde{h}$ and *nt* in the households' income.

Coefficient *a* depicts the demand attractiveness of the German quality *h* compared to North's quality $\tilde{h}$.

Good l. Good *l* is fully produced by the South. The imports of *l* by advanced countries are:

$$M_l = \gamma_l I; \qquad \tilde{M}_l = \gamma_l \tilde{I}$$

where *I* and $\tilde{I}$ denote total income in Germany and North, respectively.

Good nt. The non-tradable good is produced by each advanced country for its own consumption. At the macro level, we have (because of the utility function):[4]

$$p_{nt} Y_{nt} = p_{nt} c_{nt} = \gamma_{nt} I \tag{4}$$

$$\tilde{p}_{nt} \tilde{Y}_{nt} = \tilde{p}_{nt} \tilde{c}_{nt} = \gamma_{nt} \tilde{I} \tag{5}$$

Goods h and $\tilde{h}$. Because of the utility function, the world total expense for the sum of goods *h* and $\tilde{h}$ is:

$$p_h Y_h + p_{\tilde{h}} \tilde{Y}_{\tilde{h}} = \gamma_h (I + \tilde{I} + I^*) = \gamma_h I_W,$$

with *I** being the South's total income and $I_W = I + \tilde{I} + I^*$ that of the world.

Utility maximisation determines the world demands for goods *h* and $\tilde{h}$, $Y^d_{h,W}$ and $Y^d_{\tilde{h},W}$:

[3] We only present the German utility function, the utility functions of North and the South being identical.
[4] We do not provide this relation for the South because it is useless for what follows.

$$Y_{h,W}^d = \frac{a^\sigma \gamma_h I_W}{p_h{}^\sigma \left(a^\sigma p_h{}^{1-\sigma} + p_{\tilde{h}}{}^{1-\sigma}\right)} \Rightarrow p_h Y_{h,W}^d = \frac{a^\sigma \gamma_h I_W}{a^\sigma + (p_h / p_{\tilde{h}})^{\sigma-1}}$$

$$Y_{\tilde{h},W}^d = \frac{\gamma_h I_W}{p_{\tilde{h}}{}^\sigma \left(a^\sigma p_h{}^{1-\sigma} + p_{\tilde{h}}{}'^{1-\sigma}\right)} \Rightarrow p_{\tilde{h}} Y_{\tilde{h},W}^d = \frac{\gamma_h I_W}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1}$$

with $\sigma = (1-\beta)^{-1} > 1$ being the elasticity of substitution between goods *h* and $\tilde{h}$.

Finally, the demand for goods *h* and $\tilde{h}$ from any country *j* is:

$$p_h Y_{h,j}^d = \frac{a^\sigma \gamma_h I_j}{a^\sigma + (p_h / p_{\tilde{h}})^{\sigma-1}} \tag{6}$$

$$p_{\tilde{h}} Y_{\tilde{h},j}^d = \frac{\gamma_h I_j}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1} \tag{7}$$

with $I_j = I, \tilde{I}, I^*$ according to the considered country.

3.2. Offshoring

3.2.1. Offshore production costs

We assume that there are specific costs attached to producing offshore. These comprise transportation costs (to move the parts from a production site to another), extra-costs linked to low quality public equipment and services in the South, organisational costs (to match segments produced in different countries), training cost (to adapt the unskilled manpower to the imported technology), political, social and 'criminal' costs linked to low property right enforcement and corruption in the host country. This also covers the fact that labour productivity is typically lower in the South than in advanced countries.

As Ranjan (2013), we further assume that the cost of producing offshore is decreasing with time. This decrease derives from several channels: the decrease in transportation costs, the better enforcement of property rights, the improvement in public equipment and collective services linked to development, and the positive externalities due to better knowledge and insertion in the globalized economy generate a decrease in offshoring costs, etc.

In what follows, we focus on the offshore production cost of the German segment S_L.

We denote by ω the cost per unit of efficient (German-equivalent) unskilled labour in the production of segment S_L when this segment is offshored to the South. Hence, producing one unit of segment S_L in the South has a cost ω for German firms (Eq. 2).

The dynamics of the cost of producing offshore (henceforth '*offshore cost*') is then depicted by the simple functional form (*t* denotes time):

$$\omega = \omega(t), \qquad \partial\omega / \partial t < 0 \tag{8}$$

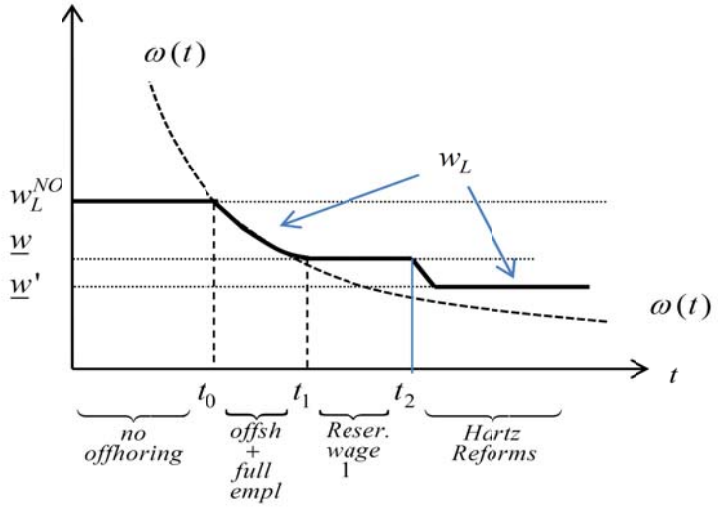
3.2.2. Offshoring decision

We denote by w_L^{NO} (*NO* for 'no-offshoring') the German full employment unskilled workers' wage when segment S_L is fully produced in Germany.

We denote by $\underline{w}$ the reservation wage in Germany, which is supposed (i) to be lower than w_L^{NO}: $\underline{w} < w_L^{NO}$ and (ii) to be positively related to social protection (unemployment and social benefits, union bargaining power, redistribution, etc.).

Fig. 6 depicts the variation over time of the German unskilled workers' wage (bold curve) depending on the cost of producing offshore, $\omega(t)$, and on the German reservation wage $\underline{w}$.

Figure 6. Offshoring and the phases of the scenario



As long as the offshore production cost ω is higher than w_L^{NO}, i.e. before t_0, the German firms producing good *h* have no incentive to outsource segment S_L. In consequence, this segment is fully produced in Germany and the German unskilled workers' wage is w_L^{NO}.

From the moment when ω goes below w_L^{NO}, i.e. from time t_0, German firms start to (partly) outsource the unskilled intensive segment S_L to the South. As long as the cost of producing this segment in the South ω is higher than the reservation wage ($\omega > \underline{w}$), the German unskilled labour wage adjusts so that $w_L = \omega$,[5] which is the case between t_0 and t_1 in Fig.6.

When the cost ω becomes lower than the reservation wage $\underline{w}$, i.e. at time t_1, the German unskilled workers' wage remains at the reservation value $\underline{w}$ and German firms fully outsource the unskilled intensive segment S_L. This creates unemployment if the production of the non-tradable service does not employ all the available unskilled labour $\bar{L}$ for $w_L = \underline{w}$.

If the reservation wage decreases from $\underline{w}$ to $\underline{w}' > \omega$ (time t_2 in Fig. 6), then the unskilled workers wage w_L moves from $\underline{w}$ down to $\underline{w}'$.

Finally, we limit our analysis to the case in which offshoring concerns the sole German variety *h* and does not affect North production of $\tilde{h}$. This simplification aims at focusing on the mechanisms linked to the behaviours of German firms and government, i.e., the interplay between outsourcing and labour market reforms. Nevertheless, the fact that German firms begin to outsource the production of S_L before North is shown by the model. In addition, the fact that the decrease in offshoring costs is larger for German firms compared to other European firms can be justified in two ways. First, in the 1990s and 2000s, German firms primarily offshored to Central and East European countries and this was clearly more profitable for them because of geographical and cultural proximity. Second, the cost of producing offshore decreases more rapidly for firms having already offshored (German firms)

[5] until the moment when the demand for *L* by sector *nt* equals the German unskilled labour supply $\bar{L}$.

than for other firms because of learning-by-doing, on-the-job training, improvement in organisation etc.

3.3. The scenario

From the above-described model, we develop the following four-stage scenario.

1) At the beginning, both advanced countries fully produce their own skill-intensive variety (*h* for Germany and $\tilde{h}$ for North) because producing the unskilled segments of goods *h* remains more costly in the South than in Germany. In this equilibrium without offshoring, the demand for each variety (depending on parameter *a*) and the countries' endowments of skilled and unskilled labour determine the differences in both the skill premia and wages between Germany and North. Given the countries' characteristics, we show that the skill premium is lower, and the wage of unskilled workers higher, in Germany than in North.

2) As the offshore production cost decreases, there is a time when this cost becomes sufficiently low to incite German firms to offshore the unskilled segment of their variety *h*. German firms outsource first because the wage of unskilled labour is higher in Germany. This makes the wage of low skilled workers to decrease and the skill premium to increase in Germany. As long as the wage of low skilled workers decreases (because the offshore cost continues to fall), this causes a move in the German production pattern: the weight of the non-tradable sector increases (because its relative price decreases) and a growing share of segment S_L is offshored.

3) As the offshore cost continues to decrease, there is a moment when this cost becomes lower than the German reservation wage. From then, (i) the whole of the unskilled segment S_L is offshored to the South, and (ii) this creates unemployment of the unskilled in Germany.

4) Facing the increase in unemployment, the German government decides to implement labour market reforms that lessen the social net and the reservation wage. This lowers the unskilled labour wage and the price of non-tradables, increasing thereby the demand for and production of *nt*, which diminishes unemployment.

3.4. Modelling strategy

The core of the above scenario lies in the decrease in the offshore production cost.

A first way to model this scenario is to build a complete framework with the three countries' endowments in skilled and unskilled labour being given and to calculate the general equilibrium values related to each aforementioned stage. This modelling strategy is twice disputable. First, it assumes a given size of the South (given endowments $\bar{L}^*$ and $\bar{H}^*$) which is at odds with the fact that a growing number of emerging countries have joined the globalized economy. Second, it comprises the calculations of all Southern values (production of each good, imports and exports, unskilled labour wage, etc.), implying thereby a complexity which is not necessary for our scenario which focuses on Germany. Finally, correcting the first shortcoming by assuming an increasing size of the South would reinforce the second critique.

In fact, there is a simpler way to model the same scenario. This consists in introducing the South through two elements, namely, the exogenously decreasing offshoring cost ω and the South balanced trade constraint. The latter permits to calculate the Southern total income as a linear function of both the German and North total incomes. This modelling strategy significantly simplifies the calculations because it allows ignoring the South 'inside equilibrium', i.e., its unit wage, its equilibrium on the labour market, its production of non-tradables, and finally its size. As we focus on equilibria in Germany and North, this is the strategy we select here. Then the different stages of our scenario can be modelled as follows.

We firstly determine the full employment equilibria when offshoring expands. In these cases, the German unskilled labour wage w_L is equal to the offshore production cost ω as long as offshoring expands until the moment when segment S_L is fully offshored (otherwise, there would be unemployment of German unskilled workers). We thus calculate the successive full employment equilibria from the situation without offshoring to the situation where segment S_L is fully offshored with $\omega = w_L$. In particular, this permits to define the full employment unskilled labour wage with no-offshoring w_L^{NO} and the full employment unskilled labour wage with full offshoring w_L^{FO}.

We can then introduce the German reservation wage $\underline{w}$ which must lie between w_L^{NO} and w_L^{FO}. The decreasing offshore cost ω becomes lower than $\underline{w}$ from a certain point in time. This leads to full offshoring (because the offshore production cost is lower than the German production cost of segment S_L) with unemployment of unskilled workers.

We finally introduce labour market reforms by making the reservation wage $\underline{w}$ decrease.

It must be noted that the model developed here is limited by construction and cannot thereby embrace a large number of specificities of the German experience. In particular, the successive equilibria assume balanced trade for the three countries, which cannot account for the large surplus of Germany. The impact of the German reunification is ignored. Finally, we shall suppose that North remains at full employment throughout the scenario so as to focus on the sole impacts of the interplay between offshoring and labour market institutions.

4. Equilibria

4.1. Full employment equilibria

4.1.1. Equilibrium without offshoring in Germany

Germany and North are at full employment. We also suppose that the cost of producing the unskilled-intensive segment is higher in Germany than in the South. Consequently, there is no offshoring.

We further assume the following two characteristics of the German economy:

1. The German relative endowment in skilled labour is higher than that of North. In fact, the proportion of workers with a tertiary degree within the working population is slightly lower in Germany compared to the rest of advanced countries, but the share of workers with post-secondary non-tertiary degree is substantially higher. This last characteristic corresponds to a specificity of the German education system in which in-the-firm apprenticeship has a significant weight. All in all, this shows that the German relative endowment in skilled labour is slightly higher than that of North, i.e.:

$$\frac{\bar{H}}{\bar{L}} > \frac{\tilde{\bar{H}}}{\tilde{\bar{L}}} \tag{9}$$

2. The following condition is met:

$$a > \left(\frac{\bar{L}}{\tilde{\bar{L}}}\right)^{1/\sigma} \left(\frac{\tilde{\bar{H}} / \tilde{\bar{L}}}{\bar{H} / \bar{L}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}} \tag{10}$$

Condition (10) establishes a relationship between (i) the demand attractiveness of the German quality, *a*, (ii) the relative endowment in skilled labour in both advanced countries, $\frac{\bar{\bar{H}} / \bar{\bar{L}}}{\bar{H} / \bar{L}}$, and (iii) the size of Germany in relation to North, $\bar{L} / \bar{\tilde{L}}$. In this relation, $a > \left(\bar{L} / \bar{\tilde{L}}\right)^{1/\sigma}$ corresponds to an attractiveness of the German good which is sufficiently high compared to the size of Germany. The full significance of Condition (10) is explained further on.

The full employment general equilibrium without offshoring is built in Appendix A. This equilibrium is characterised by the following values of the skill premia and of the wage of unskilled workers in Germany in relation to North:

$$w_{NO} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha + (1-\alpha)\gamma_{nt}} \frac{\bar{L}}{\bar{H}} \tag{11}$$

$$\tilde{w}_{NO} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha + (1-\alpha)\gamma_{nt}} \frac{\bar{\bar{L}}}{\bar{\tilde{H}}} \tag{12}$$

$$\frac{w_{NO}}{\tilde{w}_{NO}} = \frac{\bar{L} / \bar{H}}{\bar{\bar{L}} / \bar{\tilde{H}}} \tag{13}$$

$$\frac{w_L^{NO}}{\tilde{w}_L^{NO}} = a \left(\frac{\bar{\bar{L}}}{\bar{L}} \right)^{1/\sigma} \left(\frac{\bar{H} / \bar{L}}{\bar{\tilde{H}} / \bar{\tilde{L}}} \right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}} \tag{14}$$

where $\tilde{w}_L^{NO}$ ($\tilde{w}_L^{NO}$) and w_{NO} ($\tilde{w}_{NO}$) are the unskilled labour wage and the skill premium in Germany (North) in the 'no-offshoring' (NO) stage of our scenario.

From the preceding values, we infer the following two propositions:

Proposition 1: *At the full employment equilibrium without offshoring, the skill premium is lower in Germany than in North.*

Proof. From (9) and (13).

Proposition 2: *At the full employment equilibrium without offshoring, the wage of unskilled workers is higher in Germany than in North.*

Proof. From (10) and (14).

The interpretation of Proposition 1 is straightforward: the skill premium is lower in Germany because of the German higher relative skill endowment.

As regards Proposition 2, three mechanisms combine to raise the wage of unskilled workers in Germany in relation to North:

1. A high coefficient *a* makes the German quality *h* to be highly demanded in relation to North's quality $\tilde{h}$. This increases the demand for both skilled and unskilled labour in Germany, and thereby the German wage for both types of labour.

2. A higher relative size of North ($\bar{\bar{L}} / \bar{L}$) increases the supply of both skilled and unskilled workers in North in relation to Germany, which increases the German wages for both types of labour in relation to North for a given attractiveness coefficient *a*.

3. A higher German skill endowment $\bar{H} / \bar{L} > \tilde{\bar{H}} / \tilde{\bar{L}}$ signifies a lower relative supply of unskilled labour in Germany compared to North. This entails a higher wage of unskilled labour in Germany compared to North.

Mechanism 3 is obvious. Mechanisms 1 and 2 combine so as to determine the wage level in one country in relation to the other. If the variety produced by Germany is highly demanded (high coefficient *a*), then the size of Germany must be large enough to provide the world market with this good. If it is not the case, the price of this good increases which pushes up the German wages. This correspondence between the attractiveness *a* and the country size directly stems from Armington's hypothesis that states country-specific qualities of goods.

Proposition 2 can thus be interpreted as follows. The difference in skill endowments ($\bar{H} / \bar{L} > \tilde{\bar{H}} / \tilde{\bar{L}}$) results in a higher *relative* wage of unskilled labour in Germany (Proposition 1). Thus, to have a wage of unskilled workers higher in Germany than in North, it is sufficient the attractiveness of the German quality, *a*, not to be too low compared to Germany's size (low attractiveness would reduce the relative price of the German quality and thus the wages of both skilled and unskilled workers in Germany compared to North). Note that an attractiveness of the German quality higher than that of North's (i.e., $a > 1$) is not required to reach such a result.

4.1.2. Full employment equilibrium with offshoring

We now suppose that (i) Germany remains at full employment and (ii) the cost ω of unskilled labour in the offshored segment S_L is lower than w_L^{NO}. As soon as the offshoring cost moves below w_L^{NO}, German firms begin to outsource segment S_L. Then, the German wage w_L adjusts so as to ensure full employment. As long as segment S_L is not fully offshored, the wage adjustment imposes equality $w_L = \omega$ to reach full employment. When ω attains the value for which the German unskilled labour $\bar{L}$ is fully employed in the sector of non-tradables, then the full employment German wage w_L cuts of from ω. In addition:

Proposition 3. *In the skill-intensive sector, German firms begin to outsource their unskilled segment before North firms.*

Proof. As $w_L > \tilde{w}_L$, the deceasing value $\omega(t)$ attains w_L before $\tilde{w}_L$. Hence, German firms begin to outsource before North firms.

In what follows, we place ourselves in the situation in which Germany partially offshores its segment S_L whereas North still fully produces its quality $\tilde{h}$. The building of the model with full and partial offshoring is exposed in Appendix B and C. The decrease in the cost of producing offshore is introduced in the model through a decrease in the relative price $\omega / \tilde{w}_L$. The results of this modelling lead to the following proposition:

Proposition 4. *During the partial offshoring stage with full employment (implying $w_L = \omega$), the German skill premium increases from w_{NO} and tends towards the value $w_{FO} = \dfrac{1-\gamma_{nt}}{\gamma_{nt}} \dfrac{\bar{L}}{\bar{H}} > w_{NO}$ which ensures full employment of unskilled workers in the non-tradable sector.*

4.2. Reservation wage, unemployment and labour market reform

We now introduce a reservation wage $\underline{w}$ in Germany. This reservation wage is assumed to be higher than the unskilled labour wage w_L^{FO} corresponding to the situation in which the non-tradable sector generates full employment of the unskilled workers. The decrease in the offshore production cost ω makes this cost to attain the reservation wage $\underline{w}$ at a certain point in time. From then, the production of segment S_L is fully offshored to the South, and unskilled labour is thus only employed by the non-tradable sector in Germany. Consequently, the feature $\underline{w} > w_L^{FO}$ generates unemployment of the unskilled workers in Germany. We can then establish propositions 5 and 6:

Proposition 5. *Assume a reservation wage $\underline{w}$ in Germany such that $\underline{w} > w_L^{FO}$. Then:*

1) *Segment S_L is fully offshored and there is an upward jump in unemployment of the German unskilled workers as and when the offshore cost ω goes below the reservation wage $\underline{w}$, and the higher $\underline{w}$ the higher unemployment.*
2) *Unemployment subsequently decreases with the decrease in ω.*
3) *When $\underline{w} > \omega$, then the German skill premium with reservation wage w_{RW} is lower than the skill premium without, and w_{RW} decreases with the reservation wage $\underline{w}$.*
4) *The decrease in the offshore production cost ω raises the German skill premium.*

Proof. Appendix D, results D1, D2 and D3.

The explanation for Proposition 5 is as follows. When the offshore cost ω goes below the reservation wage, the whole production of segment S_L is immediately relocated to the South. This generates *a one-shot upward jump in German unemployment*. From then:

1) The German skill premium continues to rise with the decrease in ω (Proposition 5, Feature 4), but the skill premium with reservation wage and unemployment is lower than the skill premium that would have arisen without reservation wage (Feature 3). The reason for this is simple. The decrease in w_L is firstly prevented by the reservation wage, which slows the rise in the skill premium down. On the other hand, the decrease in ω lowers the cost of producing *h* and increases thereby the world demand for *h*, leading to an increase in the demand for German skilled workers and thus a rise in w_H and in the skill premium.

2) After the one-shot jump in unemployment, the subsequent continuing decrease in the offshore cost ω lessens unemployment. This is because, as the decrease in ω increases the income of skilled workers w_H (explanation above), their demand for non-tradable services augments, which raises the number of unskilled workers employed in sector *nt*. This is a key result because it shows that the decrease in unemployment would have occurred even without the reform in the labour market provided that ω continues to decrease (discussion hereafter).

3) A labour market reform that lowers the reservation wage typically lowers unemployment (Feature 1). Note that if this reform occurs when the decrease in unemployment has begun, both the reform and the decrease in ω push unemployment down, which creates a substantial gain in employment.

Hence, unemployment displays an inverted-V curve from the time when ω attains $\underline{w}$. It firstly jumps upward and it subsequently decreases as ω goes downwards, this decrease being speeded up when the reservation wage is lessened by the labour market reform.

Proposition 6. *Assume a reservation wage* $\underline{w}$ *such that* $\underline{w} > w_L^{FO}$ *. Then:*

1) *There is an upward jump in the ratio of exports to production in Germany as and when* ω *goes below the reservation wage.*
2) *The subsequent decrease in* ω *lessens this ratio.*
3) *A labour market reform that decreases* $\underline{w}$ *has no impact on this ratio if full offshoring remains and it lessens this ratio in the opposite case.*

Proof. Appendix D, result D4, D5 and D6.

The combination of propositions 5 and 6 has several key consequences.

Firstly, at the moment of the upward jump in unemployment, Germany simultaneously displays an upward jump in its exports/production ratio (Proposition 6 Feature 1). Subsequently, the decrease in ω reduces the exports/production ratio, lessens unemployment and augments the skill premium. This decrease in the X/I ratio results from the fact that a large share of the exports consists of re-exports of the imported segment S_L the price of which is reduced by the decrease in ω. Finally, the decrease in the reservation wage $\underline{w}$ due to the labour market reform reinforces both the decrease in unemployment and the rise in the skill premium. As regards the exports/production ratio, the effect of a decrease in $\underline{w}$ depends on whether this makes a part of S_L to be relocated in Germany or not. The first case corresponds to a new reservation wage such that $w_L^{FO} < \underline{w} < \omega$ and it results in a decrease in exports because of lower trade with the South (due to the lower imports of S_L). In contrast the decrease in $\underline{w}$ has no impact on the exports/production ratio if segment S_L remains fully offshored.

In short, unemployment and the exports on production ratio are moving in the same direction from the time when ω attains $\underline{w}$, firstly increasing as ω goes below $\underline{w}$ and subsequently decreasing with the reduction in ω and $\underline{w}$.

5. Extended model and simulations

The model developed in the preceding two sections is clearly better tailored to explain the observed facts than the 'traditional explanation' exposed in the introduction. Indeed, (i) the increase in the skill premium (inequality), the decrease in the wage w_L and the increase in the exports on production ratio occur before the implementation of the labour market reform, (ii) the rise in inequality and in unemployment are simultaneous before the labour market reform, and (iii) the decrease in unemployment comes with a decrease in the export/production ratio after the reform. All these predictions are consistent with observed facts.

Nevertheless, the model generates a disputable outcome: the increases in both unemployment and the exports/production ratio display one-shot upward jumps whereas they persist for several years in the German experience. Hence, the increases in unemployment and in inequality never occur at the same time whereas they were simultaneous from 2000 to 2005.

These shortcomings obviously derive from two simplifying assumptions, i.e., (i) the existence of one skill intensive sector only with thereby one single offshoring cost and (ii) the fact that all unskilled workers are identical. These assumptions generate a one-shot rise in unemployment and make that rising inequality cannot come with rising unemployment. A simple way to smooth the increase in unemployment is to assume several *H*-utilising sectors

with different offshoring costs. This is what we do now by extending the model to the case of a continuum of *H*-utilising goods.[6] Such an extension cannot generate simple analytical outcomes such as those found above. This is why the extended model is simulated so as to reveal variation profiles consistent with observed facts.

5.1. The extended model

We keep the same general framework, except that we assume a continuum of varieties in both sectors h (Germany) and $\tilde{h}$ (North), with differences in the cost of producing offshore across varieties. So as to focus on the sole German experience, we assume as before that North does not outsource abroad its segment $\tilde{S}_L$ throughout the analysed period.

The new extended framework is characterised by two major modifications:

1. Both sectors h (in Germany) and $\tilde{h}$ (in North) comprise a continuum of varieties (the German varieties are denoted *i* and North's $\tilde{i}$) over an interval normalised to 1, $[0,1]$. Hence, the utility function is now:

$$u = \gamma_l \log c_l + \gamma_h \log\left(a\int_0^1 c_i{}^{\theta} di + \int_0^1 c_{\tilde{i}}{}^{\theta} d\tilde{i}\right)^{1/\theta} + \gamma_{nt} \log c_{nt}, \quad \gamma_h + \gamma_l + \gamma_{nt} = 1$$

This generates the following demand for each German and North variety (Y_i^d and $Y_{\tilde{i}}^d$):

$$p_i Y_i^d = \frac{\gamma_h \mathcal{I}}{p_i{}^{\sigma-1}\left(\int_0^1 p_j{}^{1-\sigma} dj + a^{-\sigma}\int_0^1 p_{\tilde{j}}{}^{1-\sigma} d\tilde{j}\right)};$$

$$p_{\tilde{i}} Y_{\tilde{i}}^d = \frac{\gamma_h \mathcal{I}}{p_{\tilde{i}}{}^{\sigma-1}\left(a^{\sigma}\int_0^1 p_j{}^{1-\sigma} dj + \int_0^1 p_{\tilde{j}}{}^{1-\sigma} d\tilde{j}\right)}$$

where p_i (resp. $p_{\tilde{i}}$) is the price of the German (North) variety *i* ($\tilde{i}$) and $\mathcal{I}$ the total income of the considered area ($\mathcal{I} = I, \tilde{I}, I^*$ or I_W).

The German and North varieties *i* are produced with the same technologies as goods *h* and $\tilde{h}$ in the simple model developed above. We then denote $S_L(i) = L_{hi}$ and $S_H(i) = H_{hi}$ the unskilled and skilled segments respectively in the production of variety *i* of sector *h*.

2. In the German sector *h*, the cost of producing offshore segment S_L (denoted ω_{it} for variety *i* at time *t*) differs across varieties.

The goods $i \in [0,1]$ are ranked in ascending order of offshore cost.

We assume that, at any time *t*, the offshore cost is linearly increasing in *i* from $\underline{\omega}_t$ to $\bar{\omega}_t = \underline{\omega}_t + \kappa$, i.e.:

$$\omega_{it} = \underline{\omega}_t + i \times \kappa, \qquad i = 0,...,1$$

Suppose that, at time *t*, the *L*-segments of the German varieties $[0,k]$ are offshored whereas the varieties $]k,1]$ are fully produced in Germany. This means that the cost of

[6] Another way to get the same outcome is to assume heterogeneity between unskilled workers so that they do not share either the same reservation wage, or the same productivity.

producing offshore segment S_L for good *k* is exactly equal to the cost of producing it in Germany, i.e., to the unskilled labour wage w_L. Hence:

$$\omega_{kt} = \underline{\omega}_t + k \times \kappa = w_{Lt} \Rightarrow \underline{\omega}_t = w_{Lt} - k \times \kappa$$

And (*t* is omitted for the sake of simplification):

$$\omega(i) = w_L - (k - i)\kappa, \qquad i = 0,...,1 \tag{15}$$

The varieties with offshored segments S_L are those with an offshore cost ω lower than the cost of producing S_L in Germany w_L ($\omega(i) = w_L - (k-i)\kappa < w_L$ for variety *i*). Consequently, the decrease in $\underline{\omega}_t$ can be modelled as an increase in *k*, i.e., in the number of varieties with segment S_L being offshored.

5.2. Modelling and simulation strategy

From the above-described assumptions, we determine the general equilibrium values for Germany and North (skill premia, nominal and real unskilled labour wages, rate of unemployment and ratio of exports to total income), corresponding to the following four phases:

1) *Phase NO*: No offshoring of any German segment $S_L(i)$ and full employment in Germany. In this case, $\omega(0) > w_L^{NO}$, where 0 is the German variety with the lowest offshore cost and w_L^{NO} the German unskilled labour wage at full employment with no offshoring.

2) *Phase OFE*: We subsequently calculate the general equilibrium values in the situation where Germany remains at full employment and offshores a growing number of segments $S_L(i)$. This corresponds to the lowest offshore cost $\omega(0)$ lower than w_L^{NO} and to a growing number of varieties *i* with an offshore cost lower than the full employment unskilled labour wage in Germany. As indicated above, this is modelled by making *k* increase from 0 to 1 with (i) varieties $[0,k]$ having their segments $S_L(i)$ offshored, (ii) varieties $]k,1]$ having their segments $S_L(i)$ produced in Germany, (iii) $\omega(i) = w_L^{OFE}(k) - (k-i)\kappa$ and (iv) $w_L^{OFE}(k)$ ensuring full employment in Germany.

3) *Phase RW*: We then select a value of the reservation wage $\underline{w}$ between w_L^{NO} and $w_L^{OFE}(1)$, and we calculate the general equilibrium with reservation wage for the *k* such that $w_L^{OFE}(k) < \underline{w}$. This generates unemployment of unskilled workers.

4) *Phase HR*: We finally introduce the labour market (Hartz) reforms by assuming a decrease in the reservation wage that moves from $\underline{w}$ to $\underline{w}' < \underline{w}$.

The simulation of the last phase (corresponding to the implementation of the Hartz reforms) requires additional assumptions on (i) the offshoring behaviour of firms and (ii) the rhythm at which the reservation wage decreases. A limit situation is when (i) the reservation wage decrease is one-off, and (ii) all German firms whose offshore production cost is higher than the new reservation wage decide to 'in-shore', i.e., to relocate in Germany their segment S_L, even if they will soon move it back again to the South as the offshore cost continues to decrease. These assumptions can be considered as extreme because (i) the Harts reforms have been implemented over several years, which shows that the decrease in the reservation wage

has been spread out, and (ii) the fact that firms that have offshored their *L*-segment can bring it back to Germany and offshore it again later is rather unlikely. This is because there are fixed costs of both offshoring and 'in-shoring' (not accounted for in our model) that render these moves non-profitable. Our simulation strategy will thus be twofold. We shall firstly calculate the values corresponding to a one-shot decrease in the reservation wage with relocation of S_L to Germany for all firms with an offshore cost lower that the new reservation wage. This corresponds to the extreme and unrealistic scenario just described. For each variable, we shall secondly draw the line that joins the value corresponding to the former reservation wage at the moment when this reservation wage starts changing and the value corresponding to the moment when $k = 1$ (full offshoring of unskilled intensive segments) for the new reservation wage. The latter corresponds to the combination of a lack of in-shoring with a smooth decrease in the reservation wage.

The systems of equation corresponding to the first three cases are described in Appendix E and their construction is available from the authors upon request.

5.3. Parameters

Table 1 depicts the values of the parameters utilised in the simulations and Table 2 the factor endowments. the unskilled labour wage in North $\tilde{w}_L$ is taken as numéraire.

Table 1. The model's parameters

γ_l	γ_h	γ_{nt}	α	A	σ	δ	a
0.25	0.35	0.4	0.25	1	2	1	0.4

Table 2. Factor endowments and wages

$\bar{L}$	$\bar{H}$	$\bar{\tilde{L}}$	$\bar{\tilde{H}}$	$\tilde{w}_L$	$\underline{w}$	$\underline{w}'$	κ
7.5	2.5	55	15	1	1	0.8	0.3503

The γ_j, $j = h, l, nt$, are selected so as to broadly represent the share of traditional goods, durables goods and 'new' industries, and non-tradable services in total demand. Of course, these values are very partial because a lot of sectors and public services (health, education, justice and police etc.) are not accounted for. As most of the publicly provided services are (very) skill-intensive and given that the public manpower represents between 15% and 20% of the working population in most advanced countries, we have reduced the amount of skilled workers by about 20% in relation to what was observed in Germany and North in the late 1990s. Coefficient α is equal to 0.25, which shows that the share of less skilled workers in the total income paid by sectors *h* and $\tilde{h}$ is 1/4. The labour productivity in sector *nt* is $\delta = 1$. This unit value permits to simplify the calculations without affecting the results since the share of sector *nt* in total expenditure is unchanged and equal to 40%. Coefficient *a* is chosen so as to verify Condition (10) and to have a wage of unskilled workers in Germany that is 30% higher than in North.

Factor endowments are such that (i) Germany accounts for 12.5% of the total labour force in advanced economies, and (ii) Germany is slightly better endowed with skill labour than North. The unskilled labour wage in North is chosen as numeraire and the reservation wage is assumed to be initially lower than w_L^{NO} by about 30%, and to be reduced by 20% when the labour market reform is achieved. Finally, we suppose that the difference between the lowest and the highest offshore cost, κ, is equal to 30% of the wage w_L^{NO}.

5.4. Results

5.4.1. Initial values (no-offshoring, scenario NO)

Table 3 depicts the model values at the starting point, i.e., with full employment and no-offshoring in Germany (i.e., the offshore cost is higher than the unskilled workers wage).

As expected, the skill premium is higher in North and the wage of unskilled workers higher in Germany. In addition, the real income per capita is higher in Germany (y_{real}) than in North ($\tilde{y}_{real}$). Finally, the ratio of exports on production is 55%. This rather high level is obtained because public services are not inserted in the model.

Table 3. Values at the starting point

w_{NO}	$\tilde{w}_{NO}$	w_L^{NO}	p_h	$p_{\tilde{h}}$	P_h	p_{nt}	$p_{\tilde{n}t}$	P	$\tilde{P}$	wr_L^{NO}	$\tilde{w}r_L^{NO}$
2.454	3	1.168	4.019	4	3.45	1.168	1	1.641	1.542	0.7115	0.648

Table 3 (continuing)

I	$\tilde{I}$	I^*	y_{real} #	$\tilde{y}_{real}$ #	x ##
15.93	100	82.80	1.29	1.18	0.552

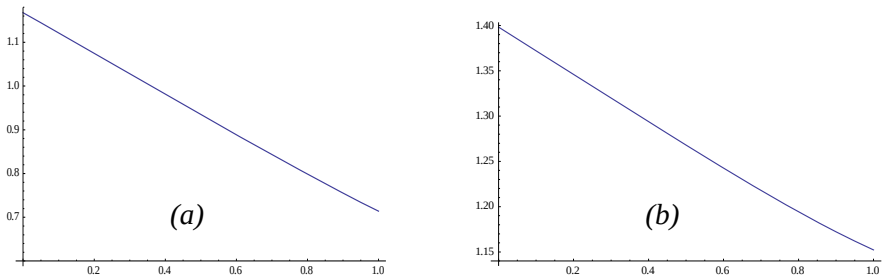
y_{real} ($\tilde{y}_{real}$) is the real income per capita in Germany (North). ##Export/production ratio.

5.4.2. Partial offshoring with full employment (Scenario OFE)

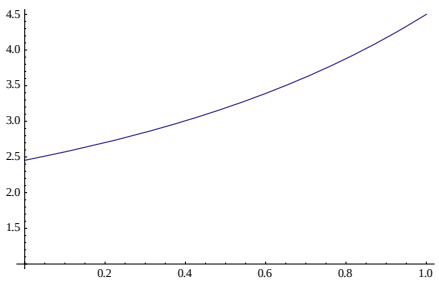
We now make *k* to move from 0 (no-offshoring) to 1 (offshoring of all *L*-segments).

Figures 7-8 depict the changes in the unskilled workers' nominal (w_L) and real (w_L / P) wages and in the skill premium. The moves in other variables (I , $\tilde{I}$, I^* , $\tilde{y}_{real}$ and $\tilde{y}_{real}$) are available from the authors upon request.

Figure 7. Unskilled workers' wage (Scenario OFE): *(a)* nominal; *(b)* real



Figures 8. The skill premium (Scenario OFE)



Offshoring results in a huge increase in the skill premium that moves from 2.45 up to 4.5. Both the nominal and real wages of unskilled workers decline. The decline in the real wage is however less intense because offshoring entails a decrease in prices.

Finally, the increase in offshoring results in an increase in trade in relation to production, the exports/production ratio (x) moving from 0.55 up to 0.75.

5.4.3. Offshoring with reservation wage (Scenario RW)

We now suppose that there is a reservation wage in Germany, the value of which is $\underline{w} = 1$. As previously, we make k move from 0 to 1 so as to depict the offshoring dynamics linked to the decrease in the offshore production cost. Then, the changes in variables are the same as those depicted in the previous Scenario OFE as long as the German unskilled labour wage at full employment is higher than $\underline{w}$. From the moment when this full employment wage goes below $\underline{w}$, unemployment emerges.

Figures 9-11 depict the variations in the nominal and real wage of unskilled workers, in the skill premium, in unemployment and in the exports/production ratio.

As expected, the skill premium continues to increase but at a slower pace once Germany attains the reservation wage, i.e., from the value w = 2.92 (Figure 10). This reflects the fact that, even if w_L remains constant at value $\underline{w}$, w_H continues to increase because the rise in the demand for German skilled workers due to the decline in the price of the German varieties in sector h (as ω decreases).

It must be noted that, if the German unskilled workers' nominal wage remains constant once it has reached the reservation wage, the related real wage increases. This reflects the decrease in the general price index linked to the decrease in the price p_h.

Figure 11a depicts the unemployment rate of unskilled workers and Fig. 11b the total unemployment rate, i.e., the ratio of unskilled unemployed to total employment. The unemployment rate increases during the period of partial offshoring (k increasing up to 1) with reservation wage ($w_L = \underline{w}$) and decreases afterwards, i.e., once all segments S_L are offshored, as predicted by the theoretical approach (Proposition 5, point 2). This reflects the fact that the continuing rise in w_H increases the demand for non-tradables, and thus employment in this sector.

Figure 9. Unskilled workers' wage (Scenario RW): *(a)* nominal; *(b)* real

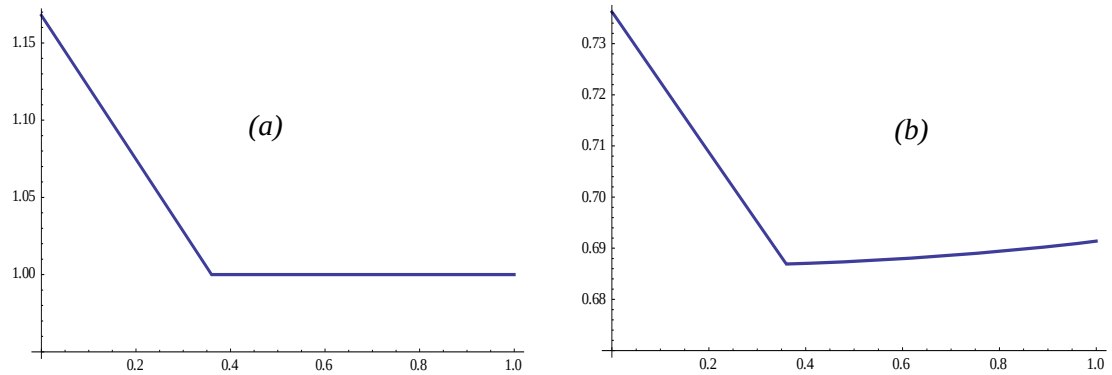


Figure 10. The skill premium (Scenario RW)

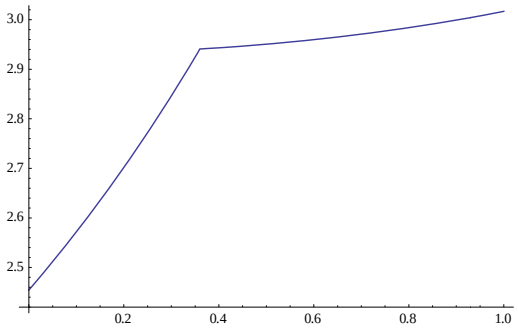
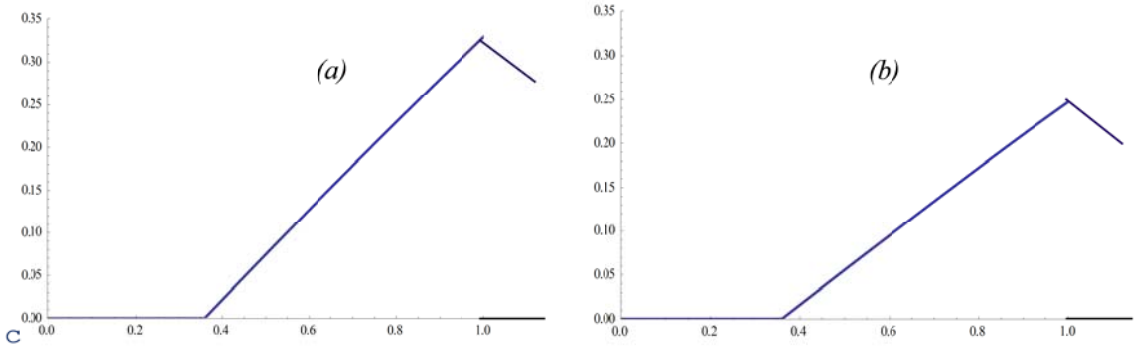


Figure 11. Unemployment rate (Scenario RW): (a) unskilled workers; (b) total



5.4.4. Hartz reforms (Scenario HR)

We now assume that the government introduces labour market reforms when the unemployment rate attains 15%, which corresponds to an unemployment rate of 20% for the unskilled workers. The reform makes the reservation wage to move from $\underline{w} = 1$ to $\underline{w}' = 0.8$, i.e., a decrease by 20%.

Figures 12-15 depict the changes in the different variables during the successive three phases corresponding (i) to Scenario OFE for $\omega = w_L^{OFE} > \underline{w}$, (ii) to scenario RW for $w_L^{OFE} < \underline{w} = w_L$ until the unemployment rate of 15%, and (iii) to the subsequent implementation of the reservation wage $\underline{w}' = 0.8$. In the latter case, the variations of the different variables are between two limits. The first limit corresponds (i) to a one-shot jump in the reservation wage from 1 to 0.8 and (ii) to all the L-segments that become cheaper in Germany because of the new reservation wage going back to Germany, albeit they will later be offshored again to the South. The second limit corresponds to (i) all the segment S_L already offshored that remain offshored, and (ii) a gradual decrease in the reservation wage. The dimmed surfaces correspond to the possible points between these two extreme trajectories.

Logically, the decrease in the reservation wage results in both a decrease in the unskilled workers' wage (Fig.12) and a significant increase in the skill premium (Fig. 13) and a substantial decrease in unemployment (Fig. 14). This decrease combines both the increase in the demand for unskilled workers from the sector of non-tradables and the return to Germany of a number of *L*-segments previously offshored. In the extreme situation where (i) the decrease in the reservation wage and its effects are immediate and (ii) all the *L*-segments that become cheaper in Germany return to Germany, then Germany goes back to full employment

and remains there for a time (i.e., the time for the unskilled wage w_L^{OFE} to become lower than the new reservation wage $\underline{w}'$). In the more realistic case in which the decrease in the reservation wage is gradual and only a limited part of the already offshored segment are relocated to Germany, the variations in the skill premium and unemployment are depicted by the dashed curve in Figure 13 and 14.

Figure 12. Unskilled workers' wage (Sc. HR)

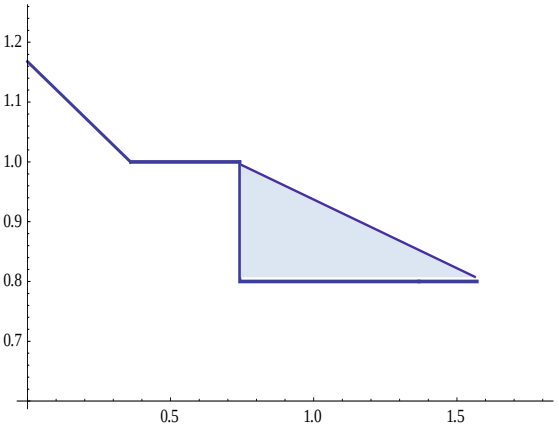


Figure 13. The Skill premium (Sc. HR)

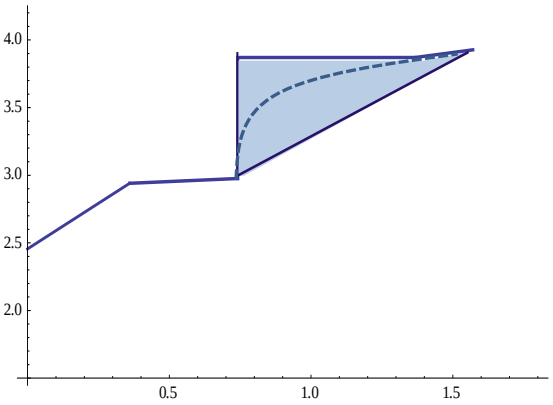
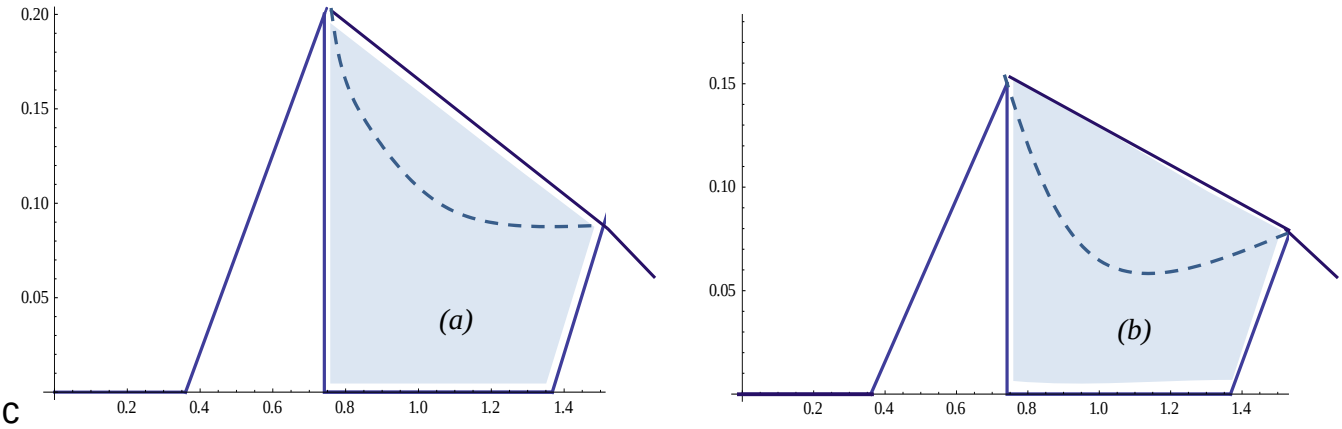
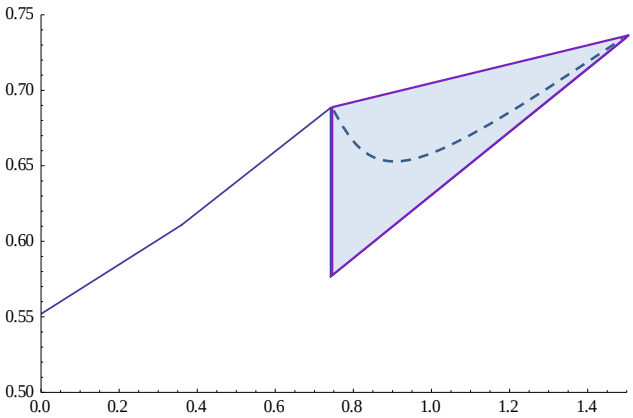


Figure 14. Unemployment rates (Scenario HR): (a) Unskilled workers; (b) Total



C

Figure 15. Exports/production ratio (Scenario HR)



Three characteristics of the simulated development can be highlighted:

1) As regard the skill premium, the curve in Figure 13 assuming the realistic scenario (dashed curve) reveals a profile which is very similar to the observed variation in inequality depicted in Figure 5 (Section 2.1).

2) As regards unemployment, its huge decrease due to the lower reservation wage in the periods following the implementation of the labour market reforms can be seen as a key explanation of the feeble impact of the 2008 crisis upon employment in Germany, as depicted in Figure 1b (Section 2.1). There are of course other explanations, such as the choice of German firms to transitorily lower the working time of their employees rather than dismissing them. Nevertheless, the increase in the number of mini-jobs and temporary agency workers (Fig. 3a) show that the economic recession that followed the 2008 financial crisis had a limited impact on German employment. This suggests that, by lessening the wage the unemployed were prepared to accept (i.e., the reservation wage), the labour market reforms have created new jobs in non-tradable services and helped maintaining jobs that would have otherwise been outsourced abroad.

Note that the fact that unemployment remains at a rather high level compared to what is observed in Germany can be explained by the fact that the public sector (representing about 15% of the working population in Germany, with a proportion of skilled worker significantly higher than the average) is not included in our model.

Finally and as before, the reduction in the offshore production cost entails a decrease in unemployment once all the segments S_L are offshored (Fig.14).

3) As regards the exports/production ratio, the simulated scenario reproduces rather well the observed profile. The major increase in this ratio occurred before the Hartz reform whereas this ratio has stopped increasing from 2006. This is exactly what is predicted by our model. The ratio exports/production increases during the phase of offshoring with full employment. This increase speeds up when unskilled workers are paid the reservation wage $\underline{w}$, and it successively decreases to rise again but moderately after the labour market reforms.

Finally, the simulation also reveals that the lower reservation wage comes with a slow-down of the rise in the weight of the non-tradable sector in total employment (Figure available upon request), which can be related to the observed slow-down in the increase in the share of the working population employed in services after the implementation of the Harz reforms. The slow-down in the rise of the weight of non-tradable services in employment, despite the increase in employment in this sector, reflects the fact that the labour market reform temporarily stops the offshoring dynamics and can even cause the return to Germany of certain unskilled segments already offshored, which augments employment in manufacturing.

6. Discussion

We firstly compare our results to the stylised facts highlighted in Section 2. We subsequently discuss the policy implications of our model.

6.1. The model's results facing observed facts

We have developed a model in which the cost of producing offshore decreases with time. Unlike the usual explanation described in the introduction, the model generates variations in the skill premium (inequality), in unemployment, and in the export/production ratio that fit with observed facts. In addition, if the simple analytical framework developed in sections 3 and 4 shows certain limits due to the one-shot jumps in unemployment and in the

exports/production ratio, the simulations performed from our extended model accurately replicate the sequence of observed facts.

On top of this adequacy, the model reveals that the decrease in unemployment would have occurred even without the Harts reforms, although later and less intensively. This is because, if the offshore production cost continues decreasing after the full offshoring of segment S_L, then the related rise in the wage of skilled workers makes them increase their demand for non-tradable services, which lowers the unemployment of unskilled workers. Of course this unemployment reduction comes to an end (as well as the increase in the skill premium) when the offshore production cost stops decreasing.

Finally the model provides an explanation for two additional observed facts:

1) The stop of the increase in the exports on production ratio from 2003 whereas one could have expected a speeding up due to the impact of wage moderation on competitiveness on foreign markets.

2) The slowdown of the rise in the share of the service sector in total employment that follows the Hartz reforms.

In summary, the model provides a rather convincing picture of the main characteristics and mechanisms that compose the German experience since 1995.

6.2. Policy implications

In the scenario modelled in this paper, (i) firms decide to offshore their unskilled-intensive stage of production when the offshore production cost has sufficiently decreased, (ii) this generates a decrease in the unskilled labour wage as long as the latter is downward flexible, and (iii) this creates unemployment from the time when the unit cost of producing abroad has attained the German reservation wage. Then, labour market reforms that lessen the reservation wage permit to reduce unemployment by creating jobs in the non-tradable sector.

One additional consequence of this strategy is that it generates inequality, which can make the least skilled to fall below the poverty line (the poverty rate has significantly increased in Germany since 1999, for both working and unemployed individuals). Low pay is the price for low unemployment, which may be considered as damaging[7].

We now tackle the following two issues: a) Is this 'strategy' applicable to other Eurozone countries? b) Is it possible to generate the same mechanism, i.e., job creation in the non-tradable sector, without reducing the wage of the less skilled?

6.2.1. Extension to other Eurozone countries

We focus on Eurozone countries because, as they share the same currency, wage moderation is the only short term way to increase price-competitiveness amongst these countries.

One frequent critique brought to the Hartz reforms is that it is a 'beggar my neighbour' policy[8]. If this is true, the implementation of similar reforms in other Eurozone countries could just set the record straight. However, this critique directly stems from the 'usual' diagnosis that wage moderation is the main driver of German competitiveness on foreign markets. In contrast, the 'beggar my neighbour' impact remains marginal if, according to our interpretation, the labour market reforms essentially act through the employment of low skilled workers in non-tradable services.

Our model makes it possible to analyse the effects of such reforms in other Eurozone countries. First, offshoring begins in other countries when the cost of producing segment $\tilde{S}_L$ in the South attains the wage $\tilde{w}_L^{NO}$ corresponding to full employment without offshoring in

[7] See Dumont (2013) and Hellier and Chusseau (2010) for analyses of the inequality-unemployment trade-off.
[8] E.g.: Interview of C. Lagarde in the Financial Times, March 14th 2010.

North (which has not been introduced in our model for the sake of simplification). From then on, the same story as displayed for Germany applies. As long as $\underline{\tilde{w}} < \omega < \tilde{w}_L^{NO}$, unskilled workers' wage decreases and the skill premium increases in North, which maintains full employment. Once ω has reached the reservation wage $\underline{\tilde{w}}$, the production of $\tilde{S}_L$ is fully offshored and unemployment appears. As in the German scenario, a set of reforms that lowers the reservation wage typically allows reducing unemployment. It must however be noted that:

1) As for Germany, this policy increases inequality, and the inequality-unemployment trade-off should be more intense in North than in Germany because North has a lower relative endowment of skilled workers.

2) The catching up of German competitiveness in the *H*-intensive sector could take time because German firms benefit from the cost advantage linked to the fact that they were the first to outsource to the South. In fact, part of the decrease in the offshore production cost occurs in-the-firm, and the firms that offshore earlier benefit from higher cost reductions. In addition, Germany benefits from a cost advantage when offshoring towards Central and Eastern European country, due to geographic and historical cultural proximity.

6.2.2. Alternative policies

In the short term, there is obviously a way to boost employment in the non-tradable sector without lessening wages. This consists in subsidising production in this sector and taxing the tradable goods to finance the subsidies. This could be implemented by modulating the value added tax or the social levies according to sectors. This strategy permits to increase the demand for non-tradables without lessening the reservation wage and without increasing inequality. Of course, this typically raises the levies on tradable goods, but this rise may be offset by cuts in the taxes on the non-tradable sector. A number of countries have attempted to increase their international competitiveness by lowering the cost of unskilled labour through both a decrease in wages and a decrease in the social contributions paid by firms on low wages, the related losses in levies being offset by an increase in the value added tax. A more targeted strategy that concentrates subsidies or decreases in contributions in the non-tradable services with a high elasticity of unskilled labour demand could prove to be more appropriate.

In the longer term, it is clear that skill upgrading is an efficient means to prevent the offshoring-related rise in inequality. Ceteris paribus, a decrease in the relative supply of unskilled labour reduces the skill premium. This provides an additional reason to prefer the sector-targeted policy to the low wage strategy. In fact, as revealed by a numerous literature, growing inequality tends to reduce human capital accumulation when the credit market is imperfect and education is costly (surveyed by Chusseau & Hellier, 2013). By impoverishing the low-skilled part of the working population, a policy that fosters inequality could be counterproductive in the longer term.

In summary, short term subsidies to, or lower levies on, the unskilled-intensive non-tradable sectors combined with an active pro-skill education and training policy could be an alternative strategy that avoids the inequality-unemployment trade-off that characterises the Hartz reforms.

7. Conclusion

From a three-country general equilibrium model in which (i) production is segmented in the skill-intensive sector, (ii) there is a decreasing cost of producing offshore and (iii) there is a non-tradable sector, we have built a scenario that aims at portraying the key characteristics and mechanisms of the German experience since the mid-nineties. The model replicates the key observed facts and sequences characterising the German economy since 1995:

1) The model explains why Germany started offshoring earlier and more intensively than other advanced countries.

2) The increase in competitiveness and in the exports/production ratio occurs before the setting of the labour market reform, and this comes with both higher inequality and higher unemployment.

3) The implementation of the labour market reform that lowers the reservation wage allows reducing unemployment and increasing production by creating new and cheaper jobs in the non-tradable sector, and this comes with a decrease in the exports/production ratio and an increase in inequality.

The model also predicts that the decrease in unemployment would have occurred even without the Hartz laws, but later and less intensively.

The same strategy can obviously be applied in other Eurozone countries once their firms have started to offshore their unskilled intensives stages of production. However, the catching up of the German external competitiveness could be difficult and slow. This is because the first country whose firms decide to offshore benefits from a lasting cost advantage and Germany could have an offshoring cost that remains lower than that of other countries in Central European countries.

In addition, the channel by which the labour market reform lessens unemployment and boosts production is the creation of jobs in non-tradable services. Based on this diagnosis, we have discussed the possibility to implement alternative policies that could act through this channel without increasing inequality.

The increase in the production of non-tradables can actually be attained by subsidising or decreasing levies on non-tradable services and increasing taxes on tradable sectors, . Such a policy could lessen unemployment without rising inequality. Combined with training and skill upgrading, this pictures a strategy that permits to escape from the inequality-unemployment trade-off, both in the short and the longer term. The sources of employment linked to such a policy are potentially substantial given the growing needs linked to the rising age of the population, the expansion of female activity and the prevention and control of pollution in most advanced economies.

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Appendix A. Equilibrium with no-offshoring (NO) & full employment

Both segments of *h* and $\tilde{h}$ are fully produced in the related advanced country, i.e., without international outsourcing.

Assuming perfect competition on the markets for goods and because of the Cobb-Douglas technology, we have $p_h = A^{-1}\left(\frac{w_H}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_L}{\alpha}\right)^{\alpha}$, $p_{\tilde{h}} = A^{-1}\left(\frac{\tilde{w}_H}{1-\alpha}\right)^{1-\alpha}\left(\frac{\tilde{w}_L}{\alpha}\right)^{\alpha}$, and thus:

$$\frac{p_h}{\tilde{p}_{\tilde{h}}} = \frac{w_L}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha} \qquad \text{(A1)}$$

Balanced trade in the South and determination of I*

Balanced trade of the South allows defining *I** in terms of *I* and $\tilde{I}$.

Let M_i^* be the value of imports of good *i* by the South and X_j^* the South's exports of good *j* value. We have $M_h^* + M_{\tilde{h}}^* = \gamma_h I^*$ and $X_l^* = \gamma_l (I + \tilde{I})$. Balanced trade ($X_l^* = M_h^* + M_{\tilde{h}}^*$) implies:

$$I^* = \frac{\gamma_l}{\gamma_h}(I + \tilde{I}) \qquad \text{(A2)}$$

Labour demands

Demand is denoted by superscript *d*.

<u>*From the non-tradable sectors.*</u> Because of zero profit, $p_{nt}Y_{nt} = w_L L_{nt}^d$ and $\tilde{p}_{nt}\tilde{Y}_{nt} = \tilde{w}_L \tilde{L}_{nt}^d$.

Hence:

$$L_{nt}^d = p_{nt}Y_{nt} / w_L = \gamma_{nt} I / w_L; \qquad \tilde{L}_{nt}^d = \gamma_{nt}\tilde{I} / \tilde{w}_L$$

<u>*From the skill-intensive sectors.*</u> Because of the Cobb-Douglas technology and relations (4) and (5) in the text:

$$L_h^d = \frac{\alpha p_h Y_h}{w_L} = \frac{\alpha a^\sigma \gamma_h I_W}{w_L p_h{}^{\sigma-1}\left(a^\sigma p_h{}^{1-\sigma} + p_{\tilde{h}}{}^{1-\sigma}\right)}; \quad \tilde{L}_{\tilde{h}}^d = \frac{\alpha p_{\tilde{h}} Y_{\tilde{h}}}{\tilde{w}_L} = \frac{\alpha \gamma_h I_W}{\tilde{w}_L p_{\tilde{h}}{}^{\sigma-1}\left(a^\sigma p_h{}^{1-\sigma} + p_{\tilde{h}}{}^{1-\sigma}\right)}$$

Demand for unskilled labour in each advanced country

$$L^d = L_h + L_{nt} = \frac{\alpha a^\sigma \gamma_h I_W}{w_L p_h{}^{\sigma-1}\left(a^\sigma p_h{}^{1-\sigma} + p_{\tilde{h}}{}^{1-\sigma}\right)} + \gamma_{nt}\frac{I}{w_L}$$

$$\tilde{L}^d = \tilde{L}_{\tilde{h}}^d + \tilde{L}_{nt}^d = \frac{\alpha \gamma_h I_W}{\tilde{w}_L p_{\tilde{h}}{}^{\sigma-1}\left(a^\sigma p_h{}^{1-\sigma} + p_{\tilde{h}}{}^{1-\sigma}\right)} + \gamma_{nt}\frac{\tilde{I}}{\tilde{w}_L}$$

Finally, inserting (A2) into the above relations:

$$L^d = \frac{\alpha a^\sigma (1-\gamma_{nt})(I + \tilde{I})}{w_L\left(a^\sigma + (p_h / \tilde{p}_h)^{\sigma-1}\right)} + \gamma_{nt}\frac{I}{w_L} \qquad \text{(A3)}$$

$$\tilde{L}^d = \frac{\alpha(1-\gamma_{nt})(I+\tilde{I})}{\tilde{w}_L\left(a^\sigma(p_{\tilde{h}}/p_h)^{\sigma-1}+1\right)} + \gamma_{nt}\frac{\tilde{I}}{\tilde{w}_L} \quad \text{(A4)}$$

Balanced trade in Germany

We now assume balanced trade in Germany. This will determine a relationship between *I* and $\tilde{I}$. Note that, when trade is balanced in both the South and Germany, it is *ipso facto* balanced in the third country (North).

$M_l = \gamma_l I$, $M_{\tilde{h}} = \frac{\gamma_h I}{a^\sigma(\tilde{p}_h/p_h)^{\sigma-1}+1}$ and $X_h = \frac{a^\sigma\gamma_h(\tilde{I}+I^*)}{p_h{}^{\sigma-1}\left(a^\sigma p_h{}^{1-\sigma}+\tilde{p}_h{}^{1-\sigma}\right)}$ because of (6) in the text, the latter inducing $X_h = \frac{(\gamma_h+\gamma_l)\tilde{I}+\gamma_l I}{1+a^{-\sigma}(p_h/\tilde{p}_h)^{\sigma-1}}$ because of (A2). Balanced trade $M_l + M_{\tilde{h}} = X_h$ entails:

$$(p_h/\tilde{p}_h)^{\sigma-1} I = a^\sigma \tilde{I} \quad \text{(A5)}$$

Equilibrium on labour markets, skill premia and unskilled labour wages

Because of full employment, total incomes in Germany and North are:

$$I = w_L\bar{L} + w_H\bar{H} = w_L(\bar{L}+w\bar{H}) \quad \text{(A6)}$$

$$\tilde{I} = \tilde{w}_L\bar{\tilde{L}} + \tilde{w}_H\bar{\tilde{H}} = \tilde{w}_L\left(\bar{\tilde{L}}+\tilde{w}\bar{\tilde{H}}\right) \quad \text{(A7)}$$

By inserting (A5), (A6) and (A7) into (A3) and (A4) yields (NO indicate the no-offshoring equilibrium):

$$w_{NO} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}}\frac{\bar{L}}{\bar{H}} \quad \text{(A8)}$$

$$\tilde{w}_{NO} = \tilde{w} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}}\frac{\bar{\tilde{L}}}{\bar{\tilde{H}}} \quad \text{(A9)}$$

Hence:

$$\frac{w_{NO}}{\tilde{w}_{NO}} = \frac{\bar{L}/\bar{H}}{\bar{\tilde{L}}/\bar{\tilde{H}}} \quad \text{(A10)}$$

By inserting (A1), and (A6) to (A10) into (A5):

$$\frac{w_L^{NO}}{\tilde{w}_L^{NO}} = a\left(\frac{\bar{\tilde{L}}}{\bar{L}}\right)^{1/\sigma}\left(\frac{\bar{H}/\bar{L}}{\bar{\tilde{H}}/\bar{\tilde{L}}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}} \quad \text{(A11)}$$

Note that <u>*relation* (A9) *that determines North's skill premium is always valid when North firms do not offshore and North stands at full employment*</u>.[9] Hence, North's skill premium will be denoted $\tilde{w}$ and equal to the value given by relation (A9) in all the stages of our scenario.

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[9] $\tilde{L}_{\tilde{h}} = \frac{\alpha}{1-\alpha}\frac{\tilde{w}_H}{\tilde{w}_L}\tilde{H}_{\tilde{h}} = \frac{\alpha}{1-\alpha}\tilde{w}\bar{\tilde{H}}$; $\tilde{L}_{nt} = \gamma_{nt}\frac{\tilde{I}}{\tilde{w}_L} = \gamma_{nt}(\bar{\tilde{L}}+\tilde{w}\bar{\tilde{H}})$; $\tilde{L}^d = \tilde{L}_{\tilde{h}} + \tilde{L}_{nt} = \bar{\tilde{L}} \Rightarrow \tilde{w} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}}\frac{\bar{\tilde{L}}}{\bar{\tilde{H}}}$

Appendix B. Full offshoring and full employment in Germany with $w_L = \omega$

We determine the skill premium w_{FO} and the relative unskilled labour wage $w_L^{FO} / \tilde{w}_L$ at the conclusion of the offshoring dynamics with full employment in Germany, i.e., when the offshore cost ω attains the German unskilled labour wage that ensures full employment when all German unskilled workers are employed in the non-tradable services. In this situation, the total German unskilled labour $\bar{L}$ is employed in sector *nt* at a wage equal to the offshore cost ω and the segment S_L of sector *h* is fully offshored to the South. We thus have $w_L^{FO} = \omega$, where *FO* indicates the case of full offshoring and full employment.
We suppose that segment S_L is produced in the South, then exported to Germany where it is combined with S_H. Germany then exports good *h* produced from the combination of S_L and S_H. Because of the Cobb-Douglas technology:

$$p_h = A^{-1}\left(\frac{w_H}{1-\alpha}\right)^{1-\alpha}\left(\frac{\omega}{\alpha}\right)^{\alpha}; \quad \tilde{p}_{\tilde{h}} = A^{-1}\left(\frac{\tilde{w}_H}{1-\alpha}\right)^{1-\alpha}\left(\frac{\tilde{w}_L}{\alpha}\right)^{\alpha}$$

Hence:

$$\frac{p_h}{\tilde{p}_{\tilde{h}}} = \left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\frac{\omega}{\tilde{w}_L} \qquad \text{(B1)}$$

Demands for goods

These are not changed by offshoring. Consequently:

$$M_l = \gamma_l I; \qquad \tilde{M}_l = \gamma_l \tilde{I}$$

$$p_{nt}Y_{nt}^d = \gamma_{nt} I; \qquad \tilde{p}_{nt}\tilde{Y}_{nt}^d = \gamma_{nt}\tilde{I}$$

Unskilled Labour demand in Germany

<u>*From the sectors of non-tradables.*</u> Because of zero profit, and as the total of unskilled labour is employed in sector *nt* in Germany:

$$L^d = L_{nt}^d = p_{nt}Y_{nt} / w_L = \gamma_{nt} I / w_L \Rightarrow w_L = \omega = \gamma_{nt} I / L_{nt}$$

$$L^d = L_{nt}^d = \gamma_{nt} I / w_L \qquad \text{(B2)}$$

Skill premium in Germany

The demand for *nt*, $\gamma_{nt} I$, is equal to the supply of *nt*, $p_{nt}Y_{nt} = w_L L$. As $I = w_L L + w_H H$, this yields:

$$w_L = \frac{\gamma_{nt} I}{L} = \frac{\gamma_{nt}(w_L L + w_H H)}{L} = \gamma_{nt}(w_L + w_H H / L) \Rightarrow w \equiv \frac{w_H}{w_L} = \frac{1-\gamma_{nt}}{\gamma_{nt}}\frac{L}{H}$$

At full employment:

$$w_{FO} = \frac{1-\gamma_{nt}}{\gamma_{nt}}\frac{\bar{L}}{\bar{H}} \qquad \text{(B3)}$$

Remark: the German skill premium is always equal to $w = \frac{1-\gamma_{nt}}{\gamma_{nt}} \frac{L}{\bar{H}}$ when segment S_L is fully offshored, with L being the total unskilled labour employment.

Finally note that $w_{FO} > w_{NO}$: $w_{NO} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \frac{\bar{L}}{\bar{H}} < \frac{1-\gamma_{nt}}{\gamma_{nt}} \frac{\bar{L}}{\bar{H}} = w_{FO}$

Skill premium in North

As North does not outsource segment $\tilde{S}_L$ and is at full employment, Relation (A9) applies:

$$\tilde{w} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}}$$

Note that the ratio of the skill premium in Germany to the skill premium in North is higher in the case FO than in the case NO (no offshoring):

$$\frac{w_{FO}}{\tilde{w}_{FO}} = \left(1+\frac{\alpha}{1-\alpha}\gamma_{nt}^{-1}\right)\frac{\bar{\tilde{H}}/\bar{\tilde{L}}}{\bar{H}/\bar{L}} > \frac{w_{NO}}{\tilde{w}_{NO}} = \frac{\bar{\tilde{H}}/\bar{\tilde{L}}}{\bar{H}/\bar{L}}.$$

Balanced trade in the South and determination of I*

Balanced trade in the South allows defining *I** in terms of I and $\tilde{I}$.

Let *M** and M_i^* be respectively the values of the South total imports and imports of good *i*, and *X** and X_j^* the values of the South total exports and exports of good *j*.

The South imports goods *h* and $\tilde{h}$. Hence:

$$M^* = M_h^* + M_{\tilde{h}}^* = \gamma_h I^*$$

The South total export is $X^* = X_l^* + X_{SL}^*$

$X_l^* = \gamma_l(I+\tilde{I})$ and $X_{SL}^* = \omega L_{SL}^* = \frac{\alpha}{1-\alpha} w_H \bar{H}$ because of the Cobb-Douglas technology.

$$X^* = X_l^* + X_{SL}^* = \gamma_l(I+\tilde{I}) + \frac{\alpha}{1-\alpha} w_H H$$

Balanced trade implies *X** = *M**. By inserting the above relations in this equality:

$$I^* = \frac{\gamma_l}{\gamma_h}(I+\tilde{I}) + \frac{\alpha}{1-\alpha}\gamma_h^{-1} w_H H \qquad \text{(B4)}$$

Balanced trade in Germany and determination of $\frac{\omega_{FO}}{\tilde{w}_L} = \frac{w_L^{FO}}{\tilde{w}_L}$

Germany exports the final good *h* (including both segments) and imports (i) the total of segment S_L from the South, (ii) good *l* from the South and (iii) good $\tilde{h}$ from the North.

$M_l = \gamma_l I$; $M_{\tilde{h}} = \tilde{p}_h Y_{\tilde{h}}^d = \frac{\gamma_h I}{a^\sigma (\tilde{p}_h / p_h)^{\sigma-1}+1}$; $M_{SL} = X_{SL}^* = \frac{\alpha}{1-\alpha} w_H \bar{H}$ because of the Cobb-Douglas;

Because of Relation (6) in the text: $X_h = \frac{a^\sigma \gamma_h (\tilde{I}+I^*)}{a^\sigma + (p_h/\tilde{p}_h)^{\sigma-1}}$.

Balanced trade implies $M_l + M_{\tilde{h}} + M_{SL} = X_h$, i.e.:

$$\gamma_l I + \frac{\gamma_h I}{\left(a^\sigma (\tilde{p}_h / p_h)^{\sigma-1} + 1\right)} + \frac{\alpha}{1-\alpha} w_H H = \frac{\gamma_h (\tilde{I} + I^*)}{\left(1 + a^{-\sigma} (p_h / \tilde{p}_h)^{\sigma-1}\right)}$$

And after re-arranging:

$$\left(a^\sigma \left(\frac{\tilde{p}_h}{p_h}\right)^{\sigma-1} + 1\right)\gamma_l I + \gamma_h I + \left(a^\sigma \left(\frac{\tilde{p}_h}{p_h}\right)^{\sigma-1} + 1\right)\frac{\alpha}{1-\alpha} w_H H = a^\sigma \left(\frac{\tilde{p}_h}{p_h}\right)^{\sigma-1} \gamma_h (\tilde{I} + I^*)$$

Inserting (B4), (B1), (B3) and (A9) into the preceding equation:

$$\frac{\omega_{FO}}{\tilde{w}_L} = \left(\frac{(1-\alpha)\gamma_{nt}}{\alpha + (1-\alpha)\gamma_{nt}}\right)^{\frac{(1-\alpha)\sigma+\alpha}{\sigma}} a \left(\frac{\bar{\tilde{L}}}{\bar{L}}\right)^{1/\sigma} \left(\frac{\bar{H} / \bar{L}}{\bar{\tilde{H}} / \bar{\tilde{L}}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}} \qquad \text{(B5)}$$

As $\frac{w_L^{NO}}{\tilde{w}_L} = a \left(\frac{\tilde{L}}{L}\right)^{1/\sigma} \left(\frac{H / L}{\tilde{H} / \tilde{L}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}}$: $\frac{\omega_{FO}}{\tilde{w}_L} = \frac{w_L^{FO}}{\tilde{w}_L} < \frac{w_L^{NO}}{\tilde{w}_L}$

Appendix C. Partial offshoring with full employment (OFE)

The decrease in the offshore cost results in a growing share of segment S_L that is offshored to the South from the moment when the offshore cost ω attains the German unskilled labour wage w_L. The wage of unskilled labour in North is taken as numéraire (we could write $\tilde{w}_L = 1$ but we prefer to keep $\tilde{w}_L$ into the equations to facilitate their understanding. Hence, we make the cost of producing offshore $\omega / \tilde{w}_L$ decrease from $\frac{w_L^{NO}}{\tilde{w}_L} = a \left(\frac{\bar{\tilde{L}}}{\bar{L}}\right)^{1/\sigma} \left(\frac{\bar{H} / \bar{L}}{\bar{\tilde{H}} / \bar{\tilde{L}}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}}$ to $\frac{\omega_{FO}}{\tilde{w}_L} = \left(\frac{(1-\alpha)\gamma_{nt}}{\alpha + (1-\alpha)\gamma_{nt}}\right)^{\frac{(1-\alpha)\sigma+\alpha}{\sigma}} a \left(\frac{\bar{H} / \bar{L}}{\bar{\tilde{H}} / \bar{\tilde{L}}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}} \left(\frac{\bar{\tilde{L}}}{\bar{L}}\right)^{1/\sigma}$. This situation of (partial) offshoring with full employment in Germany is denote *OFE*.
Because of full employment and partial outsourcing, we have:

$$w_L = \omega \qquad \text{(C1)}$$

Because of the Cobb-Douglas technologies:

$$\frac{p_h}{p_{\tilde{h}}} = \left(\frac{w_H}{\tilde{w}_H}\right)^{1-\alpha} \left(\frac{\omega}{\tilde{w}_L}\right)^{\alpha} = \left(\frac{w}{\tilde{w}}\right)^{1-\alpha} \left(\frac{\omega}{\tilde{w}_L}\right) \qquad \text{(C2)}$$

Skill premium in North

As North's firms do not outsource and North is at full employment, relation (A9) applies:

$$\tilde{w} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha + (1-\alpha)\gamma_{nt}} \frac{\tilde{L}}{\tilde{H}} \qquad \text{(C3)}$$

Balanced trade in the South

Imports of the South: $M^* = M_h^* + M_{\tilde{h}}^* = \gamma_h I^*$

Exports of the South: $X^* = X_l^* + X_{SL}^* = \gamma_l (I + \tilde{I}) + \omega S_L^*$,

where S_L^* is the portion of the unskilled-intensive segment of *h* which is relocated to the South and fully exported to Germany to be combined with segment S_H to produce *h*.
Let S_L^W be the complete unskilled-intensive segment (concurrently produced by the South and Germany) and S_L the part of S_L^W produced in Germany. Hence:

$$S_L^* = S_L^W - S_L$$

Because of the Cobb-Douglas technology:

$$\omega S_L^W = \alpha p_h Y_h = \frac{\alpha}{1-\alpha} w_H \bar{H}$$

As we stand at full employment, $S_L = L_h^d = \bar{L} - L_{nt}^d$, and:

$$S_L = \bar{L} - L_{nt} = \bar{L} - \gamma_{nt} I / \omega \Rightarrow \omega S_L = \omega \bar{L} - \gamma_{nt} I$$

Hence:

$$\omega S_L^* = \omega S_L^W - \omega S_L = \frac{\alpha}{1-\alpha} w_H \bar{H} - \omega \bar{L} + \gamma_{nt} I$$

And for the total exports from the South:

$$X^* = \gamma_l (I + \tilde{I}) + \frac{\alpha}{1-\alpha} w_H \bar{H} - \omega \bar{L} + \gamma_{nt} I = \gamma_l (I + \tilde{I}) + \frac{\alpha}{1-\alpha} w_H \bar{H} - \omega \bar{L} + \gamma_{nt} I$$

Equalising $M^* = X^*$:

$$\gamma_h I^* = \gamma_l \tilde{I} + \frac{\alpha}{1-\alpha} w_H \bar{H} - \omega \bar{L} + (1-\gamma_h) I \qquad \text{(C4)}$$

Balanced trade in North and relation between $\omega / \tilde{w}_L$ ***and*** w_{OFE}

North exports good $\tilde{h}$. Because of relation (7) in the text: $\tilde{X} = \tilde{X}_{\tilde{h}} = \frac{\gamma_h (I + I^*)}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1}$.

Inserting (C4) and as $I = \omega \bar{L} + w_H \bar{H}$:

$$\tilde{X} = \frac{\gamma_l \tilde{I} + \frac{1}{1-\alpha} w_H \bar{H}}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1}$$

North imports goods *l* and *h*: $\tilde{M} = \tilde{M}_l + \tilde{M}_h$. We know that $\tilde{M}_l = \gamma_l \tilde{I}$ and Relation (6) implies: $\tilde{M}_h = \frac{a^\sigma \gamma_h \tilde{I}}{a^\sigma + (p_h / p_{\tilde{h}})^{\sigma-1}}$. Hence:

$$\tilde{M} = \gamma_l \tilde{I} + \frac{a^\sigma \gamma_h \tilde{I}}{a^\sigma + (p_h / p_{\tilde{h}})^{\sigma-1}}$$

Balanced trade ($\tilde{X} = \tilde{M}$) can thus be written:

$$\frac{\gamma_l \tilde{I} + \frac{1}{1-\alpha} w_H \bar{H}}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1} = \gamma_l \tilde{I} + \frac{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} \gamma_h \tilde{I}}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1}$$

Inserting (C2) and (C3) and after re-arranging:

$$w_{OFE} = a^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha + (1-\alpha)\gamma_{nt}} \frac{\bar{\bar{L}}}{\bar{\bar{H}}} \left(\frac{\bar{\bar{H}}}{\bar{H}} \right)^{\frac{1}{(1-\alpha)\sigma+\alpha}} \left(\frac{\omega}{\tilde{w}_L} \right)^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \qquad \text{(C5)}$$

And:

$$\frac{\partial w_{OFE}}{\partial(\omega / \tilde{w}_L)} = -\frac{\sigma a^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}}}{(1-\alpha)\sigma+\alpha} \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha + (1-\alpha)\gamma_{nt}} \frac{\bar{\bar{L}}}{\bar{\bar{H}}} \left(\frac{\bar{\bar{H}}}{\bar{H}} \right)^{\frac{1}{(1-\alpha)\sigma+\alpha}} \left(\frac{\omega}{\tilde{w}_L} \right)^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}-1} < 0$$

Hence, $\frac{\partial w_{PO}}{\partial(\omega / \tilde{w}_L)} < 0$ and:

Result C. *The decrease in* $(\omega / \tilde{w}_L)$ *induces an increase in* w_{OFE}.

Appendix D. Reservation wage & Unemployment

$\underline{w}$ is the reservation wage and w_{RW} the reservation skill premium in Germany

We suppose that the German reservation wage is higher than the cost of unskilled labour in the outsourced segment S_L, $\underline{w} > \omega$, and higher than the full employment unskilled labour wage with full outsourcing of S_L, $\underline{w} > w_L^{FO}$. Thus, Germany fully outsources the unskilled segment S_L of the production of *h* whereas this segment is still domestically produced in North. Then, German unskilled workers are only employed by the non-tradable sector and the demand for non-tradables is determined by the reservation wage. As this wage is higher than that which ensures full employment within this production configuration, w_L^{FO}, this generates unemployment.

Because of the Cobb-Douglas technology:

$$p_h = A^{-1} \left(\frac{w_H}{1-\alpha} \right)^{1-\alpha} \left(\frac{\omega}{\alpha} \right)^{\alpha} ; \quad p_{\tilde{h}} = A^{-1} \left(\frac{\tilde{w}_H}{1-\alpha} \right)^{1-\alpha} \left(\frac{\tilde{w}_L}{\alpha} \right)^{\alpha}$$

And:

$$\frac{p_h}{p_{\tilde{h}}} = \left(\frac{w_{RW}}{\tilde{w}_{RW}} \right)^{1-\alpha} \left(\frac{\omega}{\underline{w}} \right)^{\alpha} \left(\frac{\underline{w}}{\tilde{w}_L} \right) \qquad \text{(D1)}$$

Unskilled Labour demand in Germany

The total of the German unskilled labour is employed in sector *nt*. Hence: $\underline{w}L_{nt} = p_{nt}Y_{nt} = \gamma_{nt}I \Rightarrow L_{nt} = \gamma_{nt}I / \underline{w}$ and $L_{RW} = L_{nt} \Rightarrow L_{RW} = \gamma_{nt}I / \underline{w}$. As $I = \underline{w}(L_{RW} + w_{RW}\bar{H})$:

$$L_{RW} = \frac{\gamma_{nt}}{1-\gamma_{nt}} w_{RW}\bar{H} \qquad \text{(D2)}$$

Skill premium in North

As usual, relation (A9) applies:

$$\tilde{w} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha + (1-\alpha)\gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}}$$

Balanced trade in the South and determination of I*

Balanced trade of the South allows defining *I** in terms of I and $\tilde{I}$. Let M_i^* be the import of good *i* by the South and X_j^* the South's exports of good *j*. we have:

Imports:

$$M^* = M_h^* + M_{\tilde{h}}^* = \gamma_h I^*$$

Exports:

$$X^* = X_l^* + X_{SL}^* \quad ; \quad X_l^* = \gamma_l(I + \tilde{I})$$

As $w_{RW} > \omega$, segment S_L is fully produced in the South. Hence: $X_{SL}^* = \omega L_{SL}^* = \frac{\alpha}{1-\alpha} w_H \bar{H}$ because of the Cobb-Douglas technology. Hence:

$$X^* = X_l^* + X_{SL}^* = \gamma_l(I + \tilde{I}) + \frac{\alpha}{1-\alpha} w_H \bar{H}$$

Balanced trade implies *X** = *M**. By inserting the relations above in this equality:

$$\gamma_h I^* = \gamma_l(I + \tilde{I}) + \frac{\alpha}{1-\alpha} w_H \bar{H} \qquad \text{(D3)}$$

Balanced trade in North and determination of the skill premium w_{RW}

Exports: North exports good $\tilde{h}$: $\tilde{X} = \tilde{X}_{\tilde{h}} = \frac{\gamma_h(I + I^*)}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1} = \frac{(\gamma_h + \gamma_l)I + \gamma_l \tilde{I} + \frac{\alpha}{1-\alpha} w_H \bar{H}}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1}$

Imports: North imports goods *l* and *h*: $\tilde{M} = \tilde{M}_l + \tilde{M}_h = \gamma_l \tilde{I} + \frac{\gamma_h \tilde{I}}{1 + a^{-\sigma}(p_h / p_{\tilde{h}})^{\sigma-1}}$

Balanced trade: $\tilde{X} = \tilde{M} \Rightarrow \frac{(\gamma_h + \gamma_l)I + \gamma_l \tilde{I} + \frac{\alpha}{1-\alpha} w_H \bar{H}}{a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} + 1} = \gamma_l \tilde{I} + \frac{\gamma_h \tilde{I}}{1 + a^{-\sigma}(p_h / p_{\tilde{h}})^{\sigma-1}}$

After simplifying: $I = a^\sigma (p_{\tilde{h}} / p_h)^{\sigma-1} \tilde{I} - \frac{\alpha}{(1-\alpha)(\gamma_h + \gamma_l)} w_H \bar{H}$

Inserting $I = \underline{w}L + w_H \bar{H}$ and $\tilde{I} = \tilde{w}_L \bar{\tilde{L}} + \tilde{w}_H \bar{\tilde{H}}$, (D1), (D2) and (A9) into this equation:

$$w_{RW} = a^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}} \left(\frac{\bar{\tilde{H}}}{\bar{H}}\right)^{\frac{1}{(1-\alpha)\sigma+\alpha}} \left(\frac{\underline{w}}{\omega}\right)^{\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}} \left(\frac{\tilde{w}_L}{\underline{w}}\right)^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \quad \text{(D4)}$$

As $w_{OFE} = a^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}} \left(\frac{\bar{\tilde{H}}}{\bar{H}}\right)^{\frac{1}{(1-\alpha)\sigma+\alpha}} \left(\frac{\omega}{\tilde{w}_L}\right)^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}}$, then:

$w_{RW} < w_{OFE} \Leftrightarrow \left(\frac{\underline{w}}{\omega}\right)^{\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}} \left(\frac{\tilde{w}_L}{\underline{w}}\right)^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} < \left(\frac{\tilde{w}_L}{\omega}\right)^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \Leftrightarrow \underline{w} > \omega$, which is true by definition of Scenario RW. As $w_{RW} < w_{OFE}$:

Result D1: *Assume a reservation wage* $\underline{w}$ *such that* $\underline{w} > \omega$ *and* $\underline{w} > w_L^{FO}$. *Then, the German skill premium with reservation wage is lower than the skill premium without.*

Result D2: *The German skill premium* w_{RW} *decreases with both the reservation wage* $\underline{w}$ *and the offshore production cost* ω.

Proof. Because $\partial w_{RW} / \partial \underline{w} < 0$ and $\partial w_{RW} / \partial \omega < 0$.

Result D3. *Assume a reservation wage* $\underline{w}$ *such that* $\underline{w} > \omega$ *and* $\underline{w} > w_L^{FO}$. *Then, there is unemployment of the German unskilled workers, and unemployment increases with the reservation wage* $\underline{w}$ *and decreases with the decrease in* ω.

Proof. $L_{RW} = \frac{\gamma_{nt}}{1-\gamma_{nt}} w_{RW} \bar{H}$ (Equation D2) and $\bar{L} = \frac{\gamma_{nt}}{1-\gamma_{nt}} w_{FO} \bar{H}$ (Equation B5). As $w_{RW} < w_{OFE} < w_{FO}$ (Results C and D1), then $L_{RW} < \bar{L}$: there is unemployment of unskilled workers. In addition, (i) w_{RW} decreases with the reservation wage $\underline{w}$ and the offshore cost ω (Result D2) and (ii) unemployment $U = \bar{L} - L_{RW} = \bar{L} - \frac{\gamma_{nt}}{1-\gamma_{nt}} w_{RW} \bar{H}$ decreases with w_{RW}. Hence, unemployment increases with the reservation wage $\underline{w}$ and decreases with the decrease in ω.

The German total income

The German total income is $I = \underline{w}(L + w_{RW}\bar{H})$. By inserting (D2) and (D6), it comes:

$$I_{RW} = \frac{1}{1-\gamma_{nt}} a^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \omega^{-\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}} \tilde{w}_L^{\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \left(\frac{\bar{H}}{\bar{\tilde{H}}}\right)^{\frac{(1-\alpha)(\sigma-1)}{(1-\alpha)\sigma+\alpha}} \bar{\tilde{L}} \quad \text{(D5)}$$

The German Exports/Income ratio (x = X/I)

Firstly consider the moment when the declining offshore production cost attains the German reservation wage, i.e., $\omega = \underline{w}$. At that time, there is a one-shot relocation to the South of the portion of segment S_L still produced in Germany. At the moment of this jump, the wages, and

thus the prices, remain unchanged. In contrast, (i) Germany's total income decreases because the unskilled labour formerly utilised in the production of S_L becomes unemployed, (ii) the income of the South increase because of the relocation of S_L in this country. Finally, the German exports of *h* increase[10] (because of the income-driven increase in the demand from the South) and trade is balanced by the increase the German imports of segment S_L. Consequently, both the decrease in the German income and the increase in German exports raise the Exports/Income ratio. Hence:

Result D4. *When the declining offshore production cost ω attains the German reservation wage $\underline{w}$, there is a downward jump of the Exports/Income ratio in Germany.*

Let us now calculate ratio $x = X/I$ so as to study its behaviour, (i) once the whole of segment S_L has been offshored because of the reservation wage, and (ii) when the German government set a labour market reform that lessens the reservation wage.

$$x = \frac{X}{I} = \frac{X_h}{I} = \frac{\gamma_h(\tilde{I} + I^*)/I}{1 + a^{-\sigma}(p_h / p_{\tilde{h}})^{\sigma-1}}$$

Inserting (D3), (D2) and (D1) into ;the preceding equation yields:

$$x = (1-\gamma_{nt})\frac{(1-\gamma_{nt})\left(\frac{1}{w_{RW}}\frac{\bar{\bar{L}}}{\bar{H}} + \frac{\tilde{w}}{w_{RW}}\frac{\bar{\tilde{H}}}{\bar{H}}\right) + \left(\frac{\gamma_l}{1-\gamma_{nt}} + \frac{\alpha}{1-\alpha}\right)\frac{\underline{w}}{\tilde{w}_L}}{\frac{\underline{w}}{\tilde{w}_L} + a^{-\sigma}\left(\frac{w_{RW}}{\tilde{w}}\right)^{(1-\alpha)(\sigma-1)}\left(\frac{\omega}{\underline{w}}\right)^{\alpha(\sigma-1)}\left(\frac{\underline{w}}{\tilde{w}_L}\right)^{\sigma}}$$

Inserting (D4) and $\tilde{w}$ in the relation above and after simplifying:

$$x = \frac{1-\gamma_{nt}}{1-\alpha} - \frac{\gamma_h}{a^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}}\left(\omega/\tilde{w}_L\right)^{\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}}\left(\bar{\tilde{H}}/\bar{H}\right)^{\frac{(1-\alpha)(\sigma-1)}{(1-\alpha)\sigma+\alpha}} + 1} \qquad \text{(D6)}$$

The derivative of *x* in relation to ω is:

$$\frac{\partial x}{\partial \omega} = \frac{\gamma_h \frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha} a^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}} \tilde{w}_L^{-\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}} \left(\frac{\bar{\tilde{H}}}{\bar{H}}\right)^{\frac{(1-\alpha)(\sigma-1)}{(1-\alpha)\sigma+\alpha}} \omega^{\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}-1}}{\left(a^{-\frac{\sigma}{(1-\alpha)\sigma+\alpha}}\left(\omega/\tilde{w}_L\right)^{\frac{\alpha(\sigma-1)}{(1-\alpha)\sigma+\alpha}}\left(\bar{\tilde{H}}/\bar{H}\right)^{\frac{(1-\alpha)(\sigma-1)}{(1-\alpha)\sigma+\alpha}} + 1\right)^2} > 0$$

Result D5. *Once the offshore cost is below the German reservation wage (hence segment S_L is fully offshored), a decrease in the offshore cost lowers the export/production ratio.*

Let us now suppose a downward shift of the reservation wage $\underline{w}$. If segment S_L remains fully offshored, relation (D6) still holds and there is no change in ratio *x*. In contrast, if the decrease

[10] Note that the import-content of German exports increases because segment S_L is now fully offshored.

in $\underline{w}$ is sufficient to make certain former offshored segments to be in-shored (i.e., relocated to Germany), which is the case when $w_L^{FO} < \underline{w} < \omega$, then it is straightforward that the decrease in trade with the South results in a decrease in German exports.

Result D6. *A decrease in the German reservation wage has no impact on ratio x=X/I when segment* S_L *remains fully offshored and it decreases this ratio when the new reservation wage is such that* $w_L^{FO} < \underline{w} < \omega$.

Appendix E. Systems of equations for the simulations

A comprehensive presentation of the building of the systems of equations is available from the authors upon request.

1. No offshoring (Scenario *NO*)

Skill premia

$$w_{NO} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \frac{\bar{L}}{\bar{H}}; \qquad \tilde{w}_{NO} = \frac{(1-\alpha)(1-\gamma_{nt})}{\alpha+(1-\alpha)\gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}}$$

Unit wage of unskilled labour

$$w_L^{NO} = a\left(\frac{\tilde{L}}{\bar{\tilde{L}}}\right)^{1/\sigma}\left(\frac{\bar{H}/\bar{L}}{\bar{\tilde{H}}/\bar{\tilde{L}}}\right)^{\frac{(1-\alpha)(\sigma-1)}{\sigma}} \tilde{w}_L$$

Prices

$$p_h = A^{-1} w_L^{NO} \frac{{w_{NO}}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}; \; p_{\tilde{h}} = A^{-1}\tilde{w}_L \frac{\tilde{w}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}; \; P_h = \left(a^{\sigma} {p_h}^{1-\sigma} + {p_{\tilde{h}}}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

$$p_{nt} = w_L/\delta; \quad \tilde{p}_{nt} = \tilde{w}_L/\delta; \; p_l = \bar{p}_l$$

$$P = {p_l}^{\gamma_l} {P_h}^{\gamma_h} {p_{nt}}^{\gamma_{nt}} = \delta^{-\gamma_{nt}} {p_l}^{\gamma_l} {P_h}^{\gamma_h} {w_L}^{\gamma_{nt}}$$

$$\tilde{P} = {p_l}^{\gamma_l} {P_h}^{\gamma_h} {\tilde{p}_{nt}}^{\gamma_{nt}} = \delta^{-\gamma_{nt}} {p_l}^{\gamma_l} {P_h}^{\gamma_h} {\tilde{w}_L}^{\gamma_{nt}}$$

Real wages of unskilled labour

$$wr_L^{NO} = \frac{\left(w_L^{NO}\right)^{1-\gamma_{nt}}}{\delta^{-\gamma_{nt}} {p_l}^{\gamma_l} {P_h}^{\gamma_h}} \qquad \widetilde{wr}_L^{NO} = \frac{\tilde{w}_L}{\tilde{P}} = \frac{\left(\tilde{w}_L\right)^{1-\gamma_{nt}}}{\delta^{-\gamma_{nt}} {p_l}^{\gamma_l} {P_h}^{\gamma_h}}$$

2. Partial offshoring and full employment with $w_L = \omega(k)$ (Scenario OFE)

k varies from 0 to 1. 7 equations with 7 unknown variables: $\tilde{w}$, w, w_L, I, $\tilde{I}$, I^*, x.

$$\tilde{w} = \frac{1-\gamma_{nt}}{\frac{\alpha}{1-\alpha}+\gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}}$$

$$\tilde{I} = \frac{\tilde{w}_L}{\alpha+(1-\alpha)\gamma_{nt}} \bar{\tilde{L}} \qquad I = w_L(\bar{L}+w\bar{H})$$

$$w(k) = \frac{(1-\gamma_{nt})(1-\alpha)\left(w_L - w_L\left(1-\frac{\kappa}{w_L}k\right)^{1-\alpha(\sigma-1)} + (1-k)\kappa\left(1-\alpha(\sigma-1)\right)\right)}{\left(\alpha+\gamma_{nt}(1-\alpha)\right)(1-k)\kappa\left(1-\alpha(\sigma-1)\right)+\gamma_{nt}(1-\alpha)\left(w_L - w_L\left(1-\frac{\kappa}{w_L}k\right)^{1-\alpha(\sigma-1)}\right)} \frac{\bar{L}}{\bar{H}}$$

$$I^* = \frac{1}{\gamma_h}\left((1-\gamma_{nt}) \frac{w_L \frac{1-\left(1-\frac{\kappa}{w_L}k\right)^{1-\alpha(\sigma-1)}}{\kappa\left(1+\alpha(1-\sigma)\right)} + 1 - k}{a^{-\sigma}\left(\frac{w_L}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}} + \gamma_l \right)\tilde{I} - I$$

$$I^* = \frac{1}{\gamma_h} \frac{(\alpha\gamma_h+\gamma_l)w_L \frac{1-\left(1-\frac{\kappa}{w_L}k\right)^{1-\alpha(\sigma-1)}}{\kappa\left(1-\alpha(\sigma-1)\right)} + \gamma_l(1-k) + \gamma_l a^{-\sigma}\left(\frac{w_L}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}}{\left(1-\alpha\right)w_L \frac{1-\left(1-\frac{\kappa}{w_L}k\right)^{1-\alpha(\sigma-1)}}{\kappa\left(1-\alpha(\sigma-1)\right)} + (1-k) + a^{-\sigma}\left(\frac{w_L}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}} (I+\tilde{I})$$

$$x = \gamma_h \frac{1-\left(1-\frac{\kappa}{w_L}k\right)^{1-\alpha(\sigma-1)} + (1-k)\frac{\kappa}{w_L}\left(1-\alpha(\sigma-1)\right)}{1-\left(1-\frac{\kappa}{w_L}k\right)^{1+\alpha(1-\sigma)} + (1-k)\frac{\kappa}{w_L}\left(1-\alpha(\sigma-1)\right) + a^{-\sigma}\frac{\kappa}{w_L}\left(1-\alpha(\sigma-1)\right)\left(\frac{w_L}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}} \frac{\tilde{I}+I^*}{I}$$

Prices

$$p_h = A^{-1}\left(\frac{w_H}{1-\alpha}\right)^{1-\alpha}\left(\frac{w_L}{\alpha}\right)^{\alpha} = A^{-1}w_L\frac{w^{1-\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$$

$$\tilde{p}_h = A^{-1}\left(\frac{\tilde{w}_H}{1-\alpha}\right)^{1-\alpha}\left(\frac{\tilde{w}_L}{\alpha}\right)^{\alpha} = A^{-1}\tilde{w}_L\frac{\tilde{w}^{1-\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$$

$$P_h(k) = \left(a^{\sigma} p_h^{\,1-\sigma} w_L \frac{1-\left(1-\frac{\kappa}{w_L}k\right)^{1+\alpha(1-\sigma)}}{\left(1+\alpha(1-\sigma)\right)\kappa} + a^{\sigma}(1-k)p_h^{\,1-\sigma} + \tilde{p}_h^{\,1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

$$P(k) = p_l^{\,\gamma_l}\left(P_h(k)\right)^{\gamma_h}\, p_{nt}^{\,\gamma_{nt}} = \delta^{-\gamma_{nt}} p_l^{\,\gamma_l}\left(P_h(k)\right)^{\gamma_h}\, w_L^{\,\gamma_{nt}}$$

$$\tilde{P}(k) = {p_l}^{\gamma_l} \left(P_h(k)\right)^{\gamma_h} {\tilde{p}_{nt}}^{\gamma_{nt}} = \delta^{-\gamma_{nt}} {p_l}^{\gamma_l} \left(P_h(k)\right)^{\gamma_h} {\tilde{w}_L}^{\gamma_{nt}}$$

Real incomes per head

$$y_{real}(k) = \frac{I(k)}{P(k) \times \left(\bar{H} + \bar{L}\right)} \qquad \tilde{y}_{real}(k) = \frac{\tilde{I}}{\tilde{P}(k) \times \left(\bar{\tilde{H}} + \bar{\tilde{L}}\right)}$$

3. Offshoring and unemployment in Germany with a reservation wage $\underline{w}$ (RW)

8 equations with 8 unknown variables ($\tilde{w}$, *w*, *L*, *I*, $\tilde{I}$, I*, *u*, *x*):

$$\tilde{w} = \frac{1-\gamma_{nt}}{\frac{\alpha}{1-\alpha} + \gamma_{nt}} \frac{\bar{\tilde{L}}}{\bar{\tilde{H}}}$$

$$w_{RW} = \frac{(1-\gamma_{nt})(1-\alpha)\left(\underline{w} - \underline{w}\left(1-\frac{\kappa}{\underline{w}}k\right)^{1-\alpha(\sigma-1)} + (1-k)\kappa\left(1-\alpha(\sigma-1)\right)\right)}{\left(\alpha + \gamma_{nt}(1-\alpha)\right)\left(1-k\right)\kappa\left(1-\alpha(\sigma-1)\right) + \gamma_{nt}(1-\alpha)\left(\underline{w} - \underline{w}\left(1-\frac{\kappa}{\underline{w}}k\right)^{1-\alpha(\sigma-1)}\right)} \frac{L}{\bar{H}}$$

$$I = \underline{w}(L + w_{RW}\bar{H}) \;; \quad \tilde{I} = \frac{\tilde{w}_L}{\alpha + (1-\alpha)\gamma_{nt}} \bar{\tilde{L}}$$

$$I^* = \frac{1}{\gamma_h}\left((1-\gamma_{nt}) \frac{\underline{w}\frac{1-\left(1-\frac{\kappa}{\underline{w}}k\right)^{1-\alpha(\sigma-1)}}{\kappa\left(1+\alpha(1-\sigma)\right)} + (1-k)}{a^{-\sigma}\left(\frac{\underline{w}}{\tilde{w}_L}\left(\frac{w_{RW}}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}} + \gamma_l \right) \tilde{I} - I$$

$$I^* = \frac{1}{\gamma_h} \frac{(\alpha\gamma_h + \gamma_l)\underline{w}\frac{1-\left(1-\frac{\kappa}{\underline{w}}k\right)^{1-\alpha(\sigma-1)}}{\kappa\left(1-\alpha(\sigma-1)\right)} + \gamma_l(1-k) + \gamma_l a^{-\sigma}\left(\frac{\underline{w}}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}}{(1-\alpha)\underline{w}\frac{1-\left(1-\frac{\kappa}{\underline{w}}k\right)^{1-\alpha(\sigma-1)}}{\kappa\left(1-\alpha(\sigma-1)\right)} + (1-k) + a^{-\sigma}\left(\frac{\underline{w}}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}} (I + \tilde{I})$$

$$u = \frac{\bar{L} - L}{\bar{L}}$$

$$x = \gamma_h \frac{1-\left(1-\frac{\kappa}{\underline{w}}k\right)^{1-\alpha(\sigma-1)} + (1-k)\frac{\kappa}{\underline{w}}\left(1-\alpha(\sigma-1)\right)}{1-\left(1-\frac{\kappa}{\underline{w}}k\right)^{1+\alpha(1-\sigma)} + (1-k)\frac{\kappa}{\underline{w}}\left(1-\alpha(\sigma-1)\right) + a^{-\sigma}\frac{\kappa}{\underline{w}}\left(1-\alpha(\sigma-1)\right)\left(\frac{\underline{w}}{\tilde{w}_L}\left(\frac{w}{\tilde{w}}\right)^{1-\alpha}\right)^{\sigma-1}} \frac{\tilde{I} + I^*}{I}$$

Prices

$$p_h = A^{-1}\underline{w}\frac{w^{1-\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}} \qquad p_{\tilde{h}} = A^{-1}\tilde{w}_L\frac{\tilde{w}^{1-\alpha}}{(1-\alpha)^{1-\alpha}\alpha^{\alpha}}$$

$$P_h(k) = \left(a^{\sigma} p_h^{1-\sigma}\underline{w}\frac{1-\left(1-\frac{\kappa}{\underline{w}}k\right)^{1+\alpha(1-\sigma)}}{\left(1+\alpha(1-\sigma)\right)\kappa} + a^{\sigma}(1-k)p_h^{1-\sigma} + \tilde{p}_h^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

$$p_{nt} = \underline{w}/\delta\,; \quad \tilde{p}_{nt} = \tilde{w}_L/\delta\,; \quad p_l = \overline{p}_l$$

$$P(k) = p_l^{\gamma_l}\left(P_h(k)\right)^{\gamma_h} p_{nt}^{\gamma_{nt}} = \delta^{-\gamma_{nt}} p_l^{\gamma_l}\left(P_h(k)\right)^{\gamma_h}\underline{w}^{\gamma_{nt}}$$

$$\tilde{P}(k) = p_l^{\gamma_l}\left(P_h(k)\right)^{\gamma_h}\tilde{p}_{nt}^{\gamma_{nt}} = \delta^{-\gamma_{nt}} p_l^{\gamma_l}\left(P_h(k)\right)^{\gamma_h}\tilde{w}_L^{\gamma_{nt}}$$

Real incomes per head

$$y_{real}(k) = \frac{I(k)}{P(k)\times\left(\overline{H}+\overline{L}\right)} \qquad \tilde{y}_{real}(k) = \frac{\tilde{I}(k)}{\tilde{P}(k)\times\left(\overline{\tilde{H}}+\overline{\tilde{L}}\right)}$$