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Document de Recherche du Laboratoire d'Économie d'Orléans

DR LEO 2015-20

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TECHNICAL CHANGE BIASED TOWARD THE TRADED SECTOR AND LABOR MARKET FRICTIONS*

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Abstract

This paper investigates the relative wage and the relative price effects of higher productivity growth in tradables relative to non tradables in a two-sector open economy model with search unemployment. Applying cointegration methods to a panel of eighteen OECD countries over the period 1970-2007, our estimates reveal that a 1 percentage point increase in the productivity differential between tradables and non tradables lowers the non traded wage relative to the traded wage (relative wage) by 0.22% and appreciates the relative price of non tradables by 0.64%. While the decline in the relative wage reveals the presence of mobility costs preventing from the wage equalization across sectors, the relative wage responses to a productivity differential display a large dispersion across countries, thus suggesting that labor market frictions vary substantially across OECD economies. Using a set of indicators capturing the heterogeneity of labor market frictions across economies, we find that the relative wage significantly declines more in countries where labor market regulation is more pronounced. These empirical findings can be rationalized in a two-sector open economy model with search in the labor market and an endogenous labor force participation. In line with our estimates, our quantitative analysis reveals that the relative wage falls more in countries where unemployment benefits are more generous, firing cost is high, the worker bargaining power is large, and/or the labor force is less responsive at the extensive margin. When calibrating the model to each OECD economy, our numerical results reveal that the model predicts the relative wage response fairly well, and to a lesser extent the relative price response.

Keywords: Productivity growth; Sectoral wages; Relative price of non tradables; Search theory; Unemployment;
JEL Classification: E22; F11; F41; F43; J63; L16.

*We are greatly indebted to Stefan Schubert who has provided us invaluable suggestions and comments at different stages of the model. We are grateful to Fondazione Rodolfo De Benedetti to provide us with the Labour Institutions Database. We also thank participants at the 19th Conference Theories and Methods of Macroeconomics in Berlin, 26-27th March 2015, the lunch seminar at the University of Bolzano, 23rd June 2015, for valuable comments. Obviously, all remaining shortcomings are ours.

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1 Introduction

A major structural change shared by all OECD countries is technological change biased toward the traded sector. As established by Balassa [1964] and Samuelson [1964] (BS hereafter), higher productivity growth in tradables relative to non tradables tends to appreciate the relative price of non tradables which in turn raises domestic prices, thus leading to the so-called BS effect. While the positive relationship between the technological change and the relative price of non tradables has been corroborated by a number of empirical studies, the impact of higher productivity in tradables relative to non tradables on the non traded wage relative to the traded wage (relative wage hereafter) has so far not been explored by the literature.[1] The reason is that almost all papers analyzing the BS effect imposes the assumption of perfect mobility of labor across sectors so that the sectoral wages must equalize. Unlike, our evidence for 18 OECD countries show that technological change tends to lower the relative wage of non tradables over the period 1970-2007 in all economies of our sample, and more so in countries where the labor market regulation is more pronounced. We show that these findings can be rationalized in a two sector open economy model with search in the labor market.

Surprisingly enough, it is only recently that the theory developed by Balassa [1964] and Samuelson [1964] fifty years ago has been updated, notably by Bergin et al. [2006], Ghironi and Melitz [2005]. These two papers relax the assumption of perfectly competitive goods market and show that heterogenous productivity among firms and/or entry and exit of firms amplifies the effect of higher productivity in tradables relative to non tradables on domestic prices. Ghironi and Melitz [2005] show higher traded productivity triggers firm entry which stimulates labor demand, raises wages and thus increases traded prices, which amplifies the rise in domestic prices commonly induced by the appreciation in the price of non traded goods. According to Bergin et al. [2006], technological change biased toward the traded sector induces the least productive firms in the traded sector to cease exporting; as a result, the share of non tradables in the economy increases, thus amplifying the effect of the appreciation in the relative price of non tradables on domestic prices. In our paper, we consider imperfectly competitive labor markets and show that labor market frictions moderate the appreciation in the relative price of non tradables triggered by a productivity differential between tradables and non tradables by reducing the relative wage of non tradables. In this respect, our paper can be viewed as complementary of the existing theoretical literature related to the BS effect while it is also close to the literature exploring the labor market outcomes of trade liberalization episodes by relaxing the assumption of perfect labor mobility (see e.g., Kambourov [2009]).

[1] see e.g., De Gregorio et al. [1994], Canzoneri et al. [1999], Kakkar [2003], Lane and Milesi-Ferretti [2002].

To set the stage of the quantitative analysis, we first assess empirically the effects of technological change biased toward the traded sector on both the relative wage and the relative price of non tradables. Because all variables are non stationary, we have recourse to cointegration methods. Our estimates reveal that 1 percentage point increase in the productivity of tradables relative to non tradables lowers the relative wage by 0.22% and appreciates the relative price by 0.64% for the whole sample. The long-run decline in the relative wage suggests the presence of labor market frictions preventing from the wage equalization across sectors. Moreover, when assessing the effects of technological change biased toward the traded sector at the country level, we find that estimates display a large dispersion across countries, thus suggesting a substantial heterogeneity of labor mobility costs between the economies of our sample. Using a set of indicators to capture the extent of labor market frictions, we find that the decline in the relative wage is more pronounced in countries where the unemployment benefit scheme is more generous, legal protection against dismissals is stricter, or the worker bargaining power measured by the bargaining coverage is larger.

In order to account for our evidence, we put forward a variant of the two-sector open model with tradables and non tradables and search in the labor market along with an endogenous labor force participation decision in the lines of Heijdra and Ligthart [2009].[2] Imperfect mobility across sectors arises because searching for a job is a time-consuming and thus a costly activity. In our model, the elasticity of labor supply at the extensive margin (which is assumed to be symmetric across sectors) plays a pivotal role because it measures the extent of workers' moving costs: the smaller the elasticity of labor supply, the larger the switching cost (measured by a utility loss), and thus the lower the degree of labor mobility across sectors. Conversely, when we let the elasticity of labor supply tend toward infinity, the case of perfect labor mobility is obtained in the long-run, as assumed by the standard BS model, so that the relative wage remains unaffected by technological change biased toward the traded sector, in contradiction with our empirical findings. While letting the elasticity of labor supply to take intermediate values implies that the relative wage may fall, the size of its decline depends on the degree of labor market regulation as well. More specifically, because hiring is also a costly activity which depends on labor market institutions, firms may be reluctant to raise substantially the number of job vacancies. Intuitively, our model predicts that that firms' hiring in the traded sector is more elastic

[2] A number of variants of the two-sector model with tradables and non tradables have been used to investigate the real exchange rate and trade balance effects of financial liberalization (see Cordoba (de) and Kehoe [2000], Bems and Hartelius [2006]). See also Turnovsky [1997] who presents variants of the two-sector model. While these papers abstract from labor market frictions, our model also builds on Kehoe, Midrigan and Pastorino et al. [2014] who develop a two sector open economy model with tradables and non tradables and search unemployment. Our approach and setup are different. First, the authors consider financial frictions and human capital acquisition through employment. Second, they investigate the ability of their model to account for the large fall in household debt to income, consumption, and employment during the Great Contraction of the United States while we analyze the consequences of technological change biased toward the traded sector on the relative wage.

to technological change in countries where the unemployment benefit replacement rate is higher or the worker bargaining power is larger. As a result, the rise in the traded wage is more pronounced which results in a larger decline in the relative wage of non tradables. Our model also predicts that firms' hiring in the non traded sector is less elastic to productivity growth in countries where the firing cost is larger. Hence, the relative wage falls more because the non traded wage rises by a smaller amount following productivity gains.

To shed light on key factors determining the long-run adjustment in the relative wage and the relative price, we analytically break down the responses into two components: i) a labor market frictions channel (keeping net exports fixed), and ii) a labor accumulation channel triggered by the long-run adjustment in net exports. First, the model can account for the decline in the relative wage through the labor market frictions channel only if the elasticity of substitution for consumption between traded and non traded goods is larger than one. Intuitively, technological change biased toward the traded sector stimulates hiring in the traded sector since only in this case does expenditure on tradables rise relative to expenditure on non tradables. Conversely, an elasticity smaller than one raises the relative wage by increasing the share of non tradables in expenditure which has an expansionary effect on hirings in the non traded sector. Second, while the model cannot produce the decline in the relative wage found in the data when the elasticity of substitution is smaller than one, technological change biased toward the traded sector also exerts a negative impact on the relative wage by raising net exports in the long-run. The reason is that higher productivity induces firms to hire more. Because recruiting workers is a costly activity, the open economy runs a current account deficit to finance labor accumulation. While the open economy decumulates traded bonds along the transitional path, the trade balance must improve in the long-run for the intertemporal solvency condition to hold. Hence, through the labor accumulation channel, the demand for tradables always rises which induces traded firms to hire more, thus driving down the relative wage.

While the relative wage response is ambiguous when the elasticity of substitution between traded and non traded goods is smaller than one, our quantitative analysis reveals that, for our baseline calibration, the labor accumulation effect always more than offsets the labor market frictions effect so that the relative wage falls. Moreover, in line with our evidence, our sensitivity analysis reveals that the relative wage falls more in countries where the labor market is more regulated. More specifically, we find numerically that raising the unemployment benefit replacement rate or the worker bargaining power leads to a larger decline in the relative wage because in this case, net exports rise by a larger amount. Intuitively, such economies are characterized by a low labor market tightness which makes hiring more profitable following higher productivity. As a result, recruiting expenditure rise more, thus resulting in a larger current account deficit which must be matched in the long-run by a greater improvement in the balance of trade. Hence, the labor accumulation effect exerts a larger negative impact on the relative wage. The sensitivity analysis also reveals that the decline in the relative wage is more pronounced when increasing the firing cost because the non traded wage increases less. Intuitively, because the non traded sector is induced to reduce employment, firms must pay a firing cost which in turn moderates the positive effect of higher productivity on hiring. While the labor accumulation effect is almost unchanged, the labor market frictions effect exerts a smaller positive impact on the non traded wage in countries where legal protection against dismissals is stricter so that the relative wage falls more following technological change biased toward the traded sector.

The final exercise we perform is to compare the responses of the relative wage and relative price for each OECD economy in our sample to our empirical estimates. To do so, we allow for two sets of parameters to vary across countries: the elasticity of substitution in consumption between tradables and non tradables and the labor market parameters that we estimate for each economy. It is found that the model predicts the relative wage decline pretty well and to a lesser extent the rise in the relative price.

The remainder of the paper is organized as follows. In section 2, we provide evidence on the relative price and relative wage effects of relative productivities in the long run. In section 3, we develop an open economy version of the two-sector model with unemployment arising from matching frictions in both sectors and characterize the long-run equilibrium graphically. Section 4 analytically breaks down the relative price and relative wage responses to a productivity differential between tradables and non tradables. In section 5, we discuss numerical results and investigate the ability of the model to replicate our empirical findings for each OECD economy. Section 6 summarizes our main results and concludes.

2 Empirical evidence

In this section, we revisit empirically the effects of technological biased toward the traded sector by focusing on the relative wage and the relative price responses. We denote the level of the variable in upper case, the logarithm in lower case, and the percentage deviation from its initial steady-state by a hat.

2.1 Revisiting the Relative Wage and Relative Price Effects of Technological Change Biased toward the Traded Sector

To set the stage for the empirical analysis, we revisit the theory that Balassa [1964] and Samuelson [1964] developed fifty years ago to explain the appreciation of the relative price of non tradables following higher productivity growth in tradables relative to non tradables. While the original BS framework assumes perfectly competitive labor markets, we relax this assumption which allows us to highlight the implications of labor market frictions.

As it is commonly assumed, the country is small in terms of both world goods and capital markets, and thus faces an exogenous international price for the traded good $P^{T,\star}$. We assume that the law of one price holds so that $P^T = P^{T,\star}$, and normalize the price of the traded good on world good markets to unity. Each sector produces Y^j by using labor, L^j, according to a linearly homogenous function:

$$Y^j = A^j L^j, \tag{1}$$

where A^j represents the labor productivity index. In order to explore the implications of labor market frictions for the relative wage and the relative price, we must introduce some notations that will be useful later.

Because firms face a cost by maintaining job vacancies, they receive a surplus equal to the marginal revenue of labor Ξ^j less the product wage W^j. Symmetrically, so as to compensate for the cost of searching for a job, unemployed workers receive a surplus equal to the product wage less the reservation wage W_R^j. We denote by Ψ^j the overall surplus created when a job-seeking worker and a firm with a job vacancy conclude a contract. The overall surplus is equal to the difference between the marginal revenue of labor and the sectoral reservation wage:

$$\Psi^j \equiv \Xi^j - W_R^j, \tag{2}$$

where $\Xi^N = PA^N$ and $\Xi^T = A^T$. Denoting by θ^j the labor market tightness in sector j, defined as the ratio of job vacancies to unemployed workers, the change of the reservation wage in percentage is proportional to the labor market tightness, i.e., $\hat{w}_R^j = \chi^j W_R^j \hat{\theta}^j$ where χ^j represents the share of the surplus associated with a labor contract in the marginal benefit of search. Intuitively, when firms post more job vacancies, the labor market tightness rises which increases the probability of finding a job and thus the reservation wage.

The product wage W^j paid to the worker in sector j is equal to the reservation wage W_R^j plus a share α_W of the overall surplus Ψ^j:

$$W^j = \alpha_W \Psi^j + W_R^j, \tag{3}$$

where the worker bargaining power α_W is assumed to be symmetric across sectors. Subtracting the traded wage from the non traded wage by using (3), and differentiating leads to an equation that relates the change in the relative wage of non tradables to the growth differential between sectoral labor market tightness and surpluses:

$$\hat{w}^N - \hat{w}^T = -\frac{\chi W_R}{W}\left(\hat{\theta}^T - \hat{\theta}^N\right) - \frac{\alpha_W \Psi}{W}\left(\hat{\Psi}^T - \hat{\Psi}^N\right), \tag{4}$$

where we assume that initially $W^j \simeq W$ and $\chi^j W_R^j \simeq \chi W_R$ and $\Psi^j \simeq \Psi$. In a model abstracting from labor market frictions, as the standard BS model, searching for a job is a costless activity so that Ψ and χ are nil; hence sectoral wages rise at the same speed. Unlike, in a model with labor market frictions, technological change biased toward the traded sector may lower the non traded wage relative to the traded wage. The reason is as follows. First, as captured by the first term on the RHS of (4), higher productivity growth in tradables relative to non tradables induces traded firms to recruit more than non traded firms; because agents experience a utility loss when increasing the search intensity for a job in the traded sector, traded firms must increase wages to attract workers as reflected by the rise in the ratio θ^T/θ^N. Moreover, as shown by the second term on the RHS of (4), by raising Ψ^T/Ψ^N, technological change biased toward the traded sector lowers the non traded wage relative to the traded wage. Intuitively, searching for a job is time consuming and a higher Ψ^T/Ψ^N covers the increased cost of this activity, the worker obtaining a share equal to α_W.

When a labor contract is concluded with a worker, the representative firm in sector j receives the marginal revenue of labor Ξ^j which must cover the recruiting cost plus the dividend per worker equivalent to $(1-\alpha_W)\,\Psi^j$ and the wage rate paid to the worker:

$$\Xi^j = (1-\alpha_W)\,\Psi^j + W^j. \tag{5}$$

Subtracting Ξ^T from Ξ^N, and differentiating, we obtain a relationship between the relative price growth and the growth differential between sectoral productivity gains, wages and surpluses:

$$\hat{p} = \hat{a}^T - \hat{a}^N + \frac{W}{\Xi}\left(\hat{w}^N - \hat{w}^T\right) - \frac{(1-\alpha_W)\,\Psi}{\Xi}\left(\hat{\Psi}^T - \hat{\Psi}^N\right), \tag{6}$$

where we assume that initially $\Xi^j \simeq \Xi$, $\Psi^j \simeq \Psi$, and $W^j \simeq W$. According to (6), when abstracting from labor market frictions, sectoral surpluses are nil while sectoral wages increase at the same speed; as a result, the relative price of non tradables must appreciate by the same amount as the productivity differential. Unlike, in a model with labor market frictions, as captured by the second term on the RHS of (6), the relative wage of non tradables falls because traded firms have to pay higher wages to compensate for the workers' mobility costs. Moreover, as shown by the third term on the RHS of (6), since traded firms recruit more than non traded firms, the hiring cost must be covered by an increase in Ψ^T/Ψ^N, the firm obtaining a share equal to $1-\alpha_W$. Thus, by lowering the relative wage of non tradables and increasing the hiring cost in the traded sector relative to that in the non traded sector, the relative price of non tradables appreciates by less than 1% following a rise in the productivity of tradables relative to non tradables of 1%.

The relative wage and relative price equations described by (4) and (6) respectively, allow us to explain in what labor market frictions imply that sectoral wages may no longer rise at the same speed and the elasticity of the relative price of non tradables w.r.t. the productivity differential may be smaller than one. However, such conclusions are established by abstracting from the goods market equilibrium which matters as long as labor is not perfectly mobile across sectors. In section 4, we show that the full steady-state can be solved for the relative price and the relative wage, i.e., $P = P\left(A^T, A^N\right)$ and $\Omega \equiv W^N/W^T = \Omega\left(A^T, A^N\right)$. Because all variables display trends, our empirical strategy consists in estimating the cointegrating relationships with the productivity discrepancy between tradables and non tradables.

2.2 Data Construction

Before empirically exploring the relative price and relative wage effects of a productivity differential, we briefly describe the dataset we use and provide details about data construction below and in Appendix A as well. Our sample consists of a panel of eighteen OECD countries: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Germany (DEU), Denmark (DNK), Finland (FIN), France (FRA), Ireland (IRL), Italy (ITA), Japan (JPN), Korea (KOR), Netherlands (NLD), Norway (NOR), Spain (ESP), Sweden (SWE), United Kingdom (GBR) and the United States (USA). Our sample covers the period 1970-2007 (except for Japan: 1974-2007), for eleven 1-digit ISIC-rev.3 industries.

To split these eleven industries into traded and non traded sectors, we follow the classification suggested by De Gregorio et al. [1994]. Agriculture, hunting, forestry and fishing; Mining and quarrying; Total manufacturing; Transport, storage and communication are classified as traded industries. Following Jensen and Kletzer [2006], we updated the classification of De Gregorio et al. [1994] by treating Financial intermediation as a traded industry. Electricity, gas and water supply; Construction; Wholesale and retail trade; Hotels and restaurants; Real estate, renting and business services; Community, social and personal services are classified as non traded industries.[3]

We use the EU KLEMS [2011] database which provides domestic currency series of value added in current and constant prices, labor compensation and employment (number of hours worked) for each sector j (with $j = T, N$), permitting the construction of price indices p^j (in log) which correspond to sectoral value added deflators, sectoral wage rates w^j (in log), and sectoral measures of productivities a^j (in log). The relative price of non tradables p is the log of the ratio of the non traded value added deflator to the traded value added deflator (i.e., $p = p^N - p^T$). The relative wage ω is the log of the ratio of the non traded wage to the traded wage (i.e., $\omega = w^N - w^T$). We use sectoral labor productivities A^j to approximate technical change. Sectoral productivities A^j_t at time t are constructed from constant-price (domestic currency) series of value added Y^j_t and hours worked L^j_t, i.e., $A^j_t = Y^j_t / L^j_t$.

[3] De Gregorio et al. [1994], classify a sector as tradable if more than 10 percent of its total production is exported. This classification has been updated by Jensen and Kletzer [2006] who use locational Gini coefficients to measure the geographical concentration of different sectors and classify sectors with a Gini coefficient below 0.1 as non-tradable and all others as tradable (the authors classify activities that are traded domestically as potentially tradable internationally). Unlike De Gregorio et al. [1994] who treat "Financial intermediation" as non tradable, we classify this industry as tradable, following Jensen and Kletzer [2006].

2.3 A First Glance at the Data

We begin by examining the data for the 18 OECD economies over the period 1970-2007. Figure 1 plots the average relative price growth against the average relative wage growth which have been scaled (i.e., divided) by the average productivity growth differential between tradables and non tradables. Quantitatively, the BS model predicts that a 1 percentage point increase in the productivity differential leaves unaffected the relative wage of non tradables and appreciates the relative price of non tradables by 1%. Hence, according to the BS model, all countries should be positioned at point BS along the X-axis with coordinates (1,0). However, we find that all countries are positioned to the south-west of point BS. Quantitatively, we find that a 1 percentage point increase in the productivity differential is associated with a fall in the relative wage which varies between -0.02% for Belgium and -0.41%for Denmark. Regarding the relative price, we find that its appreciation varies between 0.34% for Canada to 0.97% for Japan while Norway experiences a fall in the relative price of non tradables due to the large increase of prices in traded industries such as 'Mining and Quarrying' (which accounts for about one fourth of GDP) over 1995-2007.

The data seem to challenge the conventional wisdom that labor mobility would gradually eliminate wage differences across sectors. If it were the case, the ratio of the non traded wage to the traded wage would remain unchanged. Unlike the relative wage tends to fall. Moreover, because non traded wages increase by a smaller amount that that if labor were perfectly mobile, the relative price of non tradables appreciates by a smaller amount than that suggested by the standard BS model. To confirm these findings, in the following, we have recourse to panel data unit root tests and cointegration methods.

< Please insert Figure 1 about here >

We test for the presence of unit roots in the logged relative wage ω (i.e., $w^N - w^T$) and in the difference between the (log) relative price p (i.e., $p^N - p^T$) and the (log) relative productivities (i.e., $a^T - a^N$). If the wage equalization hypothesis was right, sectoral wages would increase at the same speed so that the relative wage of non tradables would be stationary. As a result, the non tradable unit labor cost would rise by the same amount as the productivity differential. Hence, the difference between the (logged) relative price and the (logged) relative productivity should be stationary as well.

We consider five panel unit root tests among those most commonly used in the literature: i) Levin, Lin and Chu's [2002] test based on a homogenous alternative assumption, ii) a t-ratio type test statistic by Breitung [2000] for testing a panel unit root based on alternative detrending methods , iii) Im, Pesaran and Shin's [2003] test that allows for a heterogeneous alternative, iv) Fisher type test by Maddala and Wu [1999], and v) Hadri [2000] who proposes a test of the null of stationarity against the alternative of a unit root in the panel data. Results are summarized in Table 1.[4]

< Please insert Table 1 about here >

As shown in the first column Table 1, all panel unit root tests, except for the Levin et al.'s [2002] test, reveal that the relative wage variable is non-stationary. This finding suggests that the sectoral wage differential persists in the long run which casts doubt on the wage equalization hypothesis. Regarding the relative price of non tradables and the productivity of tradables relative to productivity of non tradables, these variables are found to be non-stationary. As shown in the last column, the difference between the relative price of non and the relative productivity is integrated of order one which implies that the productivity differential is not fully reflected in the relative price.[5]

2.4 Estimating Long-Run Relationships

We turn to the estimation of the relative wage and the relative price responses to higher productivity of tradables relative to non tradables. To do so, we regress the (log) relative wage ω and the (log) relative price p on the (log) relative productivity, respectively:

$$\omega_{i,t} = \delta_i + \beta \left(a^T_{i,t} - a^N_{i,t}\right) + v_{i,t}, \tag{7a}$$

$$p_{i,t} = \alpha_i + \gamma \left(a^T_{i,t} - a^N_{i,t}\right) + u_{i,t}, \tag{7b}$$

where i and t index country and time and $v_{i,t}$ and $u_{i,t}$ are i.i.d. error terms. Country fixed effects are captured by country dummies δ_i and α_i.

Because all variables are non-stationary, we have recourse to cointegration techniques. Having verified that the assumption of cointegration is empirically supported, we estimate the cointegrating relationships by using fully modified OLS (FMOLS) and dynamic OLS (DOLS) procedures for the cointegrated panel proposed by Pedroni [2000], [2001].[6] Both estimators give the same results and coefficients β and γ of the cointegrating relationships are significant at 1%. Two major results emerge. First, estimates reported in the Table 2 reveal that a 1 percentage point increase in the productivity differential between tradables

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[4]In Table 1, LLC and Breitung are the t-statistics developed by Levin et al. [2002] and Breitung [2000] respectively. IPS denotes the Im, Pesaran and Shin's [2003] W_{tbar} test. MW (ADF) and MW (PP) are the Maddala and Wu's [1999] P test based on Augmented Dickey-Fuller and Phillips-Perron p-values respectively. Hadri corresponds to Hadri's [2000] Z_μ test.

[5]We present the first generation tests which assume that all cross-sections are independent. In the Technical Appendix, as a robustness check, we also consider some second generation tests that allow for cross-unit dependencies. We find that second generation tests yield similar conclusions.

[6]Cointegration tests can be found in the longer version of the paper. The panel FMOLS and DOLS of Pedroni ([2000], [2001]) are used to estimate the cointegrating vector. The DOLS estimator adds q leads and lags of $\triangle(a^T - a^N)$ as additional regressors in (4). We set $q = 1$; our results were identical for $q = 2$ and $q = 3$. We also used alternative estimators: dynamic fixed effects estimator, mean group estimator (Pesaran and Smith [1995]), pooled mean group estimator (Pesaran et al. [1999]) and the panel DOLS (Mark and Sul [2003]). The results were almost identical and are relegated in the Technical Appendix.

and non tradables lowers the relative wage by about 0.22% and appreciates the relative price by 0.64%. Second, as shown in the second line and the third line of Table 2, the predictions of the model abstracting from labor market frictions are strongly rejected: the slope of the cointegrating vector β (γ) is statistically significantly different from zero (one).

< Please insert Table 2 about here >

< Please insert Table 3 about here >

We now assess if our conclusion for the whole sample also holds for each country. To do so we run again the regression of relative wage and relative price on relative productivity by letting β and γ vary across countries. Table 3 show DOLS and FMOLS estimates for the eighteen countries of our sample. The first result that emerges is that the responses display a large dispersion across countries. More specifically, when considering the fully modified OLS estimates and excluding Sweden and Canada, the elasticity of the relative wage to relative productivity varies between -0.49 for Germany to -0.08 for Norway; while the elasticity of the relative price varies between 0.36 for Denmark to about 0.90 for Japan approximately. The second result is that despite these large cross-country variations, technological change biased toward the traded sector significantly lowers the relative wage in all countries while non traded prices relative to traded prices rise less than the productivity differential.

2.5 How to Explain the Long-Run Decline in the Relative Wage?

As shown in section 2.1, the less than proportional increase in the relative price relies upon the fall in the non traded wage relative to the traded wage which so far remains explained. How to rationalize the long-run decline in the relative wage? Our panel unit root tests reveal that the sectoral wage differential persists in the long-run, thus indicating the existence of substantial mobility costs across sectors.

The standard neoclassical model abstracting from labor market frictions predicts that technological change will trigger a reallocation of resources towards sectors with higher productivity, thus progressively eliminating the wage differential. Contrary to conventional wisdom, the literature adopting a structural empirical approach has questioned the assumption of wage equalization and has uncovered substantial mobility costs. Artuç et al. [2010] estimate that inter-sectoral costs of mobility in the United States are in the order of six times annual average wages. Lee and Wolpin [2006] find that the cost of moving between the goods and the services sectors within the same occupation is estimated to be significantly larger than moving between occupations within the same sector. According to Lee and Wolpin's estimates over 1968-2000, the mobility cost between sectors ranges from 50 to 75% of average annual earnings while the intersectoral wage differential is persistent in the long-run. Using 25 years of matched employer-employee data from Brazil, Dix-Carneiro and Kovak [2015] present evidence of large mobility costs following the country's trade liberalization in the early 1990s. More precisely, it is found that local shocks have steadily growing effects on regional formal sector wages and employment for 20 years. Hence, the impact of local shocks is not dissipated over time through wage-equalizing migration.

While the causes of mobility costs are diverse, they can be classified into two categories: those related to the workers' characteristics, thus affecting labor supply, and those related to rigid labor markets influencing firms' labor demand. From the worker point of view, the mobility costs can be interpreted as psychological costs when switching from one sector to another (see e.g., Dix-Carneiro [2014]), geographic mobility costs (see e.g., Kennan and Walker [2011]) or can be the result of sector-specific human capital (see e.g., Lee and Wolpin [2006]). As in Dix-Carneiro [2014], in our model presented in section 3, we consider that mobility costs experienced by workers are captured by a utility loss. More precisely, we assume an endogenous labor force participation decision which implies that the allocation of the labor force across sectors is elastic to the ratio of sectoral reservation wages. Following technological change biased toward the traded sector, traded firms have to pay higher wages in order to compensate for the workers' utility loss when switching. As a result, the relative wage of non tradables must fall, and more so the lower the elasticity of labor supply at the extensive margin.

While technological change biased toward the traded sector drives down the relative wage because traded firms have to pay higher wages than those paid by the non traded sector in order to attract workers, the size of the decline in the relative wage may vary across countries. The reason is that labor market institutions influence the elasticity of labor demand with respect to technological change. Recently, Kambourov [2009] put forward higher firings costs as an explanation of lower inter-sectoral reallocation following trade reform episodes in Latin American countries. In the same spirit, we conjecture that the degree of labor market regulation influences firms' hiring decisions and thus the relative wage response to higher productivity growth in tradables relative to non tradables.

Labor market regulation encompasses several dimensions. In our paper, we consider three aspects: the strictness of employment protection against dismissals, the generosity of unemployment benefit scheme, and the worker bargaining power. The advantage to restrict our attention to these three dimensions is that the indicators are available for almost all countries of our sample and over a long enough time horizon. In the following, we use these indicators to test our conjecture according to which the relative wage of non tradables falls more in countries where the labor market regulation is more pronounced. As will be clear later when we will go into further detail on the transmission mechanism, the labor regulation influences the relative wage response through two channels:

- First, we expect the traded wage to increase more in countries where unemployment benefits are more generous or workers have a larger bargaining power; intuitively, because theses economies display a low labor market tightness, hiring is more profitable following technological change because it is easier to fulfill job vacancies; as will be detailed subsequently, a larger increase in hirings in the short-run leads a higher rise in net exports in the long-run; consequently, labor demand in the traded sector is more elastic to productivity growth in countries where the replacement rate or the worker bargaining power is higher.
- Second, we conjecture that in countries with higher firing costs, the non traded wage should rise less. More specifically, non traded firms reduce employment and thus are subject to the redundancy cost; as a result, they are less prone to recruit more workers. Hence, labor demand in the non traded sector is less elastic to technological in countries where employment protection is more pronounced.

2.6 Labor Market Regulation and the Relative Wage Response to Technological Change

To evaluate the role of labor market regulation in explaining the relationship between relative wage and relative productivity, we proceed as follows. First, we present the indicators of labor market regulation. Then we empirically explore our conjecture by using a simple split-sample analysis.

2.6.1 Measures for Labor Market Regulation

To explore its role in the determination of the relative wage response, we measure the degree of labor market regulation which commonly involves three dimensions:

- The first aspect is the difficulty of redundancy that we measure by the employment protection legislation (EPL hereafter) index provided by the OECD; this index which captures the strictness of legal protection against dismissals for permanent workers has the advantage to be available for all countries of our sample over the period 1985-2007 (except for Korea, 1990-2007).[7] As emphasized by Boeri and Van Ours [2006], the measure for strictness of employment protection can be misleading because regulation was eased in most European countries for temporary contracts, such as Spain, while the regulation for workers with permanent contracts hardly changed. Moreover, at

[7]The OECD indicator takes into account various aspects of firing cost, such as the administrative procedures, the length of the advance notice period, the amount of the severance payment, the severity of enforcement. We take the measure for strictness of employment protection for individual and collective dismissals (regular contracts).

the same time, the scope of fixed-term contracts was significantly expanded. In order to have a more accurate measure of the difficulty of redundancy, we use an alternative indicator by adjusting EPL for regular workers with the share of permanent workers in the economy. As summarized in Table 9, EPL index is lower in english speaking countries and higher in Southern (see e.g., Spain), Western (see e.g., the Netherlands), and Northern (see e.g., Sweden) European countries. By and large, adjusting the EPL index by excluding from total employment workers employed with a temporary contract merely modifies the ranking of countries, except for Spain.

- The generosity of unemployment benefit system is measured by using the replacement rate provided by the OECD. The data we use for the unemployment replacement rate for both European countries and the US are taken from the OECD database which calculates the average of the net unemployment benefit (including social assistance and housing benefits) replacement rates for two earnings levels, three family situations and three durations of unemployment (1st year, 2nd and 3rd year, 4th and 5th year).[8] Table 9 in the Appendix gives the replacement rate for each country of our sample and its unweighted average for the twelve European countries. There is considerable heterogeneity in this indicator, which varies from a low of about 10% for Italy and 26% for the United States to a high of 78% for Denmark. As shown in the last line, the average EU-12 replacement rate is more than twice as high as the US's.

- Measuring the extent of the worker bargaining power is a difficult task. In the empirical literature, the worker bargaining power is commonly captured by the bargaining coverage; we thus use this indicator which gives the proportion of employees covered by collective bargaining. Excluding Korea since data are only available from 2002, the bargaining coverage averages 69%. While the bargaining coverage is much lower than the sample average, in English-speaking (except for Australia) and Japan, it exceeds 80% in Scandinavian countries and Western countries, except for Spain. Source: ICTWSS (Jelle Visser [2009]).

As a first pass at gauging the role of labor market regulation in the determination of the relative wage effects of technological change biased toward the traded sector, we plot the FMOLS estimates for the relative responses against the three indicators capturing the extent of labor market regulation in Figure 7. More specifically, Figures 2(a), 2(b), 2(c) plot the absolute values of β_i taken from Table 3 against the EPL index adjusted with the share of permanent workers, the net unemployment benefit replacement rates, and the bargaining coverage, respectively. Because time series for the unemployment benefit replacement rate

[8] It is worthwhile noticing that the unemployment benefit rates are very similar across counties when considering short-term unemployment (less than one year) but display considerable heterogeneity for long-term unemployment. We believe that the last measure is more able to capture the extent of generosity of the unemployment benefit scheme.

and bargaining coverage are available only from the beginning of the 2000's for Korea and thus are too short, we exclude this country from Figures 2(b) and 2(c). In line with our conjecture, the trend lines in Figures 2(a), 2(b), 2(c) show that the estimated responses of the relative wage and our three measures of labor market regulation are positively related across countries.

While for an economy such as the United States, the labor market regulation is unanimously low along its three dimensions, the conclusion is not clear-cut for the majority of OECD economies; for example, while the Italian unemployment benefit scheme is the least generous, the strictness of employment protection is among the highest; conversely, while replacement rates are higher than OECD countries' average in Canada and the United Kingdom, the firing costs are low in these two economies. Because labor market regulation encompasses three dimensions, we recourse to a principal component analysis in order to have one overall indicator encompassing all the dimensions of labor market institutions. We believe that this indicator gives a more accurate measure of the degree of labor market regulation; in particular, Figure 2(d) displays the traditional distinction between English-speaking and European economies, labor markets being much less regulated in the former than the latter countries. Importantly, in accordance with our conjecture, the trend line is upward sloping, thus suggesting that technological change biased toward the traded sector lowers the relative wage more in countries where labor market regulation is more pronounced.

< Please insert Figure 2 about here >

2.6.2 Empirical results

To empirically explore our conjecture according to which the relative wage falls more following higher productivity growth in tradables relative to non tradables in countries with more regulated labor market, we perform a simple split-sample analysis. Hence, we compare the relative wage behavior of 9 countries with high and 9 economies with low labor market regulation by running the regression of the relative wage on relative productivity for each sub-sample:

$$\omega_{i,t} = \delta_i + \beta^c \left(a^T_{i,t} - a^N_{i,t}\right) + \upsilon_{i,t}, \quad c = H, L, \tag{8}$$

where β^H (β^L) captures the response of the relative wage to a productivity differential in countries with higher (lower) labor market regulation.

The DOLS and FMOLS estimates are reported in the first and the second line of Table 4 for countries with high and low labor market regulation. The two last lines of Table 4 gives the sub-sample's average of the corresponding labor market regulation index. As the results in Table 4 show, the decline in the relative wage is greater for countries with more regulated labor markets. While countries providing lower unemployment benefits experience a decline in the relative wage of -0.16% approximately, the second set of countries with generous unemployment benefits experience a decline in ω of -0.26%. A similar pattern emerges when we exploit a second dimension of labor market regulation, namely the strictness of employment protection. Since series for EPL are available over 1985-2007, we run again the regression (8) over this period to be consistent. We find that a 1 percentage point increase in the productivity differential between tradables and non tradables lowers the relative wage by 0.17% in countries with higher firing costs while ω declines by only 0.13%. Furthermore, as shown in the third column of Table 4, the worker bargaining power captured by the bargaining coverage exerts a significant impact on the relative wage response; more precisely, the relative wage falls by -0.24% instead of -0.18% in countries where the worker bargaining power is relatively higher. Finally, as displayed in the last column of Table 4, when we recourse to a principal component analysis, we find that countries with more regulated labor markets experience a larger decline in the relative wage.

< Please insert Table 4 about here >

To conclude, this empirical evidence suggest that labor market regulation plays a key role in the determination of the relative wage response to higher productivity in tradables relative to non tradables. In the following, we develop a dynamic general equilibrium model with a traded and a non traded sector by allowing for labor market frictions. In particular, our aim is to assess its ability to account for the following set of empirical findings. A productivity differential of 1% between tradables and non tradables: i) raises the relative price of non tradables p by 0.64%, ii) lowers the relative wage ω by 0.22%, iii) ω declines more in countries where the labor market regulation is more pronounced.

3 The Framework

The country is small in terms of both world goods and capital markets, and faces a given world interest rate, $r^{\star}$.[9] The small open economy is populated by a constant number of identical households and firms that have perfect foresight and live forever. Households decide on labor market participation and consumption while firms decide on hours worked.[10] The economy consists of two sectors. A sector produces a traded good denoted by the superscript T that can be exported while the other sector produces a non-traded good

[9]The price of the traded good is determined on the world market and exogenously given for the small open economy.

[10]More details on the model as well as the derivations of the results which are stated below are provided in a Technical Appendix which is available upon request.

denoted by the superscript N. The setup allows for traded and non-traded goods to be used for consumption. The traded good is chosen as the numeraire. The labor market, in the tradition of Diamond-Mortensen-Pissarides, consists of a matching process within each sector between the firms who post job vacancies and unemployed workers who search for a job. Time is continuous and indexed by t.

3.1 Households

At each instant the representative agent consumes traded goods and non-traded goods denoted by $C^T(t)$ and $C^N(t)$, respectively, which are aggregated by a constant elasticity of substitution function:

$$C\left(C^T(t), C^N(t)\right) = \left[\varphi^{\frac{1}{\phi}}\left(C^T(t)\right)^{\frac{\phi-1}{\phi}} + (1-\varphi)^{\frac{1}{\phi}}\left(C^N(t)\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \tag{9}$$

where φ is the weight attached to the traded good in the overall consumption bundle ($0 < \varphi < 1$) and ϕ is the intratemporal elasticity of substitution ($\phi > 0$).

The economy that we consider consists of a representative household with a measure one continuum of identical infinitely lived members. At any instant, members in the household derive utility from consumption goods C and experience disutility from working and searching efforts. More precisely, the representative household comprises members who engage in only one of the following activities: working and searching a job in each sector, or enjoying leisure. Assuming that the representative individual is endowed with one unit of time, leisure is defined as $l(t) \equiv 1 - L^T(t) - L^N(t) - U^T(t) - U^N(t)$, where $L^j(t)$ denotes units of labor time and $U^j(t)$ corresponds to time spent on searching for a job in sector j (with $j = T, N$). Hence, the labor force is not constant which enables us to focus on both the transition between employment and unemployment on the one hand, and the transition between leisure and labor force on the other. Unemployed agents are randomly matched with job vacancies according to a matching function described later. Since the timing of a match is random, agents face idiosyncratic risks. To simplify the analysis, we assume that members in the household perfectly insure each other against variations in labor income.

We consider that the utility function is additively separable in the disutility received by working and searching in the two sectors. As will become clear later, such specification makes it impossible to switch immediately from one sector to the other. This can be justified on the grounds of sector specific skills. The representative household chooses the time path of consumption and labor force to maximize the following objective function:

$$U = \int_0^{\infty}\left\{\frac{1}{1-\frac{1}{\sigma_C}}C(t)^{1-\frac{1}{\sigma_C}} - \frac{\zeta^T}{1+\frac{1}{\sigma_L^T}}F^T(t)^{1+\frac{1}{\sigma_L^T}} - \frac{\zeta^N}{1+\frac{1}{\sigma_L^N}}F^N(t)^{1+\frac{1}{\sigma_L^N}}\right\}e^{-\rho t}\mathrm{d}t, \tag{10}$$

where ρ is the consumer's subjective time discount rate, $\sigma_C > 0$ is the intertemporal elasticity of substitution for consumption, and $\sigma_L^j > 0$ is the elasticity of labor supply at the extensive margin in sector $j = T, N$. For later use, we denote by $u^j(t)$ the sectoral unemployment rate defined as $u^j = \frac{U^j(t)}{U^j(t)+L^j(t)} = \frac{U^j(t)}{F^j(t)}$ with $F^j(t) = L^j(t) + U^j(t)$ the labor force in sector j.

At each instant of time, $m^j(t)U^j(t)$ unemployed agents find a job in sector $j = T, N$ and $s^j L^j(t)$ employed individuals lose their job. Employment in sector j evolves gradually according to:

$$\dot{L}^j(t) = m^j(t)U^j(t) - s^j L^j(t), \quad j = T, N, \tag{11}$$

where $m^j(t)$ denotes the rate at which unemployed agents find jobs and s^j is the constant rate of job separation; $1/m^j(t)$ can be interpreted as the average unemployment duration; m^j is a function of labor market tightness $\theta^j(t)$ which is defined as the ratio of the number of job vacancies over unemployed agents in sector j.

Households supply $L^j(t)$ units of labor services in sector $j = T, N$ for which they receive the product wage $W^j(t)$. We denote by $A(t)$ the stock of financial wealth held by households which comprises internationally traded bonds, $B(t)$, and shares on domestic firms. Because foreign bonds and domestic shares are perfect substitutes, the stock of financial wealth yields net interest rate earnings $r^\star A(t)$. Denoting by $T(t)$ the lump-sum taxes, the flow budget constraint is equal to households' real disposable income less consumption expenditure $P_C(t)C(t)$:

$$\dot{A}(t) = r^\star A(t) + W^T(t)L^T(t) + W^N(t)L^N(t) + R^T U^T(t) + R^T U^T(t) - T(t) - P_C\left(P(t)\right)C(t), \tag{12}$$

where P_C is the consumption price index which is a function of the relative price of non-traded goods P and R^j represents unemployment benefits received by job seekers in sector j.

The representative household selects consumption, time dedicated for searching a job in sector j, and financial wealth:[11]

$$C(t) = \left(P_C(t)\lambda(t)\right)^{-\sigma_C} \tag{13a}$$

$$F^j(t) = \left\{\lambda(t)\left[m^j\left(\theta^j(t)\right)\xi^j(t) + R^j\right]\right\}^{\sigma_L^j}, \tag{13b}$$

$$\dot{\lambda}(t) = \lambda(t)\left(\rho - r^\star\right), \tag{13c}$$

$$\dot{\xi}^j(t) = \left(s^j + r^\star\right)\xi^j(t) - \left[W^j(t) - \frac{\left(F^j(t)\right)^{1/\sigma_L^j}}{\lambda(t)}\right], \tag{13d}$$

and the appropriate transversality conditions; λ and $\xi^j(t)$ denote the shadow prices of wealth and finding a job in sector j, respectively. Eq. (13b) shows that labor market

[11]First-order conditions consist of (13a) and (13c) together with $\left(F^j\right)^{1/\sigma_L^j} = m^j \xi^{\prime,j} + R^j \lambda$ and $\dot{\xi}' = \left(s^j + \rho\right)\xi^{\prime,j} - \left[\lambda W^j - \left(F^j\right)^{1/\sigma_L^j}\right]$. Denoting by $\xi^j \equiv \xi^{\prime,j}/\lambda$, using (13a) and (13c), we get (13b) and (13d). Since $\xi^{\prime,j}$ is the utility value of an additional job and λ is the marginal utility of wealth, ξ^j is the pecuniary value of an additional job.

participation is a positive function of the reservation wage $W_R^j(t)$, which is defined as the sum of the expected value of a job $m^j(t)\xi^j(t)$ and the unemployment benefit R^j. Solving eq. (13d) forward and invoking the transversality condition yields:

$$\xi^j(t) = \int_t^{\infty} \left[W^j(\tau) - W_R^j(\tau)\right] e^{\left(s^j + r^\star\right)(t-\tau)} \mathrm{d}\tau. \tag{14}$$

Eq. (14) states that ξ is equal to the present discounted value of the surplus from an additional job consisting of the excess of labor income over the household's outside option. Note that as described above, we consider a representative household who splits available time between leisure and market activities (i.e., time devoted to job search and work). While labor supply is elastic at the extensive margin, search effort and worked hours are supplied inelastically.[12] For the sake of clarity, we drop the time argument below when this causes no confusion.

Applying Shephard's lemma (or the envelope theorem) yields expenditure in tradables and non tradables, i.e., $PC^N = \alpha_C P_C C$, $(1-\alpha_C) P_C C$, with α_C being the share of non traded goods in consumption expenditure.[13] Intra-temporal allocation of consumption follows from the following optimal rule:

$$\left(\frac{1-\varphi}{\varphi}\right)\frac{C^T}{C^N} = P^{\phi}. \tag{15}$$

An appreciation in the relative price of non tradables P increases expenditure on tradables relative to expenditure on non tradables (i.e. C^T/PC^N), only when $\phi > 1$.

3.2 Firms

Each sector consists of a large number of identical firms. Both the traded and non-traded sectors use labor, L^T and L^N, according to constant returns to scale production functions, $Y^T = A^T L^T$ and $Y^N = A^N L^N$. Firms post job vacancies V^j to hire workers and face a cost per job vacancy κ^j which is assumed to be constant and measured in terms of the traded good. Firms pay the wage W^j decided by the generalized Nash bargaining solution. As producers face a labor cost w^j per employee and a cost per hiring of κ^j, the profit function of the representative firm in sector j is:

$$\pi^j = \Xi^j L^j - W^j L^j - \kappa^j V^j - x^j \,.\max\left\{0, -\dot{L}^j\right\}, \tag{16}$$

where Ξ^j is the marginal revenue of labor with $\Xi^T = A^T$ and $\Xi^N = PA^N$; x^j is a firing tax paid to the State when layoffs are higher than hirings, i.e. if $\dot{L}^j < 0$ (see e.g., Heijdra and Ligthart [2002], Veracierto [2011]). The firing tax is introduced to capture the strictness of

[12] More precisely, depending on the search parameters captured by s^j and m^j, labor force is split between working time and job search. Along the transitional dynamics, using the fact that $U^j = F^j - L^j$, agents supply working time L^j according to the following accumulation equation $\dot{L}^j = m^j U^j - s^j L^j = m^j F^j - \left(m^j + s^j\right) L^j$, where F^j is labor force and L^j corresponds to hours worked in sector j supplied by the representative household.

[13] Specifically, we have $\alpha_C = \frac{(1-\varphi)P^{1-\phi}}{\varphi + (1-\varphi)P^{1-\phi}}$. Note that α_C depends negatively on the relative price P as long as $\phi > 1$.

legal protection against dismissals. It is worthwhile noticing that firing taxes are modelled as a tax on reducing employment. While employment is reduced, the shrinking establishment is hiring; thus the representative firm simultaneously pays a firing tax and receives a hiring subsidy, i.e., $-x^j \dot{L}^j = x^j s^j L^j - x^j f^j V^j > 0$.

Denoting by f^j the rate at which a vacancy is matched with unemployed agents, the law of motion for labor is given by:

$$\dot{L}^j = f^j V^j - s^j L^j, \tag{17}$$

where $f^j V^j$ represents the flow of job vacancies which are fulfilled; note that $f^j\left(\theta^j\right)$ decreases with labor market tightness θ^j.

Denoting by γ^j the shadow price of employment to the firm, and keeping in mind that f^j is taken as given, the maximization problem yields the following first-order conditions:

$$\gamma^j + x^j = \frac{\kappa^j}{f^j\left(\theta^j\right)}, \tag{18a}$$

$$\dot{\gamma}^j = \gamma^j\left(r^\star + s^j\right) - \left(\Xi^j + r^\star x^j - W^j\right), \tag{18b}$$

where $\Xi^T = A^T$ and $\Xi^N = PA^N$. Eq. (18a) requires the marginal cost of vacancy, κ^j, to be equal to the marginal benefit of vacancy, $f^j(.)\left(\gamma^j + x^j\right)$. Solving equation (18b) forward and invoking the transversality condition yields:

$$\gamma^j(t) = \int_t^\infty \left[\Xi^j(\tau) - x^j s^j - W^j(\tau)\right] e^{\left(s^j + r^\star\right)(t-\tau)} \mathrm{d}\tau. \tag{19}$$

Eq. (19) states that γ^j is equal to the present discounted value of the cash flow earned on an additional worker, consisting of the excess of marginal revenue of labor Ξ^j over the wage W^j and the expected firing cost $x^j s^j$. Following higher productivity A^j, the marginal revenue of labor Ξ^j rises; hence hiring becomes more profitable which induces firms to post job vacancies, but less so in countries with a higher firing cost x^j.

Differentiating $\gamma^j(t)L^j(t)$ w. r. t. time and inserting the law of motion for employment (17) together with the dynamic optimality condition (18b), solving forward, and making use of the transversality condition, we get:[14]

$$\gamma^j(t)L^j(t) = \int_t^\infty \pi^j(\tau)\, e^{-r^\star(\tau-t)} \mathrm{d}\tau, \quad j = T, N, \tag{20}$$

where we used eq. (18a). Eq. (20) states that the value of human assets $\gamma^j L^j$ (or stock market value of the firm) is equal to the present discounted value of profits π^j.

3.3 Matching and Wage Determination

In each sector, there are job-seeking workers U^j and firms with job vacancies V^j which are matched in a random fashion. Assuming a constant returns to scale matching function, the

[14] We made use of the fact that $\pi^j = \Xi^j L^j - W^j L^j - x^j \,.\max\left\{0, -\dot{L}^j\right\} - \kappa^j V^j$ since production functions are linearly homogeneous in labor.

number of labor contracts M^j concluded per job seeker U^j gives the probability of finding a job m^j which is increasing in the labor market tightness θ^j:

$$m^j = \frac{M^j}{U^j} = X^j \left(\frac{V^j}{U^j}\right)^{\alpha_V^j} = X^j \left(\theta^j\right)^{\alpha_V}, \quad \alpha_V^j \in (0,1), \tag{21}$$

where α_V^j represents the elasticity of vacancies in job matches and X^j corresponds to the matching efficiency.[15] We can also express the number of matches M^j per job vacancies:

$$f^j = \frac{M^j}{V^j} = X^j \left(\theta^j\right)^{\alpha_V^j - 1}. \tag{22}$$

Eq. (22) shows that the probability of fulfilling a job vacancy is higher the lower the labor market tightness θ^j.

When a vacancy and a job-seeking worker meet, a rent is created which is equal to $\xi^j + \gamma^j + x^j$, where ξ^j is the value of an additional job, γ^j is the value of an additional worker, and x^j corresponds to the hiring subsidy.[16] The division of the rent between the worker and the firm is determined by generalized Nash bargaining over the wage rate:

$$\max_{W^j} \left(\xi^j\right)^{\alpha_W^j} \left(\gamma^j + x^j\right)^{1-\alpha_W^j}, \quad \alpha_W^j \in (0,1), \tag{23}$$

where α_W^j and $1 - \alpha_W^j$ correspond to the bargaining power of the worker and the firm, respectively.[17]

Solving for (23), the product wage W^j is defined as a weighted sum of the labor marginal revenue plus the interest income from the hiring subsidy and the reservation wage:

$$W^j = \alpha_W^j \left(\Xi^j + r^\star x^j\right) + \left(1 - \alpha_W^j\right) \frac{\left(F^j\right)^{1/\sigma_L^j}}{\bar{\lambda}}. \tag{24}$$

An increase in the marginal product of labor, Ξ^j, which exerts an upward pressure on labor demand, or a rise in the labor market tightness, by raising the reservation wage (see eq. (13b)), pushes up the product wage.[18]

[15] Note that the flows of workers in and out of employment are equal to each other in any symmetric equilibrium, i.e., $m^j U^j = f^j V^j$. Hence equations $\dot{L}^j = f^j V^j - s^j L^j$ and $\dot{L}^j = m^j U^j - s^j L^j$ indicate that the demand for labor indeed equates the supply.

[16] As mentioned above, the firing tax is modelled as a tax on reducing employment; because firms experience simultaneously outflow and inflow of workers, this shortcut to encompass the strictness of employment protection implies that establishments pay firing taxes and receive hiring subsidies at the same time; obviously, the former amount is larger than the latter.

[17] It is worthwhile noticing that while the modelling of employment protection as a tax on reducing employment implies that the firm receives a hiring subsidy, the firing tax reduces γ^j (see eq. (19)) at the same time.

[18] Note that the Nash bargaining wage depends positively on unemployment benefits R^j. To see it more formally, using the fact that $\xi^j = \frac{\alpha_W^j}{1-\alpha_W^j}\gamma^j$, $\gamma^j + x^j = \kappa^j / f^j$, $m^j/f^j = \theta^j$, we have $\left(F^j\right)^{1/\sigma_L^j}/\bar{\lambda} = \frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\theta^j + R^j$. Plugging this term into the Nash bargaining wage (24), we have:

$$W^j = \alpha_W^j \left(\Xi^j + r^\star x^j\right) + \left(1 - \alpha_W^j\right)\left[\frac{\alpha_W^j}{1 - \alpha_W^j}\kappa^j\theta^j + R^j\right] = \alpha_W \left(\Xi^j + \kappa^j\theta^j + r^\star x^j\right) + \left(1 - \alpha_W^j\right) R^j.$$

3.4 Government

The final agent in the economy is the government. Unemployed benefits $R^T U^T + R^N U^N$ are covered by lump-sum taxes T and the proceeds from the firing tax $\sum_j x^j \; . \max\left\{0, -\dot{L}^j\right\}$ according to the following balanced budget constraint:[19]

$$\sum_j x^j \; . \max\left\{0, -\dot{L}^j\right\} + T = \sum_j R^j U^j. \tag{25}$$

3.5 Market Clearing Conditions

Before characterizing the equilibrium dynamics and discussing the steady-state, we have to impose the market clearing condition for the non traded good according to which non traded output is only consumed domestically:

$$Y^N(t) = C^N(t). \tag{26}$$

Using the definition of the stock of financial wealth $A(t) \equiv B(t) + \gamma^T(t)L^T(t) + \gamma^N(t)L^N(t)$, differentiating with respect to time, substituting the accumulation equations of labor (11) and financial wealth (12) together with the dynamic equation for the shadow value of an additional worker (18b), using the government budget constraint (25) and the market clearing condition for the non traded good market (26), the accumulation equation for foreign assets is:

$$\dot{B}(t) = r^\star B(t) + A^T L^T(t) - C^T(t) - \kappa^T V^T(t) - \kappa^N V^N(t). \tag{27}$$

3.6 Short-Run Static Solutions

In an open economy model with a representative agent having perfect foresight, a constant rate of time preference and perfect access to world capital markets, we impose $\beta = r^\star$ in order to generate an interior solution. This standard assumption made in the literature implies that the marginal utility of wealth, λ, will undergo a discrete jump when individuals receive new information and must remain constant over time from then on, i.e. $\lambda = \bar{\lambda}$. Equation (13a) can be solved for consumption:

$$C = C\left(\bar{\lambda}, P\right). \tag{28}$$

A rise in the shadow value of wealth induces agents to cut their real expenditure (i.e., $C_{\bar{\lambda}} < 0$) while an increase in the consumption price index triggered by an appreciation in the relative price of non-tradables P drives down consumption (i.e., $C_P < 0$). Inserting (28) into $C^T = (1 - \alpha_C) P_C C$ and $PC^N = \alpha_C P_C C$ allows us to solve for consumption in

[19] In the numerical analysis, we consider government spending for calibration purpose. In this case, where eq. (25) can be rewritten as follows: $\sum_j x^j \; . \max\left\{0, -\dot{L}^j\right\} + T = \left(R^T U^T + R^N U^N\right) + G^T + PG^N$ where G^T and G^N government spending on tradables and non tradables, respectively. When $\dot{L}^j < 0$, government proceeds from the firing costs are redistributed back to agents as lump-sum transfers.

tradables and non tradables, i.e., $C^T = C^T(\bar{\lambda}, P)$ and $C^N = C^N(\bar{\lambda}, P)$ with $C^j_{\bar{\lambda}} < 0$, $C^T_P \gtrless 0$ depending on whether $\phi \gtrless \sigma_C$ and $C^N_P < 0$.

Substituting first the short-run static solution for consumption in non tradables $C^N = C^N(\bar{\lambda}, P)$, the market clearing condition for the non traded good (26) can be solved for the relative price of non tradables as follows:

$$P = P\left(L^N, \bar{\lambda}, A^N\right), \tag{29}$$

where $P_{L^N} = \partial P / \partial L^N = A^N / C^N_P < 0$, $P_{\bar{\lambda}} = -C^N_{\bar{\lambda}} / C^N_P < 0$, and $P_{A^N} = \partial P / \partial A^N = L^N / C^N_P < 0$.

3.7 Saddle-Path Stability

In this subsection, we analyze saddle-path stability; hence, we first derive the system of differential equations. To determine the dynamic equation for labor market tightness θ^j in sector j, differentiate (18a) w. r. t. time, insert (18b), and eliminate γ^j by using (18a):

$$\dot{\theta}^j = \frac{\theta^j}{\left(1 - \alpha^j_V\right)} \left\{ \left(s^j + r^\star\right) - \frac{f^j\left(\theta^j\right)\left(1 - \alpha^j_W\right)\Psi^j}{\kappa^j} \right\}, \tag{30}$$

where the overall surplus from an additional job in sector j denoted with Ψ^j is defined as the difference between the marginal product of labor and the reservation wage :

$$\Psi^j = \left(\Xi^j + r^\star x^j\right) - \frac{\left(F^j\right)^{1/\sigma^j_L}}{\bar{\lambda}}. \tag{31}$$

Differentiating first (13b) w. r. t. time and substituting (13d) yields the dynamic equation for job seekers:

$$\frac{1}{\sigma^j_L} \frac{\left(F^j\right)^{\frac{1}{\sigma^j_L} - 1}}{\bar{\lambda}} \dot{U}^j = \left[\frac{\left(F^j\right)^{1/\sigma^j_L}}{\bar{\lambda}} - R^j \right] \left[\left(s^j + r^\star\right) + \alpha^j_V \frac{\dot{\theta}^j}{\theta^j} \right] - m^j\left(\theta^j\right) \alpha^j_W \Psi^j - \frac{\left(F^j\right)^{\frac{1}{\sigma^j_L} - 1}}{\sigma^j_L \bar{\lambda}} \dot{L}^j, \tag{32}$$

where we used the fact that $W^j - W^j_R = \alpha^j_W \Psi^j$.

Due to our assumption that disutility functions from participating to the labor market in the traded and the non traded sector are additively separable, hiring and search decisions in the traded and non traded labor markets are independent which implies that the Jacobian matrix is block recursive; hence, the saddle-path stability condition in the traded and non traded sectors can be explored separately. Inserting first appropriate short-run static solutions, linearizing in the neighborhood of the steady-state, the dynamic system for the traded (non traded) sector which comprises three equations, i.e. the accumulation equation for employment (11), the dynamic equation for labor market tightness (30) and the dynamic equation for job seekers (32), we find that the determinant of the Jacobian matrix for the traded (non traded) sector is negative.[20] Hence, the linearized dynamic system possesses

[20] When focusing on the non traded sector, we have $\Xi^N = PA^N$; in this case, we have to insert the short-run stock solution for the relative price of non tradables (29) into the dynamic equation for θ^N and U^N.

one negative eigenvalue denoted by ν_1^j and two positive eigenvalues denoted by ν_2^j and ν_3^j. Assuming that the Hosios condition holds, i.e., setting $\alpha_W^j = \left(1 - \alpha_V^j\right)$, eigenvalues satisfy $\nu_1^j < 0 < r^\star < \nu_2^j$, with $\nu_2^j = r^\star - \nu_1^j > 0$, and $\nu_3^j = s^j + r^\star > 0$. Note that when the considering the traded sector, the negative and the positive eigenvalues reduces to $\nu_1^T = -\left(s^T + \tilde{m}^T\right) < 0$ and $\nu_2^T = \left(s^T + r^\star + \tilde{m}^T\right) > 0$.

Denote the long-term values with a tilde, the stable paths for employment, labor market tightness, and job seekers are given by:[21]

$$L^T(t) - \tilde{L}^T = D_1^T e^{\nu_1^T t}, \quad \theta^T(t) - \tilde{\theta}^T = \omega_{21}^T D_1^T e^{\nu_1^T t}, \quad U^T(t) - \tilde{U}^T = \omega_{31}^T D_1^T e^{\nu_1^T t}, \tag{33a}$$

$$L^N(t) - \tilde{L}^N = D_1^N e^{\nu_1^N t}, \quad \theta^N(t) - \tilde{\theta}^N = \omega_{21}^N D_1^N e^{\nu_1^N t}, \quad U^N(t) - \tilde{U}^N = \omega_{31}^N D_1^N e^{\nu_1^N t}, \tag{33b}$$

where we have normalized ω_{11}^j to unity; it can be proven formally that $\omega_{21}^T = 0$, $\omega_{31}^T = -1$, $\omega_{21}^N < 0$, $\omega_{31}^N < 0$.

Two features of the two-sector economy's equilibrium dynamics deserve special attention. First, the dynamics for labor market tightness in the traded sector $\theta^T(t)$ degenerate as reflected by $\omega_{21}^T = 0$. Unlike, because the relative price of non tradables adjusts to clear the non traded good market while labor L^N is a state variable, $\theta^N(t)$ exhibits transitional dynamics; because $\omega_{21}^N < 0$, L^N and θ^N move in opposite directions. Second, in both sectors, the number of job seekers U^j falls as employment L^j builds up.

Inserting first the short-run static solution for the relative price of non tradables (29) into $C^T = C^T\left(\bar{\lambda}, P\right)$, linearizing (27) around the steady-state, substituting the solutions (33), and invoking the transversality condition, yields the stable solution for traded bonds $B(t) - \tilde{B} = \Phi^T\left(L^T(t) - \tilde{L}^T\right) + \Phi^N\left(L^N(t) - \tilde{L}^N\right)$ consistent with the intertemporal solvency condition:[22]

$$\tilde{B} - B_0 = \Phi^T\left(\tilde{L}^T - L_0^T\right) + \Phi^N\left(\tilde{L}^N - L_0^N\right). \tag{34}$$

Because $\Phi^T < 0$ and $\Phi^N < 0$, the current account is negatively related to changes in sectoral employment. Intuitively, to raise employment, firms must post more job vacancies; because hiring is a costly activity, recruiting expenditure rise which deteriorates the current account.

[21] Elements ω_{21}^N and ω_{31}^N of the eigenvector (associated with the stable eigenvalue ν_1^N) are:

$$\omega_2^1 = \frac{\left(2s^N + r^\star\right) + \left(s^N + r^\star - \nu_i^N\right)\left(\frac{s^N + \nu_i^N}{\tilde{m}^N}\right) + \tilde{m}^N\left(P_{L^N} A^N \frac{\bar{\lambda}}{v_{FF}^N} + 1\right)}{\frac{\left(m^N\right)' \tilde{U}^N}{\tilde{m}^N}\left(s^N + \tilde{m}^N + r^\star - \nu_i^N\right)} < 0, \quad \omega_{31}^N = \left(\frac{s^N + \nu_1^N}{\tilde{m}}\right) - \frac{\left(m'\right)^N \tilde{U}^N}{\tilde{m}^N}\omega_{21}^N < 0.$$

[22] The terms Φ^T and Φ^N are negative and given by:

$$\Phi^T \equiv \frac{\Lambda^T}{\nu_1^T - r^\star} = -\frac{\left(A^T + \kappa^T \tilde{\theta}^T\right)}{\left(s^T + \tilde{m}^T + r^\star\right)} < 0, \quad \Phi^N \equiv \frac{\Lambda^N}{\nu_1^N - r^\star} < 0.$$

where $\Lambda^N \equiv -C_{L^N}^T - \kappa^N \tilde{U}^N\left(1 - \alpha_V^N\right)\omega_{21}^N - \frac{\kappa^N \tilde{\theta}^N\left(s^N + \nu_1^N\right)}{\tilde{m}^N} > 0$.

3.8 Steady-State

We now describe the steady-state of the economy which comprises six equations. First, setting $\dot{\theta}^j = 0$ into eq. (30), we obtain the vacancy creation equation (which holds for the traded sector and non traded sector):

$$\frac{\kappa^j}{f^j\left(\tilde{\theta}^j\right)} = \frac{\left(1-\alpha_W^j\right)}{s^j + r^\star}\tilde{\Psi}^j, \quad \tilde{\Psi}^j \equiv \left(\Xi^j + r^\star x^j\right) - W_R^j, \quad j = T, N. \tag{35}$$

The LHS term of eq. (35) represents the marginal cost of recruiting in sector $j = T, N$. The RHS term represents the marginal benefit of an additional worker which is equal to the share, received by the firm, of the rent created by the encounter between a vacancy and a job-seeking worker. A rise in labor productivity raises the surplus from hiring $\tilde{\Psi}^j$; as a result, firms to post more job vacancies which raises the labor market tightness $\tilde{\theta}^j$.

Second, using the fact that $\tilde{\xi}^j = \frac{\alpha_W^j}{1-\alpha_W^j}\tilde{\gamma}^j$, $\tilde{\gamma}^j + x^j = \frac{\kappa^j}{\tilde{f}^j}$ (as will be clear later, $x^T = 0$ and $x^N > 0$), $\frac{\tilde{m}^j}{\tilde{f}^j} = \tilde{\theta}^j$, to rewrite the reservation wage, the decision of search equation reads as (which holds for the traded sector and non traded sector):

$$\tilde{L}^j = \frac{\tilde{m}^j}{\tilde{m}^j + s^j}\left[\bar{\lambda}\left(\frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\tilde{\theta}^j + R^j\right)\right]^{\sigma_L^j}, \quad j = T, N, \tag{36}$$

where $\left(\frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\tilde{\theta}^j + R^j\right)$ corresponds to the reservation wage $\tilde{W}_R^j$ reflecting the marginal benefit from search; note that we have eliminated $\tilde{U}^j$ from (13b) by using the fact that in the long-run the number of unemployed agents who find a job $\tilde{m}^j\tilde{U}^j$ and workers who lose their job $s^j\tilde{L}^j$ must equalize. According to (36), higher labor market tightness increases labor $\tilde{L}^j$ by raising the probability of hiring and thus the employment rate $\frac{\tilde{m}^j}{\tilde{m}^j+s^j}$. Moreover, for given $\bar{\lambda}$, the rise in the reservation wage $\frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\tilde{\theta}^j + R^j$ induces agents to supply more labor.

Third, setting $\dot{B} = 0$ into eq. (27), we obtain the market clearing condition for the traded good:

$$r^\star\tilde{B} + A^T\tilde{L}^T - \tilde{C}^T - \kappa^T\tilde{U}^T\tilde{\theta}^T - \kappa^N\tilde{U}^N\tilde{\theta}^N = 0, \tag{37}$$

where $\tilde{C}^T = C^T\left(\tilde{L}^N, \bar{\lambda}, A^N\right)$.

The system comprising eqs. (35)-(37) can be solved for the steady-state labor market tightness, employment, and traded bonds. All these variables can be expressed in terms of the labor productivity index A^j and the marginal utility of wealth, i.e. $\tilde{\theta} = \theta\left(A^T\right)$, $\tilde{L}^T = L^T\left(\bar{\lambda}, A^T\right)$, $\tilde{\theta}^N = \theta^N\left(\bar{\lambda}, A^N\right)$, $\tilde{L}^N = L^N\left(\bar{\lambda}, A^N\right)$, and $\tilde{B} = B\left(\bar{\lambda}, A^T, A^N\right)$.[23] Inserting first $\tilde{B} = B\left(\bar{\lambda}, A^T, A^N\right)$, and $\tilde{L}^j = L^j\left(\bar{\lambda}, A^N\right)$, the intertemporal solvency condition (34) can be solved for the equilibrium value of the marginal utility of wealth:

$$\bar{\lambda} = \lambda\left(A^T, A^N\right). \tag{38}$$

[23] Setting first $\dot{L}^j = 0$ into (11), inserting $\tilde{L}^j = L^j\left(\bar{\lambda}, A^j\right)$, one can solve for U^j; then the relationship $V^j = \theta^j U^j$ can be solved for the steady-state job vacancy in sector j.

3.9 Graphical Apparatus

Before turning to the derivation of steady-state effects of technological change biased toward the traded sector, we characterize the steady-state graphically. Because we restrict our attention on the long-run equilibrium, the tilde is suppressed for the purposes of clarity. The steady-state can be described by considering alternatively the labor market or the goods market.

When focusing on the goods market, the equilibrium can be summarized by two schedules in the $(y^T - y^N, p)$-space where we denote the logarithm in lower case. The steady state is summarized graphically in Figure 3(b).

Denoting by $\upsilon_{NX} \equiv NX/Y^T$ the ratio of net exports to traded output, combining the zero current account equation with (26) yields the goods market equilibrium (GME henceforth) schedule:[24]

$$\frac{Y^T\left(1-\upsilon_{NX}\right)}{Y^N} = \frac{C^T}{C^N}, \tag{39}$$

where $-\upsilon_{NX} = \upsilon_B - \upsilon_V^T - \upsilon_V^N$ and the allocation of aggregate consumption expenditure between traded and non traded goods follows from (15). Totally differentiating (39) and denoting the percentage deviation from its initial steady-state by a hat gives:

$$\left.\hat{y}^T - \hat{y}^N\right|^{GME} = \phi\hat{p} - \mathrm{d}\ln\left(1-\upsilon_{NX}\right). \tag{40}$$

According to (40), the GME-schedule is upward-sloping in the $(y^T - y^N, p)$-space with a slope equal to $1/\phi$. Following a rise in traded output relative to non traded output, the relative price of non tradables must appreciate to clear the goods market, and all the more so as the elasticity of substitution ϕ is smaller. The 45° dotted line allows us to consider two cases. When $\phi > 1$ ($\phi < 1$), the GME-schedule is flatter (steeper) than the 45° dotted line.

Assuming an elasticity of labor supply identical across sectors, i.e., $\sigma_L^j = \sigma_L$, so that the wealth effect does not impinge on the ratio of sector labor, denoting the steady-state unemployment rate in sector j by $u^j = \frac{s^j}{m^j+s^j}$ and the share of the surplus associated with a labor contract in the marginal benefit of search by $\chi^j = \frac{\frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\theta^j}{W_R^j}$, and totally differentiating (35) and (36), one obtains the labor market equilibrium (LME henceforth) schedule:

$$\left.\hat{y}^T - \hat{y}^N\right|^{LME} = -\Theta^N\hat{p} + \left(1+\Theta^T\right)\hat{a}^T - \left(1+\Theta^N\right)\hat{a}^N, \tag{41}$$

where we set

$$\Theta^T \equiv \frac{A^T\left[\alpha_V^T u^T + \sigma_L\chi^T\right]}{\left[\left(1-\alpha_V^T\right)\Psi^T + \chi^T W_R^T\right]} > 0, \quad \Theta^N \equiv \frac{PA^N\left[\alpha_V^N u^N + \sigma_L\chi^N\right]}{\left[\left(1-\alpha_V^N\right)\Psi^N + \chi^N W_R^N\right]} > 0. \tag{42}$$

[24]Denoting by $\upsilon_B \equiv \frac{r^\star B}{Y^T}$ the ratio of interest receipts to traded output and $\upsilon_V^j \equiv \frac{\kappa^j V^j}{Y^T}$ the ratio of the cost of hiring in sector $j = T, N$ to traded output, the zero current account equation (26) implies $\upsilon_B - \upsilon_V^T - \upsilon_V^N = -\upsilon_{NX}$. While for simplicity purposes, we refer to υ_{NX} as the ratio of net exports to traded output, it also includes hiring expenditure, i.e., $NX \equiv Y^T - C^T = Y^T - C^T - \kappa^T V^T - \kappa^N V^N + +\kappa^T V^T + \kappa^N V^N$.

As depicted in Figure 3(b), the LME-schedule is downward-sloping in the $(y^T - y^N, p)$-space with a slope equal to $-1/\Theta^N$ (see eq. (41)). An appreciation in the relative price of non tradables raises the surplus from hiring which induces non traded firms to post more job vacancies. By raising the expected value of a job, the consecutive rise in the labor market tightness induces agents to increase the search intensity for a job in the non traded sector but less so as the elasticity of labor supply σ_L is lower. More precisely, lower values of σ_L indicate that workers are more reluctant to shift from one sector to another; in this configuration, the term Θ^j is smaller so that the LME-schedule is steeper. Conversely, when we let σ_L tend toward infinity, the case of perfect mobility of labor across sectors is obtained, as in the standard BS model; in this configuration, the LME-schedule becomes a horizontal line.

< Please insert Figure 3 about here >

When focusing on the labor market, the model can be summarized graphically by two schedules in the $(l^T - l^N, \ln\left(\frac{\theta^T}{\theta^N}\right))$-space, as shown in Figure 3(a).

Using eq. (36) and setting $\sigma_L^j = \sigma_L$ yields the decision of search-schedule (DS henceforth):

$$\frac{L^T}{L^N} = \frac{m^T}{m^N}\frac{m^N + s^N}{m^T + s^T}\left(\frac{W_R^T}{W_R^N}\right)^{\sigma_L}, \tag{43}$$

where $W_R^j \equiv \frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\theta^j + R^j$ is the reservation wage. Totally differentiating (43) and assuming that labor markets display similar features across sectors, i.e., $\chi^j \simeq \chi$, and $u^j \simeq u$ yields:

$$\left(\hat{\theta}^T - \hat{\theta}^N\right)\Big|^{DS} = \frac{1}{(\alpha_V u + \sigma_L \chi)}\left(\hat{L}^T - \hat{L}^N\right), \tag{44}$$

where $\chi^j = \frac{\frac{\alpha_W^j}{1-\alpha_W^j}\kappa^j\theta^j}{W_R^j}$ is the surplus associated with a labor contract in % of the reservation wage. According to (44), the DS-schedule is upward-sloping in the $(l^T - l^N, \ln\left(\frac{\theta^T}{\theta^N}\right))$-space where the slope is equal to $\frac{1}{(\alpha_V u + \sigma_L\chi)}$. The reason is that a rise in the ratio of labor market tightness θ^T/θ^N increases the probability of finding a job in the traded sector relative to the non traded sector. Hence, a worker gets a larger share of the surplus associated with a labor contract via higher traded wage, and thereby is induced to supply more labor toward the traded sector.

As will be useful, we solve the goods market equilibrium (39) for the relative price of non tradables:

$$P = P\left[\left(\frac{L^T}{L^N}\right), (1 - \upsilon_{NX}), \left(\frac{A^T}{A^N}\right)\right]. \tag{45}$$

Combining the vacancy creation schedule (35) and the number of matches per job vacancies

(22) while assuming $\alpha_V^j = \alpha_V$, gives:

$$\frac{\kappa^T}{\kappa^N}\frac{\left(s^T+r^\star\right)}{\left(s^N+r^\star\right)}\frac{X^T}{X^N}\left(\frac{\theta^T}{\theta^N}\right)^{1-\alpha_V} = \frac{A^T + r^\star x^T - W_R^T}{P\left(.\right) A^N + r^\star x^N - W_R^N}. \tag{46}$$

Totally differentiating (43) and assuming that labor markets initially display similar features across sectors, i.e., $\Xi^j \simeq \Xi$, $\Psi^j \simeq \Psi$, $\chi^j W_R^j \simeq \chi W_R$ yields:

$$\left(\hat{\theta}^T - \hat{\theta}^N\right)\Big|^{VC} = -\frac{\Xi\left(\hat{L}^T - \hat{L}^N\right)}{\phi\left[\left(1-\alpha_V\right)\Psi + \chi W_R\right]} + \frac{\Xi\left[\left(\phi-1\right)\left(\hat{A}^T - \hat{A}^N\right) - d\ln\left(1-\upsilon_{NX}\right)\right]}{\phi\left[\left(1-\alpha_V\right)\Psi + \chi W_R\right]}. \tag{47}$$

According to (47), the VC-schedule is downward-sloping in the $(l^T - l^N, \ln\left(\frac{\theta^T}{\theta^N}\right))$-space where the slope is equal to $-\frac{\Xi}{\phi[(1-\alpha_V)\Psi+\chi W_R]}$. Intuitively, as hours worked are shifted toward the traded sector, non traded output declines relative to traded output; as a result, the relative price of non tradables must appreciate which encourages non traded firms to hire more workers; because the non traded sector posts more job vacancies, the ratio of labor market tightness θ^T/θ^N falls.

4 Relative Price and Relative Wage Effects

This section analyzes graphically and analytically the consequences on the relative price and the relative wage of an increase in relative sectoral productivity A^T/A^N. It compares the steady-state of the model before and after the productivity shock biased towards the traded sector. To shed light on the transmission mechanism, we analytically break down the relative wage and relative price effects in two components: a labor market frictions effect and a labor accumulation effect.

4.1 Relative Wage and Relative Price Effects

We first explore the relative price effect of technological change biased toward the traded sector by equating demand (40) and supply (41) of tradables in terms of non tradables, both expressed in percentage deviation from its initial steady-state, to eliminate $\hat{y}^T - \hat{y}^N$. One obtains a relationship between the deviation in percentage of the relative price from its initial steady-state and the productivity growth differential between tradables and non tradables:

$$\hat{p} = \frac{\left(1+\Theta^T\right)\hat{a}^T - \left(1+\Theta^N\right)\hat{a}^N}{\left(\phi+\Theta^N\right)} + \frac{\mathrm{d}\ln\left(1-\upsilon_{NX}\right)}{\left(\phi+\Theta^N\right)}, \tag{48}$$

where the term Θ^j

$$\Theta^j \equiv \frac{\Xi^j\left(s^j+r^\star\right)\left[\alpha_V^j u^j + \sigma_L \chi^j\right]}{\Psi^j\left[\left(1-\alpha_V^j\right)\left(s^j+r^\star\right) + \alpha_W m^j\right]}. \tag{49}$$

is the elasticity of sectoral employment L^j w.r.t. the marginal revenue of labor Ξ^j. In order to facilitate the discussion, we assume that $\Theta^j \simeq \Theta$. As will be clear later, Θ is a measure of the degree of labor mobility across sectors.[25] Under this assumption, eq. (48) reduces to:

$$\hat{p} = \frac{(1+\Theta)\left(\hat{a}^T - \hat{a}^N\right)}{(\phi+\Theta)} + \frac{\mathrm{d}\ln(1-\upsilon_{NX})}{(\phi+\Theta^N)}, \tag{50}$$

where $\mathrm{d}\ln(1-\upsilon_{NX}) \simeq -d\upsilon_{NX}$ by using a first-order Taylor approximation.

Eq. (50) breaks down the relative wage response into two components: a labor market frictions effect and a labor accumulation effect. The first term on the RHS of eq. (50) corresponds to the labor market frictions effect. Through this channel, higher productivity growth in tradables relative to non tradables tends to appreciate the relative price. The reason is that technological change biased toward the traded sector raises traded output relative to non traded output so that the relative price of non tradables must increase to clear the goods market. Importantly, the size of the relative price appreciation is given by the elasticity $\frac{(1+\Theta)}{(\phi+\Theta)}$. When we let σ_L tend toward infinity, workers no longer experience a utility loss when shifting from one sector to another; hence the case of perfect mobility of labor across sectors is obtained as reflected by the term Θ that tends toward infinity; in this configuration, a 1 percentage point increase in the productivity differential between tradables and non tradables appreciates the relative price by 1% as well, in line with the prediction of the standard BS model.[26] Graphically, as shown in Figure 4(a), the LME-schedule is a horizontal line because the allocation of the labor force across sectors is perfectly elastic to the ratio of sectoral reservation wages. A productivity shock biased toward the traded sector shifts higher the LME-schedule which results in a relative price appreciation, from p_0 to p_{BS}, i.e., by the same amount as the productivity differential. The LME-schedule intercepts the 45° line at point BS'.

As long as $\sigma_L < \infty$, workers experience a mobility cost when moving; in this case, Θ takes finite values while graphically, the LME-schedule is downward sloping in the $(y^T - y^N, p)$-space. When workers experience mobility costs, the relative price of non tradables is jointly determined by technological and demand conditions. More precisely, the elasticity ϕ between traded and non traded goods in consumption plays a pivotal role in the determination of the relative price response. Graphically, technological change biased toward the traded sector shifts to the right the LME-schedule from LME_0 to LME_1: this shift corresponds to the labor market frictions effect. If $\phi > 1$, the GME-schedule is flatter than the 45° line so that the interception is at G'; since $p' < p_{BS}$, the relative price appreciates by less than the productivity productivity differential between tradables and non tradables, in line with our empirical findings. Intuitively, when the elasticity is

[25] For the baseline calibration, while labor market parameters are allowed to vary across sectors Θ^T and Θ^N are very similar if not identical. It is only when the firing costs are important that Θ^T and Θ^N differ substantially.

[26] Formally, we have:

$$\lim_{\sigma_L \to \infty} \frac{(1+\Theta)}{(\phi+\Theta)} = 1.$$

larger than one, households are willing to substitute traded for non traded goods so that a moderate (i.e., less than 1%) appreciation in the relative price is necessary following a rise in the productivity differential (by 1 percentage point). Conversely, if $\phi < 1$, the relative price must appreciate more than proportionately (i.e., by more than 1%) following higher productivity of tradables relative to non tradables (by 1 percentage point). In this configuration, the GME-schedule is steeper that the 45° line so that the LME_1-schedule intercepts the GME-schedule at a point which lies to the north west of BS'. Hence, through the labor market frictions channel, a 1 percentage point increase in the productivity differential between tradables and non tradables appreciates the relative price of non tradables by less (more) than 1% if traded and non traded goods are substitutes (complements).

The second term on the RHS of eq. (50) reveals that technological change biased toward the traded sector also impinges on the relative price of non tradables by affecting net exports and hiring expenditure expressed as a share of traded output, as summarized by $d\upsilon_{NX}$. More precisely, through the labor accumulation channel, higher productivity growth in tradables relative to non tradables increases υ_{NX} which exerts a negative impact on the relative price by raising the demand for tradables in the long-run. Intuitively, higher labor productivity (i.e., a rise in A^j) raises the shadow value of an additional worker γ^j and thus induces firms in both sectors to hire more. Because job vacancies V^j are a jump variable, it overshoots on impact. Since hiring is a costly activity, recruiting expenditure rise substantially. While employment builds up, the open economy finances labor accumulation by running a current account deficit in the short-run. For the intertemporal solvency condition to hold, the decumulation of traded bonds must be offset by a steady-state increase in net exports. The combined effect of the improvement in the trade balance and permanently increased hiring expenditure has an expansionary effect on the demand for tradables which drives down the relative price of non tradables. Graphically, in terms of Figure 4(a), the labor accumulation channel shifts the GME-schedule to the right, regardless of the value of the elasticity of substitution between traded and non traded goods. It is worthwhile noticing that a change in υ_{NX} no longer impinges on the relative price p and thus the labor accumulation channel vanishes when we let σ_L tend toward infinity, i.e. if agents are not subject to switching costs from one sector to another.[27] In this case, the GME_1-schedule intercepts the LME_1-schedule at BS_1. Unlike, when $\sigma_L < \infty$, the intercept is at G_1 if $\phi > 1$. In this case, the relative price unambiguously appreciates by less than 1% following a 1 percentage point increase in the productivity differential between tradables and non tradables. While through the labor market frictions channel, $\hat{p} > 1\%$ if $\phi < 1$, the labor market accumulation channel exerts a negative impact on p, and all the more so the smaller the elasticity ϕ, as shown by the second term on the RHS of (50).

[27]When $\sigma_L \to \infty$, the term $\frac{1}{\phi+\Theta}$ tends toward zero.

< Please insert Figure 4 about here >

We now explore the long-run response of the relative wage of non tradables to a productivity differential. To do so, we first totally differentiate the vacancy creation equation (35) that we substitute into the Nash bargaining wage (24) expressed in rate of change relative to the steady-state:[28]

$$\hat{w}^j = \Omega^j \hat{\Xi}^j, \quad \Omega^j \equiv \frac{\Xi^j}{W^j} \frac{\alpha_W \left[\left(1-\alpha_V^j\right)\left(s^j + r^\star\right) + m^j\right]}{\left[\left(1-\alpha_V^j\right)\left(s^j + r^\star\right) + \alpha_W m^j\right]} > 0, \tag{51}$$

where $\hat{\Xi}^T = \hat{a}^T$ and $\hat{\Xi}^N = \hat{p} + \hat{a}^N$. Calculating $\hat{\omega} \equiv \hat{w}^N - \hat{w}^T$ by using (51) and substituting (48) yields the deviation in percentage of the relative wage from its initial steady-state:

$$\hat{\omega} = \left\{\Omega^N \left[\frac{\left(1+\Theta^T\right)\hat{a}^T + (\phi-1)\,\hat{a}^N}{\left(\phi+\Theta^N\right)}\right] - \Omega^T \hat{a}^T\right\} - \Omega^N \frac{\mathrm{d}\upsilon_{NX}}{\phi+\Theta^N} \tag{52}$$

To facilitate the discussion, we assume that $\Theta^j \simeq \Theta$ and $\Omega^j \simeq \Omega$.[29] Under theses assumptions, eq. (52) reduces to:

$$\hat{\omega} = -\Omega \left[\frac{(\phi-1)}{\phi+\Theta}\left(\hat{a}^T - \hat{a}^N\right) + \frac{\mathrm{d}\upsilon_{NX}}{\phi+\Theta}\right]. \tag{53}$$

When assuming perfect mobility of labor across sectors, i.e., if we let σ_L tend toward infinity, we have $\Theta \to \infty$; hence eq. (53) shows that a productivity differential leaves unaffected the relative wage. Unlike, as long as workers experience a utility loss when shifting (i.e., assuming $\sigma_L < \infty$), technological change biased toward the traded sector impinges on the relative wage through two channels.

When keeping fixed υ_{NX}, eq. (53) reduces to $-\Omega\frac{(\phi-1)}{\phi+\Theta}\left(\hat{a}^T - \hat{a}^N\right)$. Hence, through the labor market frictions channel, higher productivity growth in tradables relative to non tradables lowers the relative wage ω only if $\phi > 1$. As discussed above, technological change biased toward the traded sector raises traded output relative to non traded output which appreciates the relative price of non tradables; with an elasticity of substitution ϕ greater than one, the demand for tradables rises more than proportionally. By raising the share of tradables in total expenditure, higher productivity growth in tradables relative to non

[28]Totally differentiating the wage rate W^j (24) gives:

$$\hat{w}^j = \frac{\alpha_W \Xi^j}{W^j}\hat{\Xi}^j + (1-\alpha_W)\frac{\chi^j W_R^j}{W^j}\hat{\theta}^j.$$

Totally differentiating the vacancy creation equation (35) yields

$$\hat{\theta}^j = \frac{\Xi^j \hat{\Xi}^j}{\left[\left(1-\alpha_V^j\right)\Psi^j + \chi^j w_R^j\right]}.$$

Substituting the latter equation into the former and using the fact that at the steady-state, $\chi^j W_R^j = m^j \xi^j = \frac{m^j \alpha_W^j \Psi^j}{s^j + r^\star}$, one obtains (51).

[29]For the baseline scenario of our quantitative analysis, i.e., when calibrating to a typical OECD economy, Ω^T and Ω^N are almost identical.

tradables induces traded firms to hire more which lowers the relative wage. In terms of Figure 4(b), technological change biased toward the traded sector shifts to the right the VC-schedule from VC_0 to VC'. Unlike, with an elasticity ϕ smaller than one, the VC-schedule would shift to the left because the share of non tradables rises which has an expansionary effect on recruitment in the non traded sector. Hence, in this case, the relative wage of non tradables increases instead of declining, in contradiction with our empirical findings.

As captured by the second term on the RHS of eq. (53), technological change biased toward the traded sector also impinges on the relative wage through a labor accumulation channel. More specifically, by raising steady-state net exports, a productivity differential encourages traded firms to hire more which exerts a negative impact on the relative wage. Graphically, as depicted in Figure 4(b), higher productivity growth in tradables relative to non tradables shifts further to the right the VC-schedule from VC' to VC_1. Hence, while ω unambiguously declines if the elasticity of substitution is larger then one, when $\phi < 1$, the relative wage response to a productivity differential is ambiguous. In the latter case, technological change biased toward the traded sector drives down ω through the labor accumulation channel while it increases the relative wage through the labor market frictions channel. We address this ambiguity numerically later.

In contrast to most macroeconomic models of search, we endogenize labor supply along the extensive margin. When the labor force participation decision is endogenized, the situations of total immobility ($\sigma_L = 0$) and perfect mobility ($\sigma_L \to \infty$) of labor emerge as special cases. If we let $\sigma_L = 0$, the situation of total labor immobility is obtained. Because the mobility costs are prohibitive, the labor force F^j is fixed in both sectors. As will be clear later when discussing quantitative results, such a configuration makes less likely our model to replicate our empirical findings, in particular when $\phi < 1$. Graphically, in terms of Figure 4(b), setting $\sigma_L = 0$ rotates to the left the DS-schedule. With an elasticity ϕ smaller than one, technological change biased toward the traded sector shifts to the left the VC-schedule through the labor market frictions channel; because it moves along a steeper DS-schedule, the ratio of labor market tightness θ^T/θ^N falls more which in turn pushes up further the relative wage, thus making less likely to replicate the decline in ω.[30]

Conversely, when we let σ_L tend toward infinity, workers are no longer subject to switching costs; in this configuration, we have $\Theta^j \to \infty$ so that eq. (48) reduces to $\hat{p} = \left(\hat{a}^T - \hat{a}^N\right)$, as in the standard BS model. Inserting the relative price equation into $\hat{\Xi}^N = \hat{p} + \hat{a}^N$, the deviation in percentage of the relative wage from its initial steady-state (51) can be rewritten as $\hat{\omega} = \left(\Omega^N - \Omega^T\right)\hat{a}^T$. Such an equality reflects the fact that even if mobility costs are absent, technological change biased toward the traded sector may produce different

[30]It is worthwhile noticing that when $\sigma_L = 0$, the change in relative labor L^T/L^N is achieved through a decline in sectoral unemployment. For example, when $\phi > 1$, L^T/L^N unambiguously increases because more unemployed workers find a job in the traded sector while the labor force F^T is fixed.

sectoral wage responses because search parameters vary across sectors. However, the quantitative analysis conducted in section 5 reveals that the elasticity Ω^j of sectoral wages w.r.t. the marginal revenue of labor is almost identical across sectors, i.e., $\Omega^T \simeq \Omega^N$; hence, if $\sigma_L \to \infty$, we would have $\hat{\omega} \simeq 0$.

4.2 Implications of Labor Market Regulation

So far, we have shown that the relative wage of non tradables no longer remains fixed following technological change biased toward the traded sector because workers experience a mobility cost (as captured by $0 < \sigma_L < \infty$) which must be covered by higher wages. While searching for a job is costly because it is time consuming, in a model with search in the labor market, hiring is also a costly activity. By affecting the recruiting cost, labor market institutions determine the elasticity of labor demand to technological change. More precisely, the more labor demand in the traded sector increases relative to that in the non traded sector, the larger the decline in the relative wage of non tradables. In this section, our objective is to assess the ability of our model to account for our empirical findings established in section 2 according to which the relative wage falls more in countries where unemployment benefits are more generous, the worker bargaining power is larger or legal protection against dismissals is more stringent. Because the transmission mechanism varies according the type of labor market institution, we differentiate between the firing cost on the one hand, the generosity of the unemployment benefit scheme and the worker bargaining power on the other.

Implications of a Higher Firing Tax

In our model, the strictness of legal protection against dismissals is captured by a firing tax denoted by x^j paid to the State by the representative firm in the sector which reduces employment. Technological change exerts two opposite effects on labor L^j. On the one hand, by producing a positive wealth effect, as reflected by a fall in the shadow value of wealth $\bar{\lambda}$ (38), a higher productivity exerts a negative impact on employment by driving down labor supply (see (36)). On the other hand, by increasing the marginal revenue of labor, a rise in A^j induces firms to recruit more which pushes up labor. Because technological change is biased toward the traded sector, employment in the traded sector increases while labor in the non traded sector declines. According to (19), higher productivity induces non traded firms to post more job vacancies but less so as the firing tax is increased because the surplus from hiring rises by a smaller amount. Since labor demand in the non traded sector increases less in countries where the firing tax is higher, as reflected by a smaller rise in the labor market tightness θ^N, the relative wage of non tradables falls more.

The implications of a higher firing tax is depicted in Figure 5(a) where we assume an elasticity between traded and non traded goods in consumption ϕ larger than one. In this configuration, as mentioned previously, technological change biased toward the traded sector shifts to the right the VC-schedule. As highlighted in Figure 5(a), higher productivity growth in tradables relative to non tradables shifts further to the right the VC-schedule from VC' to VC'', thus resulting in a larger increase in θ^T/θ^N because hiring in the non traded sector which decumulates employment is limited by the firing tax. Consequently, the relative wage ω declines more, in line with our empirical findings, through a stronger labor market frictions effect. However, a higher firing tax also moderates the decline in the relative wage since net exports increase less. Intuitively, by curbing recruiting expenditure, the productivity differential leads to a smaller current account deficit. As a result, net exports must rise less.[31]

In terms of eq. (52), a higher firing tax (paid by non traded firms) lowers substantially the term Ω^N which is the elasticity of the non traded wage to the marginal revenue of labor.[32] The term in braces in eq. (52) which captures the labor market frictions channel is thus higher in absolute terms (or more negative) when $\phi > 1$. Conversely, when $\phi < 1$, the term in braces in eq. (52) becomes positive but smaller as the firing tax x is increased. As mentioned above, in countries where the firing tax is higher, net exports increase less which lowers $d\upsilon_{NX} > 0$ in the last term of eq. (52) and thus moderates the labor accumulation effect which exerts a negative impact on ω.[33]

In conclusion, increasing the firing tax exerts two opposite effects on the relative wage response to technological change biased toward the traded sector. On the one hand, higher productivity growth in tradables relative to non tradables produces a larger decline in ω as x is raised by limiting the expansionary effect on labor demand in the non traded sector. On the other hand, increasing the firing tax moderates the expansionary effect of a productivity differential on the demand of tradables in the long-run (captured $d\upsilon_{NX} > 0$) and thus the steady-state fall in the relative wage. We will address this ambiguity numerically.

Implications of a More Generous Unemployment Benefit Scheme or a Higher Worker Bargaining Power

In our framework, the generosity of the unemployment benefit scheme is captured by the level of R^j; unemployment benefits are assumed to be a fixed proportion r of the wage rate W^j, i.e., $R^j = rW^j$. Additionally, a higher worker bargaining power measured empirically by the bargaining coverage is captured by the parameter α_W which is assumed to be identical across sectors.

[31] Because our quantitative analysis shows that increasing substantially the firing tax merely affects the labor accumulation channel, for clarity purposes, we restrict our attention to the labor market frictions in Figure 5(a).

[32] A higher firing tax lowers both Ω^N and Θ^N which exerts opposite effects on the first term in braces in eq. (52). Our quantitative analysis indicates that the effect of a lower Ω^N on $\hat{\omega}$ predominates. For clarity purposes, we concentrate on this term while leaving aside the impact on Θ^N in order to avoid unnecessary complications.

[33] To be more precise, a higher firing tax lowers both Ω^N and Θ^N and moderates the change in net exports $d\upsilon_{NX} > 0$ which exert opposite effects on $\hat{\omega}$. as shown by the last term in eq. (52); our quantitative analysis reveals that the firing tax tends to moderate the labor accumulation effect.

In contrast to a firing tax, raising the unemployment benefit replacement rate or the worker bargaining power leads to a larger long-run rise in net exports and thus amplifies the decline in the relative wage through the labor accumulation channel. The reason is as follows. In countries where unemployment benefits are more generous or the worker bargaining power is larger, there are more job-seeking workers and less job vacancies, thus resulting in lower labor market tightness θ^j in both sectors. Consequently, following higher productivity, firms are more willing to recruit additional workers because hiring is more profitable as the probabilities of fulfilling vacancies (f^j) are much higher. Hence, the open economy experiences a larger current account deficit along the transitional path which must be matched in the long-run by a greater improvement in the balance of trade. By amplifying the rise in net exports and thus the demand for tradables, technological change biased toward the traded sector exerts a larger negative impact on the relative wage in countries with a higher replacement rate r or a larger worker bargaining power α_W. While a productivity differential lowers further the relative wage through the labor accumulation channel, it also moderates its decline through the labor market frictions channel. More precisely, by reducing the cost of hiring (because the probability f^j is higher) and by raising the marginal benefit of search, larger values of r or α_W increase the mobility of labor across sectors which in turn moderates the change in the relative wage through the labor market market frictions channel.

The implication of a higher replacement rate r or a larger worker bargaining power α_W is depicted in Figure 5(b) where we consider an elasticity of substitution ϕ larger than one. Figure 5(b) shows that technological change biased toward the traded sector shifts further to the right the VC-schedule from VC_1 to VC_2 in countries where the replacement rate r is higher or the worker bargaining power α_W larger. As mentioned above, the larger increase in net exports amplifies the expansionary effect on hiring in the traded sector which pushes up further the ratio of labor market tightness θ^T/θ^N. Hence, the relative wage of non tradables falls more through a stronger labor accumulation effect. Raising r or α_W also modifies the labor market frictions channel by increasing the mobility of labor across sectors.[34] Because we find numerically that modifying r or α_W merely modifies the relative wage response to technological change biased toward the traded sector through the labor market frictions channel, we restrict our attention to the labor accumulation channel in Figure 4(b).

< Please insert Figure 5 about here >

[34] In countries with a higher worker bargaining power α_W, firms are willing to recruit more (because it is relatively less costly due to a higher probability f^j) while workers are less reluctant to move from one sector to another (since they receive a larger share χ of the surplus associated with a labor contract in the marginal benefit of search). In economies with a more generous unemployment benefit scheme, while workers are more reluctant to move from one sector to another (because χ falls), the vacancy creation is more elastic to technological change. Because the latter effect predominates, the labor mobility rises.

5 Quantitative Analysis

In this section, we analyze the effects of a labor productivity differential quantitatively. For this purpose we solve the model numerically.[35] Therefore, first we discuss parameter values before turning to the long-term consequences of higher productivity in tradables relative to non tradables.

5.1 Calibration

To calibrate our model, we estimated a set of parameters so that the initial steady state is consistent with the key empirical properties of a representative OECD economy. While at the end of the section we move a step further and calibrate the model for each economy, we first have to evaluate the ability of the two-sector open economy model with labor market frictions to accommodate the decline in the relative wage. Our sample covers the eighteen OECD economies in our dataset. Since we calibrate a two-sector model with labor market frictions, we pay particular attention to match the labor market differences between the two sectors. To do so, we carefully estimate a set of sectoral labor market parameters parameters shown in Table 9. Because we consider an open economy setup with traded and non traded goods, we provide the non-tradable content of employment, consumption, and government spending, and gives the productivity in tradables in terms of non tradables, for all countries in our sample in Table 7. Our reference period for the calibration of the non tradable share given in Table 7 is running from 1990 to 2007 while labor market parameters have been computed over various periods due to data availability. unemployment benefit replacement rates and the firing cost shown in the latter two columns of Table 9 correspond to averages over 1980-2007 (except Korea: 2001-2007) and 1980-2005, respectively.[36]

We start with the values of the labor market parameters which are chosen so as to match a typical OECD economy.[37] We choose the model period to be one month, which corresponds to the frequency of the employment data we use. Some of the values of the labor market parameters can be taken directly from data, but others need to be endogenously calibrated to fit a set of labor market features. To capture the labor labor market of a typical

[35] Technically, the assumption $\beta = r^{\star}$ requires the joint determination of the transition and the steady state.

[36] To calibrate the labor market for the traded and the non traded sector, we need to estimate the job finding and the job destruction rate for each sector. To do so, we apply the methodology developed by Shimer [2012]. Appendix B.2 presents the source and construction of the data while more details about the measures of the job finding probability for unemployed workers and the exit probability for employed workers can be found in the Technical Appendix.

[37] Due to the availability of data, we were able to estimate sectoral unemployment rates for 10 European countries and 5 OECD economies as ILO does not provide series for sectoral employment and unemployment for France, the Netherlands, and Norway at a sectoral level. Regarding Korea, while ILO provides data necessary for the computation of sectoral unemployment rates, the OECD does not provide unemployment by duration for this country which makes unable the computation of job finding and job destruction rates.

OECD economy which is chosen as the baseline scenario, we take unweighed average values shown in the last line of 9. We set the matching efficiency in the traded (non traded) sector X^T (X^N) to 0.307 (0.262) and the job destruction rate s^T (s^N) to 1.48% (1.54%) to target an unemployment rate u^T (u^N) of 7.9% (8.3%) and a monthly job finding rate m^T (m^N) of 17.4% (17.0%). We obtain an overall unemployment rate u of 8.1% in line with our estimate shown in Table 9. To target the labor market tightness in the traded sector, $\theta^T = 0.24$, and in the non traded sector, $\theta^N = 0.34$, we set the share of recruiting costs in GDP to 2.3% by choosing $\kappa^T = 1.482$ and $\kappa^N = 0.582$. In the numerical analysis, we assume that unemployment benefits are a fixed proportion of the wage rate, i.e. $R^j = rW^j$, with r the replacement rate. The unemployment benefit replacement rate has been set to 52.4%, in line with our estimates shown in Table 9.

Because the features of labor markets vary substantially across OECD economies, we also analyze two different calibrations of the model, one aimed at capturing the U.S. labor market, the other aimed at capturing Europe with its more 'rigid' labor market. To calibrate a typical European labor market, we take the EU-12 unweighed average.[38] For these both calibrations, we present the implications of a productivity differential. To capture the U.S. (EU-12) sectoral labor markets, we set the matching efficiency parameters X^T and X^N to 0.620 (0.231) and 0.521 (0.197), respectively and the job destruction rates s^T and s^N to 2.2% (1.2%) and 2.4% (1.2%), to target an unemployment rate in the traded sector u^T and in the non traded sector u^N of 4.8% (8.7%) and 5.3% (9.3%), respectively, and a monthly job finding rate m^T in the traded sector and in the non traded sector m^N of 44.4% (12.4%) and 44.0% (12.2%), respectively, in line with the data shown in Table 9. It is worth noting this allows us to match the unemployment rate for the US and EU-12 which averages 5.2% and 9.1%. Furthermore, the replacement rates has been set to 26.1% and 55.9%. To target the sectoral labor market tightness for the US (EU-12), i.e. $\theta^T = 0.43$ ($\theta^T = 0.21$) and $\theta^N = 0.65$ ($\theta^N = 0.30$), respectively, we choose $\kappa^T = 1.333$ ($\kappa^T = 1.535$) and $\kappa^N = 0.481$ ($\kappa^N = 0.605$).

Using U.S. data, Barnichon [2012] reports an elasticity of the matching function with respect to unemployed workers of about 0.6, an estimate which lies in the middle of the plausible range reported by Petrongolo and Pissarides [2001]. Hence, we set the elasticity $1 - \alpha_V^j$ (with $j = T, N$) of the matching function with respect to unemployed workers to 0.6.[39] As it is common in the literature, we impose the Hosios [1990] condition, and set the worker bargaining power α_W to 0.6 in the baseline scenario but conduct a sensitivity analysis with respect to this parameter by setting α_W to 0.9 while keeping fixed $1 - \alpha_V$.

We model firing costs as a tax that firms have to pay to the State when their employment

[38]For sectoral unemployment rates, and monthly job finding and job destruction rates, we take the EU-10 unweighed average due to data availability.

[39]Due to the lack of empirical estimates at a sectoral level, we assume $1-\alpha_V^j$ to be identical across sectors.

levels decline, i.e. if $\dot{L}^j < 0$. To calibrate the firing cost, we take data from the Fondazione De Benedetti which provides series for the eighteen countries of our sample over the period 1980-2005. To compute the firing tax, we add the advance notice and the severance payment which are averages after 4 and 20 years of employment. Since the advance notice and the severance payment are both expressed in monthly salary equivalents, we have $x^j = \tau W^j$ with $\tau \geq 0$. Values of τ are shown in the last column of Table 9. For the baseline calibration, we set the firing tax τ to 4.2.[40] When calibrating to the US (EU-12) economy, we set $\tau = 0$ ($\tau = 4.3$).

Next, we turn to the Frisch elasticity of labor supply at the extensive margin σ_L. Empirical studies based on micro data generally report much larger values for the Frisch elasticity of labor supply on the extensive margin than on the intensive margin. More precisely, while the former falls in the range of 0.6 to 0.8, the latter falls in the range of 0.1 to 0.5. We choose σ_L to be 0.5 in our baseline setting which is close to recent microeconometric estimates, see e.g., the discussion by Haefke and Reiter [2011], but conduct a sensitivity analysis with respect to this parameter.[41] Furthermore, in order to target a non tradable content of labor of 66% which corresponds to the 18 OECD countries' unweighted average shown in the last line of Table 7, we set ζ^T to 1 and ζ^N to 0.15 (see eq. (10)).

We now turn to the calibration of consumption-side parameters that we use as a baseline. In light of our discussion above, besides country's labor market regulation, ϕ plays a key role in the determination of the relative wage and relative price responses to a productivity differential. Building on our panel data estimations, we set the elasticity of substitution to 1 in the baseline calibration.[42] But we conduct a sensitivity analysis by considering alternatively a value of ϕ smaller or larger than one (i.e., ϕ is set to 0.6 and 1.5, respectively).[43] The weight of consumption in non tradables $1 - \varphi$ is set to 0.42 to target a non-tradable content in total consumption expenditure (i.e. α_C) of 42%, in line with the average of our estimates shown in the last line of Table 7. The intertemporal elasticity of substitution for consumption σ_C is set to 1.

For calibration purposes, we introduce government spending on traded and non traded

[40] As mentioned previously, because traded employment monotonically increases while the non traded sector reduces continuously employment following a productivity differential, only the non traded sector is subject to the firing tax.

[41] Using the Panel Study of Income Dynamics, Fiorito and Zanella [2008] find that aggregate time-series results deliver a Frisch elasticity of about 0.8, the contribution of employment (extensive margin) accounting for about 4/5 of the aggregate elasticity. Using Japanese data, Kuroda and Yamamoto [2007] report a Frisch elasticity on the extensive margin which falls in the range of 0.6 to 0.8 for both sexes.

[42] As shown in Table 8, estimates of ϕ for Belgium and Italy are either negative or not statistically significant. Hence, column 1 of Table 6 reports only consistent estimates for the elasticity of substitution ϕ between traded and non traded goods which average to 0.9. The advantage of setting ϕ to 1 in the baseline scenario is twofold. First, the share of non traded goods in consumption expenditure α_C coincides with the weight of the non traded good in the overall consumption bundle $1 - \varphi$ if $\phi = 1$. Second, setting $\phi = 1$ implies that only the labor accumulation channel is (mostly) in effect as the labor market frictions channel almost totally vanish which allows us to highlight the intertemporal effect trigged by the hiring boom.

[43] These values for ϕ of 0.6 and 1.5 correspond roughly to the averages of estimates of ϕ for countries with $\phi < 1$ and $\phi > 1$, respectively.

goods in the setup.[44] We set G^N and G^T so as to yield a non-tradable share of government spending of 90%, and government spending as a share of GDP of 20%. Close to the averages of the values reported in the last line of Table 7, the ratios G^T/Y^T and G^N/Y^N are 4% and 35% in the baseline calibration.

We consider a permanent increase in the productivity index A^j of both sectors biased towards the traded sector so that the labor productivity differential between tradables and non tradables, i.e., $\hat{a}^T - \hat{a}^N$, is 1%. While in our baseline calibration we set $\phi = 1$, $\sigma_L = 0.5$, $\alpha_W = 0.6$, $r = 0.524$, $\tau = 4.2$, we conduct a sensitivity analysis with respect to these five parameters by setting alternatively: ϕ to 0.6 and 1.5, σ_L to 0, 0.2 and 1, α_W to 0.9, r to 0.782, and τ to 13.[45] Finally, in the latter two columns of Table 5, we compare the results for the US economy with those obtained for a typical European economy (EU-12).

5.2 Discussion

Before analyzing in the detail the role of labor market frictions in shaping the long-run dynamics of the relative price and the relative wage in response to technological change biased toward the traded sector, we recall the set of observations established in section 2. For the whole sample, our empirical findings indicate that a productivity differential of 1% lowers the relative wage by 0.22%. When performing a sample-split analysis, estimates reveal that the relative wage falls more in countries where the labor market regulation is more pronounced. We also find that the elasticity of the relative price with respect to the relative productivity is equal to 0.64 for the whole sample.

The relative wage and relative price responses are summarized in Table 5. Since the relative wage response is ambiguous when the elasticity of substitution is smaller than one, it is convenient to first discuss the numerical results in this configuration. Panels C and D of Table 5 report the long-run changes for the relative wage W^N/W^T and the relative price of non traded goods P^N/P^T expressed as a percentage. The numbers reported in the first line of each panel give the (overall) responses of these variables to 1 percentage point increase in the productivity differential between tradables and non tradables. Column 1 of Table 5 shows that when abstracting from labor market frictions, i.e., setting $\kappa^j = 0$ and $\sigma_L \rightarrow \infty$, the model cannot account for our empirical evidence. Intuitively, because hiring and searching for a job are costless activities, labor is perfectly mobile across sectors. Hence, technological change biased toward the traded sector leaves unaffected the relative wage (i.e., $\hat{\omega} = 0$). Because the non tradable unit labor cost increases at the same speed as the productivity differential, the relative price appreciates by 1%.

[44] The market clearing condition for the traded good and the non traded good at the steady-state are $r^{\star}B + Y^T = C^T + G^T + \kappa^T V^T + \kappa^N V^N$ and $Y^N = C^N + G^N$.

[45] When conducting the sensitivity analysis, we raise r from 52.4% to 78.2% for and τ from 4.2 to 13, which correspond to the highest value in our sample of countries for the replacement rate and the firing cost, respectively.

Unlike, numerical results summarized in column 2 show that when calibrating to a typical OECD economy, a model with labor market frictions can produce a decline in ω and a less than proportional increase in the relative price as found in the data. To shed light on the transmission mechanism of technical change biased toward the traded sector in a model with labor market frictions, it is useful to numerically break down the responses into two channels; i) a labor market frictions channel stemming from the effect of higher productivity on hiring while keeping the trade balance fixed and ii) a labor accumulation channel arising from the long-run rise in net exports.

As shown in the second line of panels C and D, a rise by 1% in the productivity of tradables relative to non tradables raises the relative wage by 0.31% and appreciates the relative price by 1.35% through the labor market frictions effect. Intuitively, a productivity shock biased toward the traded sector increases traded output relative to non traded output, thus requiring a rise in the relative price to clear the goods market. Because ϕ is smaller than one, the relative price must appreciate more than proportionately which in turn raises the share of non tradables into expenditure and thus encourages non traded firms to recruit relatively more than traded firms. To attract workers who experience mobility costs when shifting, the non traded wage must rise relative to the traded wage. As shown in the third line of panels C and D, the labor accumulation effect counteracts the labor market frictions effect. More specifically, technological change biased toward the traded sector also raises net exports which has an expansionary effect on hiring in the traded sector, thus driving down the relative wage by 0.49%. Higher demand for tradables also depreciates the relative price by 0.52%. Importantly, the labor accumulation effect more than offsets the labor market frictions effect so that the relative wage declines by 0.19% and the relative price appreciates by 0.83%, as summarized in the first line of panels C and D.

Our model with search in the labor market and an endogenous labor force participation sheds light on two sets of factors influencing the mobility of labor across sectors and thus the relative wage response to a productivity differential: the workers' mobility cost reflected by a utility loss when increasing the search intensity for a job in one sector (as captured by σ_L) and labor market institutions determining the elasticity of hiring to labor productivity (as captured by r and τ). While columns 3 to 5 explore the consequences of the workers' mobility cost, columns 6 to 8 investigate the implications of stringent labor market regulation.

As we move from column 3 to column 5, the elasticity of labor supply at the extensive margin σ_L is raised from zero to 1 so that the workers' utility loss decline. Column 3 of panels C and D of Table 5 shows numerical results if labor is totally immobile across sectors as captured by setting $\sigma_L = 0$. In this configuration, the labor force is fixed in both sectors because the mobility cost is prohibitive. Since the decision of search is inelastic to the sectoral wage, the relative wage falls by 0.48% instead of 0.19% in the baseline scenario. Hence, such a polar case tends to substantially overstate the decline in the relative wage and thus confirms the pivotal role of an endogenous labor force participation decision. Columns 4 and 5 of panels C and D of Table 5 analyze the effect of raising the elasticity the labor supply at the extensive margin from 0.2 to 1. Because the utility loss induced by the shift from one sector to another is lowered, the decline in the relative wage is moderated, as shown in the first line of panel C. Because the shift of labor from the non traded to the traded sector is increased, traded output rises more relative to non traded output, thus raising the appreciation in the relative price from 0.81% to 0.87%, as displayed in the first line of panel D.

Scenarios summarized in columns 6 and 7 of Table 5 show that raising the worker bargaining power α_W or the unemployment benefit replacement rate r amplifies the decline in the relative wage from 0.19% to 0.23% and 0.28%, respectively. In accordance with our model's predictions, in countries with a higher worker bargaining power or providing more generous unemployment benefits, technological change biased toward the traded sector lowers more the relative wage through the labor accumulation effect, as shown in the third line of panel C. The reason is that the elasticity of hiring to technological change is higher since the labor market tightness is initially low in both sectors. Hence, job vacancies increase substantially following a productivity shock. Higher recruiting expenditure produce larger current account deficits along the transitional paths. Hence, net exports must rise more for the intertemporal solvency condition to hold, thus resulting in a greater expansionary effect on labor demand in the traded sector and thereby on traded wages. The stronger labor accumulation effect also moderates the appreciation in the relative price from 0.83% to 0.78% and 0.73%, as shown in the first line of panel D, because the demand for tradables increases more than in the baseline scenario. The second line of panel C also reveals that the relative wage increases less than in the baseline scenario through the labor market frictions effect. Intuitively, raising the worker bargaining power or the replacement rate increase the mobility of labor across sectors by raising the marginal benefit of search and reducing the recruiting cost, respectively.

Column 8 of Table 5 gives results when the firing cost is about about three times larger than in the baseline scenario. In accordance with our empirical findings, raising the firing cost drives down further the relative wage from -0.19% to -0.21%. As shown in the third line of panel C, the labor accumulation channel is merely affected by the firing cost. On the contrary, the second line of panel C reveals that the relative wage increases by a smaller amount because the firing cost curbs the expansionary effect of technological change on hiring by non traded firms and thus moderates the rise in the non traded wage from 0.31% to 0.27%. Moreover, as shown in the first line of panel D, countries with stringent legal protection against dismissals also experience a larger appreciation in the relative price of non tradables because traded output increases more relative to non traded output.

The latter two columns of Table 5 compare the relative wage and relative price effects of technological change biased toward the traded sector between a typical European country and the US. Because the legal protection against dismissals is stricter while unemployment benefits are higher, a typical European economy experiences a smaller increase in the non traded wage through the labor market frictions channel and a larger increase in the traded wage through the labor accumulation channel. As a result, the relative wage falls by 0.22% in EU-12 and declines by only 10% in the US. While a higher firing cost tends to amplify the appreciation in the relative price, a larger replacement rate tends to moderate it. The first line of panel D shows that the latter effect dominates so that a productivity differential raises the relative price of non tradables more in the US (0.89%) than in a European economy (0.79%).

We briefly discuss the scenario of an elasticity of substitution between traded and on traded goods larger than one. Panels E and F of Table 5 report the relative wage and relative price long-run responses to a productivity differential between tradables and non tradables of 1%. Because the labor accumulation channel reinforces the labor market frictions channel, the first line of panel E reveals that the model tends to overstate the decline in the relative wage when $\phi > 1$. Because in this configuration, a productivity differential of 1% appreciates the relative price less than proportionately through the labor labor market frictions effect while the rise in net exports depreciates p, the model tends to understate the rise in p, as shown in the first line of panel F.

Finally, we explore the relative wage and relative price effects when the elasticity of substitution between tradables and non tradables is set to one. This case is shown in panel A and panel B of Table 5. Keeping fixed net exports, higher productivity growth in tradables relative to non tradables would have no effect on the relative wage while the relative price would appreciate by 1% if labor market parameters were identical because the share of tradables in total expenditure remains unchanged. As shown in the second line of panel A, the relative wage falls very slightly though because the elasticity of hiring in the traded sector is merely higher than that in the non traded sector. The third line of panel A and B reveals that technological change biased toward the traded sector lowers substantially the relative wage and produces an appreciation in the relative price close to our estimates due to the improvement in the balance of trade. Alternative scenarios yield similar results to those discussed above and therefore do not merit further comment.

< Please insert Table 5 about here >

5.3 Taking the Model to the Data

We now move a step further and compare the predicted values with estimates for each country and the whole sample. To do so, we use the same baseline calibration for each country, except for the elasticity of substitution ϕ between traded and non-traded goods, and labor market parameters which are allowed to vary across countries. More specifically, the elasticity of substitution ϕ between traded and non traded goods is set in accordance with its estimates shown in the first column of Table 6. The parameters which capture the degree of labor market regulation such as the firing cost x, and the replacement rate r are set to their values shown in the latter two columns of Table 9. The job destruction rate s^j, and the matching efficiency X^j in sector j are set to target the unemployment rate u^j and the job finding rate m^j summarized in columns (2), (3), and in columns (5), (7) of Table 9. The costs per job vacancy κ^T and κ^N are chosen to target the aggregate labor market tightness θ shown in column (13) and the ratio of sectoral labor market tightness θ^T/θ^N obtained by dividing column (10) by column (11).[46]

Results are shown in Table 6. Columns 2 and 5 of Table 6 give the predicted responses of $\hat{\omega}$ and $\hat{p}$ to a productivity differential between tradables and non tradables by 1%. Columns 3 and 6 report fully modified OLS estimates of $\hat{\omega}$ and $\hat{p}$ for each country and the whole sample.[47] Columns 4 and 7 gives the difference between the actual and the predicted value. The prediction error averages 0.106 for the relative wage and 0.150 for the relative price. Column 4 reveals that our model's predictions for $\hat{\omega}$ are relatively close to the evidence for half of the countries in our sample, including Australia, Germany, France, the UK, Ireland, Italy, Japan, the Netherlands, Sweden, and the US; for these economies, the prediction error is smaller than average. When calibrating to the whole sample, the model predicts fairly well the relative wage response to a 1 percentage point increase in the productivity differential; more precisely, we find numerically a decline in the relative wage of 0.267% while in the data, ω falls by 0.223%. Inspection of the prediction error in column 4 of Table 6 reveals that our model tends to overstate the decline in the relative wage for two third of the 18 economies and the whole sample as well. This result suggests that an elasticity of

[46]Ideally, the recruiting cost κ^j would be set in order to target θ^j; however, the series for job vacancies by economic activity are available for a maximum of seven years. On the contrary, the OECD provides data for job openings (for the whole economy) over the period 1980-2007 allowing us to calculate the labor market tightness, i.e., $\theta = V/U$, for several countries that we target along with the ratio θ^T/θ^N by choosing κ^T and κ^N. When data for sectoral labor market tightness are not available, we target the average value θ^T/θ^N for EU-12 if the country is a member of the European Economic Area, the average value for the US (Australia), and average value for the OECD otherwise. When data for job openings are not available at an aggregate level, we first calibrate the model to EU-12 (US, OECD), in particular choosing κ^T and κ^N to target an aggregate labor market tightness θ of 0.12 (0.59, 0.18) and a ratio θ^T/θ^N of 0.75 (0.66, 0.77); then, we set κ^T and κ^N chosen for EU-12 if the country is a member of the European Economic Area, chosen for the US for Canada, and chosen for the OECD otherwise. Finally, because labor market parameters cannot be calculated at a sectoral level for France, the Netherlands, Norway and Korea (only sectoral unemployment rates are available for Korea), we assume that the job destruction rate s and the matching efficiency X are identical across sectors and are chosen so as to target u and m shown in columns (4) and (5) of Table 9.

[47]FMOLS and DOLS cointegration procedures give very similar estimates. Since the model has been calibrated by using FMOLS estimates of ϕ, we compare predicted values with FMOLS estimates. We reach similar conclusions when using DOLS estimates.

labor supply at the extensive margin σ_L of 0.5, although in line with estimates documented by empirical studies, may be too low, thus leading the model to overstate the workers' mobility cost.

While the prediction error is larger than for the relative wage in average, the model predicts fairly well the relative price response for half countries of our sample, including Austria, Belgium, Germany, Finland, Japan, the Netherlands, Spain, the UK, and the US. The prediction error is also lower than average in Denmark, Ireland and Italy. It is worthwhile mentioning that that the prediction error is large for Australia, Canada, and Norway which are important natural resources exporters. Hence, for these three economies, we believe that our assumption of given terms of trade is too strong. Turning to the whole sample, a rise in productivity of tradables relative to non tradables of 1% produces a rise in the relative price by 0.745% while we find empirically an elasticity of 0.636.

< Please insert Table 6 about here >

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6 Conclusion

While the literature exploring the implications of technological change biased toward the traded sector commonly assume frictionless labor markets, our empirical results show that the non traded wage tends to decline relative to the traded wage. More specifically, using a sample of eighteen OECD countries over the period 1970-2007, we find that a rise in the productivity of tradables relative to non tradables by 1% lowers the relative wage of non tradables by 0.22%. Because the the non traded wage increases at a lower speed than the traded wage, it is found empirically that the relative price of non tradables appreciates by 0.64% only instead of 1% as predicted by the standard neoclassical model abstracting from labor market frictions. When estimating the relative wage response by country, we conjecture that the large cross-country variations found in the data is the result of labor market institutions. In accordance with our interpretation, using a set of three indicators, our findings reveal that countries with stringent legal protection against dismissals, a more generous unemployment benefit scheme, or a higher bargaining coverage experience a significant larger decline in the relative wage following higher productivity in tradables relative to non tradables.

To account for the evidence, we develop a two-sector open economy model with search in the labor market and an endogenous labor force participation decision. We find analytically that two sets of parameters play a pivotal role in the determination of the relative wage response to technological change biased toward the traded sector: i) preference parameters such as the elasticity of labor supply at the extensive margin and the elasticity of substitution in consumption between tradables and non tradables, ii) parameters capturing the 'rigidities' in the labor market such as the firing tax, the unemployment benefit replacement rate and the worker bargaining power. Our quantitative analysis indicates that higher productivity growth in tradables relative to non tradables lowers the relative wage across all scenarios as long as the elasticity of labor supply that measures the workers' mobility cost takes a finite value. On the contrary, the situations of total immobility or perfect mobility of labor across sectors that emerge as special cases cannot account for the evidence. Importantly, the relative wage falls by a larger amount when raising the replacement rate or the worker bargaining power because traded firms are encouraged to hire more, thus amplifying the rise in the traded wage. Increasing the firing cost curbs hiring in the non traded sector, and thus produces a larger decline in the relative wage, in accordance with our evidence.

The final exercise we perform is to compare the responses of the relative price and relative wage for each OECD economy in our sample to our empirical estimates. To do so, we estimate the elasticity of substitution in consumption between tradables and non tradables and the labor market parameters for each country. Allowing these two sets of pivotal parameters to vary across countries, it is found that the model predicts the relative wage growth fairly well and to a lesser extent the elasticity of the relative price to relative productivity.

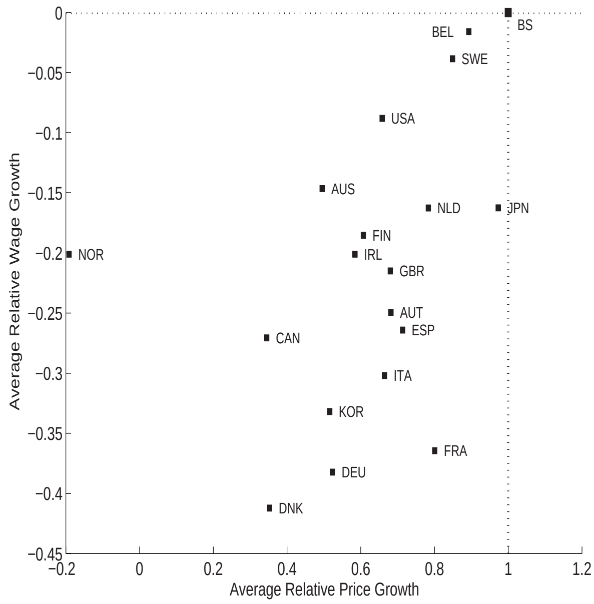


Figure 1: The Relative Price and the Relative Wage Growth. Notes: Figure plots the annual average growth of the relative price of non tradables and the relative wage of non tradables, both scaled by the average productivity growth differential between tradables and non tradables, for each country of our sample over 1970-2007.

Table 1: Panel Unit Root Tests (p-values)

Test	Stat	Variables			
		ω	p	$a^T - a^N$	$p - (a^T - a^N)$
Levin et al. [2002]	t-stat	0.075	0.376	0.998	0.510
Breitung [2000]	t-stat	0.273	0.667	0.760	0.124
Im et al. [2003]	W-stat	0.558	1.000	1.000	0.999
Maddala and Wu [1999]	ADF	0.329	0.972	1.000	0.950
	PP	0.289	0.953	0.999	0.983
Hadri [2000]	Z_μ-stat	0.000	0.000	0.000	0.000

Notes: For all tests, except for Hadri [2000], the null of a unit root is not rejected if p-value ≥ 0.05 at a 5% significance level. For Hadri [2000], the null of stationarity is rejected if p-value ≤ 0.05 at a 5% significance level.

Table 2: Panel Cointegration Estimates of β and γ for the Whole Sample (eqs. (7))

	Relative wage eq. (7a)		Relative price eq. (7b)	
	DOLS	FMOLS	DOLS	FMOLS
$(a^T - a^N)$	-0.2^a (−29.72)	-0.223^a (−33.85)	0.646^a (76.543)	0.636^a (83.01)
$t(\beta) = 0$	0.000	0.000		
$t(\gamma) = 1$			0.000	0.000
Number of countries	18	18	18	18
Number of observations	680	680	680	680

Notes: all regressions include country fixed effects. Heteroskedasticity and autocorrelation consistent t-statistics are reported in parentheses. [a] denotes significance at 1% level. The rows $t(\beta) = 0$ and $t(\gamma) = 1$ report the p-value of the test of $H_0 : \beta = 0$ and $H_0 : \gamma = 1$ respectively.

Table 3: Panel Cointegration Estimates of β_i and γ_i for Each Country (eqs. (7))

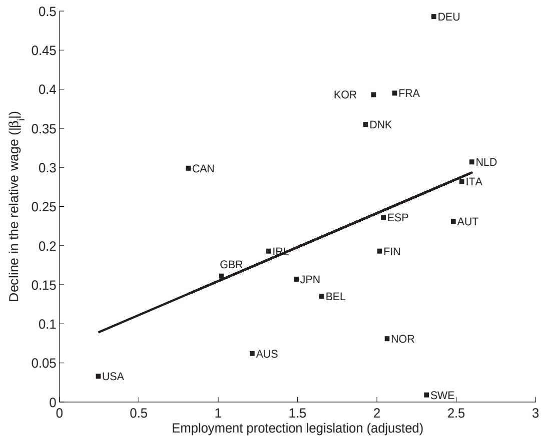
	Relative wage equation		Relative price equation	
Country	$\hat{\beta}_i^{DOLS}$	$\hat{\beta}_i^{FMOLS}$	$\hat{\gamma}_i^{DOLS}$	$\hat{\gamma}_i^{FMOLS}$
AUS	-0.047 (−1.51)	-0.062^b (−2.19)	0.567^a (10.95)	0.559^a (10.88)
AUT	-0.220^a (−12.62)	-0.231^a (−13.95)	0.687^a (20.14)	0.689^a (21.89)
BEL	-0.150^a (−6.36)	-0.135^a (−5.74)	0.732^a (17.49)	0.740^a (17.52)
CAN	-0.298^a (−6.11)	-0.299^a (−7.19)	0.549^a (4.95)	0.524^a (5.19)
DEU	-0.502^a (−20.60)	-0.493^a (−22.90)	0.532^a (9.76)	0.517^a (10.70)
DNK	-0.366^a (−4.96)	-0.355^a (−5.86)	0.361^a (9.51)	0.357^a (12.63)
ESP	-0.231^a (−8.30)	-0.236^a (−11.10)	0.689^a (19.14)	0.709^a (21.50)
FIN	-0.197^a (−11.14)	-0.193^a (−12.99)	0.645^a (19.98)	0.628^a (23.02)
FRA	-0.396^a (−6.56)	-0.395^a (−7.00)	0.787^a (29.79)	0.790^a (31.01)
GBR	-0.152^b (−2.35)	-0.161^a (−2.94)	0.842^a (6.63)	0.810^a (7.41)
IRL	-0.187^a (−3.64)	-0.193^a (−4.20)	0.554^a (18.09)	0.562^a (19.20)
ITA	-0.265^a (−10.04)	-0.282^a (−11.74)	0.761^a (23.91)	0.727^a (23.34)
JPN	-0.161^a (−8.05)	-0.157^a (−9.29)	0.879^a (42.50)	0.898^a (41.06)
KOR	-0.403^a (−10.77)	-0.393^a (−12.53)	0.529^a (40.46)	0.532^a (45.58)
NLD	-0.331^a (−5.90)	-0.307^a (−5.82)	0.724^a (15.95)	0.731^a (18.04)
NOR	-0.071^a (−5.84)	-0.081^a (−6.17)	0.094 (0.75)	0.034 (0.29)
SWE	-0.020 (−0.66)	-0.009 (−0.52)	0.908^a (11.23)	0.882^a (18.13)
USA	-0.017 (−0.69)	-0.033 (−1.47)	0.784^a (23.50)	0.765^a (24.80)
UE-12	-0.252^a (−26.89)	-0.249^a (−30.24)	0.685^a (58.20)	0.679^a (64.78)
All sample	-0.223^a (−29.72)	-0.223^a (−33.85)	0.646^a (76.543)	0.636^a (83.01)

Notes: Heteroskedasticity and autocorrelation consistent t-statistics are reported in parentheses. ^{a}, ^{b} and ^{c} denote significance at 1%, 5% and 10% levels.

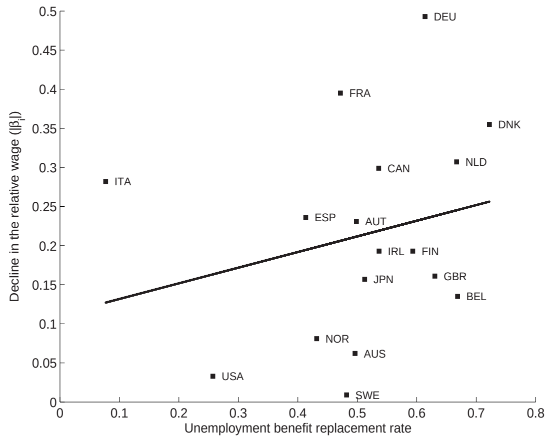
Table 4: Panel Cointegration Estimates of β for subsamples (eq. (8))

LMR	r		EPL$_{adj}$		BargCov		LMR	
	DOLS	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS	FMOLS
high LMR	-0.261^a (−23.04)	-0.255^a (−25.65)	-0.165^a (−30.29)	-0.172^a (−32.59)	-0.242^a (−22.18)	-0.238^a (−24.91)	-0.166^a (−31.68)	-0.173^a (−33.20)
low LMR	-0.158^a (−16.34)	-0.166^a (−19.14)	-0.130^a (−13.97)	-0.130^a (−11.57)	-0.180^a (−17.25)	-0.185^a (−19.93)	-0.113^a (−10.74)	-0.112^a (−8.26)
$t(\hat{\beta}_{low} = \hat{\beta}_{high})$	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000
Time period	1970-2007		1985-2007		1970-2007		1985-2007	
Countries	17		18		17		17	
Observations	642		414		642		390	
mean LMR (high)	0.609		2.280		0.864		1.376	
mean LMR (low)	0.389		1.296		0.448		-0.578	

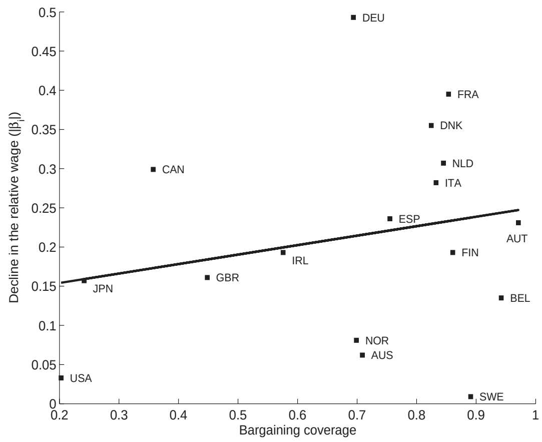
Notes: ^{a} denotes significance at 1% level. The row $t(\hat{\beta}_{low} = \hat{\beta}_{high})$ reports the p-value of the test of $H_0 : \hat{\beta}_{low} = \hat{\beta}_{high}$. r is the unemployment benefits replacement rate, EPL the strictness of employment protection against dismissals, $BargCov$ the bargaining coverage and LMR the labor market regulation index obtained by using a principal component analysis.



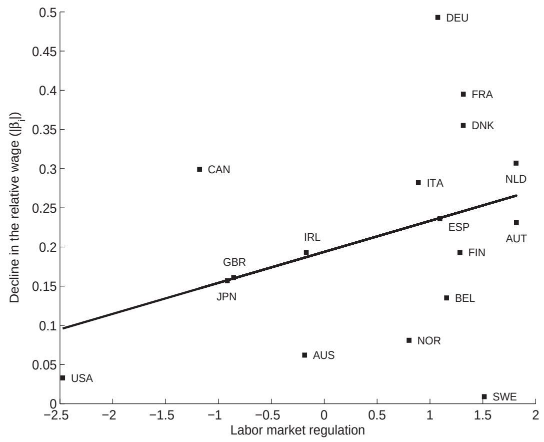
(a) Relative Wage Responses against Firing Cost



(b) Relative Wage Responses against Generosity of Unemployment Benefit Scheme

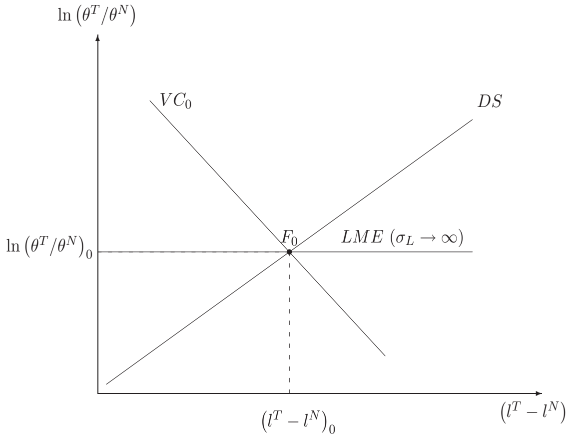


(c) Relative Wage Responses against Worker Bargaining Power

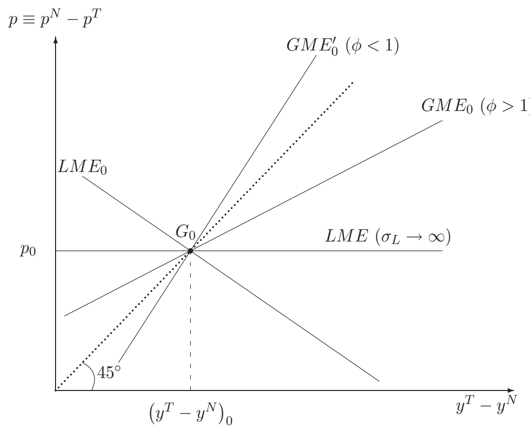


(d) Relative Wage Responses against Labor Market Regulation Index

Figure 2: Labor Market Regulation and The Relative Wage Response to Technological Change Biased toward the Traded Sector Notes: Figure plots fully modified OLS estimates of relative wage responses to a labor productivity differential against indicators of labor market regulation. FMOLS estimates for each country are taken from Table 3. Firing cost is captured by the employment protection legislation index adjusted with the share of permanent workers in the economy (source: OECD); the generosity of unemployment benefit scheme is measured by average of net unemployment benefit replacement rates for three duration of unemployment (source: OECD); the worker bargaining power is measured by the bargaining coverage (source: Visser [2009]); in Figure 2(d), we recourse to a principal component analysis in order to have one overall indicator encompassing the three dimensions of labor market regulation.

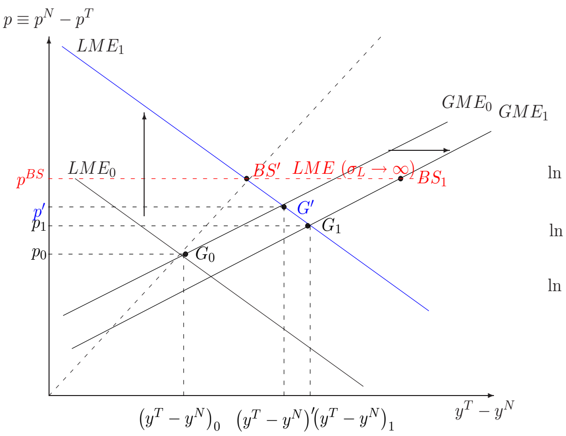


(a) $(l^T - l^N, \ln(\theta^T/\theta^N))$-space

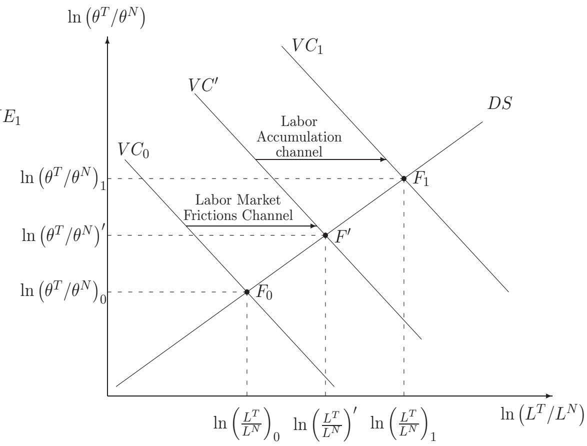


(b) $(y^T - y^N, p)$-space

Figure 3: Steady-State

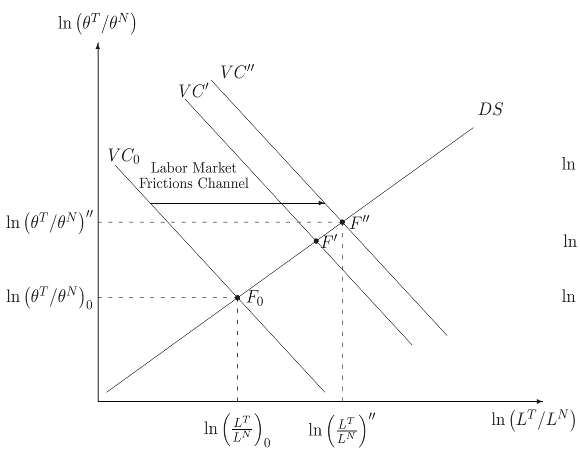


(a) $(y^T - y^N, p)$-space

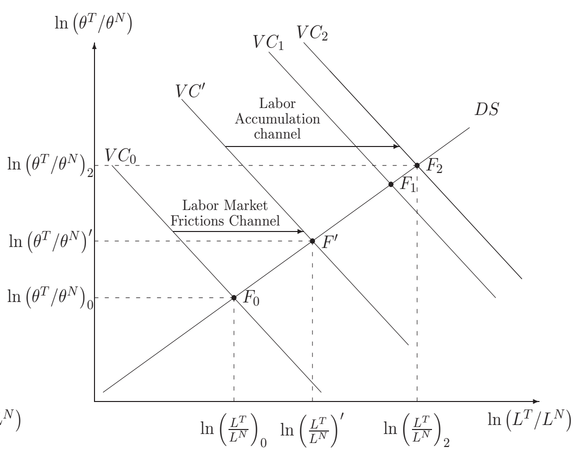


(b) $(l^T - l^N, \ln(\theta^T/\theta^N))$-space

Figure 4: Long-Run Relative Price and Relative Wage Effects of Technological Change Biased toward the Traded Sector



(a) Consequences of a Higher Firing Tax



(b) Consequences of a higher replacement rate or worker bargaining power

Figure 5: Implications for the Relative Wage Response of Labor Market Regulation in the $(l^T - l^N, \ln(\theta^T/\theta^N))$-space

Table 5: Long-Term Relative Price and Relative Wage Responses to a Productivity Differential between Tradables and Non Tradables (in %)

	BS	OECD	Labor force			Bargaining power	Replacement rate	Firing	UE-12	US
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$(u=0)$	$(u=8.1\%)$	$(\sigma_L=0)$	$(\sigma_L=0.2)$	$(\sigma_L=1)$	$(\alpha_W=0.9)$	$(r=0.782)$	$(\tau=13)$	$(u=9.1\%)$	$(u=5.2\%)$
$\underline{\phi=1}$										
A.Relative Wage										
Relative wage, $\hat{\omega}$	0.00	-0.34	-0.59	-0.43	-0.25	-0.37	-0.40	-0.37	-0.36	-0.27
Labor market frictions effect	0.00	-0.03	-0.04	-0.02	-0.03	-0.03	-0.03	-0.07	-0.03	-0.00
Labor accumulation effect	0.00	-0.31	-0.55	-0.42	-0.22	-0.35	-0.37	-0.30	-0.34	-0.26
B.Relative Price										
Relative price, $\hat{p}$	1.00	0.67	0.42	0.57	0.77	0.64	0.60	0.70	0.64	0.72
Labor market frictions effect	0.00	1.01	0.99	1.01	1.01	1.01	1.00	1.03	1.01	1.00
Labor accumulation effect	0.00	-0.33	-0.57	-0.44	-0.24	-0.36	-0.39	-0.33	-0.35	-0.26
$\underline{\phi<1}$										
C.Relative Wage										
Relative wage, $\hat{\omega}$	0.00	-0.19	-0.48	-0.20	-0.15	-0.23	-0.28	-0.21	-0.22	-0.10
Labor market frictions effect	0.00	0.31	0.52	0.44	0.21	0.29	0.26	0.27	0.30	0.35
Labor accumulation effect	0.00	-0.49	-1.00	-0.64	-0.35	-0.52	-0.54	-0.48	-0.52	-0.44
D.Relative Price										
Relative price, $\hat{p}$	1.00	0.83	0.53	0.81	0.87	0.78	0.73	0.87	0.79	0.89
Labor market frictions effect	0.00	1.35	1.57	1.49	1.25	1.33	1.32	1.39	1.35	1.34
Labor accumulation effect	0.00	-0.52	-1.03	-0.67	-0.37	-0.54	-0.58	-0.52	-0.54	-0.44
$\underline{\phi>1}$										
E.Relative Wage										
Relative wage, $d\hat{\omega}$	0.00	-0.47	-0.68	-0.58	-0.36	-0.50	-0.50	-0.50	-0.49	-0.41
Labor market frictions effect	0.00	-0.26	-0.35	-0.30	-0.22	-0.26	-0.25	-0.31	-0.26	-0.25
Labor accumulation effect	0.00	-0.21	-0.34	-0.29	-0.14	-0.24	-0.26	-0.20	-0.23	-0.17
F.Relative Price										
Relative price, $\hat{p}$	1.00	0.54	0.32	0.42	0.65	0.51	0.49	0.56	0.52	0.58
Labor market frictions effect	0.00	0.76	0.68	0.72	0.81	0.77	0.77	0.78	0.76	0.75
Labor accumulation effect	0.00	-0.22	-0.36	-0.30	-0.16	-0.26	-0.28	-0.22	-0.24	-0.16

Notes: Effects of a 1 percentage point increase in the labor productivity differential between tradables and non tradables. Panels A and B show the deviation in percentage relative to steady-state for the relative price of non tradables $p \equiv p^N - p^T$ and the relative wage of non traded workers $\omega \equiv w^N - w^T$, respectively, and break down changes in a labor market frictions effect (keeping unchanged net exports NX), and a labor capital accumulation effect (stemming from the hiring boom causing a current account deficit in the short-run and therefore requiring a steady-state improvement in the balance of trade). While panels A and B show the results when setting ϕ to one, panels C and D show results for $\phi < 1$ and panels E and F show results for $\phi > 1$; ϕ is the elasticity of substitution between tradables and non tradables; σ_L is the elasticity of labor supply at the extensive margin; α_W corresponds to the worker bargaining power; r is the unemployment benefits replacement rate; τ measures the strictness of employment protection with $x = \tau .W$ the firing tax expressed in monthly salary equivalents.

Table 6: Comparison of Predicted Values with Empirical Estimates

Country	Parameter	Relative wage response			Relative price response		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Substitutability ϕ	$\hat{\omega}^{predict}$	$\hat{\omega}^{FMOLS}$	(3)-(2)	$\hat{p}^{predict}$	$\hat{p}^{FMOLS}$	(6)-(5)
AUS	0.295	0.042	-0.062	-0.104	1.040	0.559	-0.481
AUT	1.019	-0.363	-0.231	0.132	0.664	0.689	0.025
BEL	0.749	-0.332	-0.135	0.197	0.685	0.740	0.055
CAN	0.439	-0.08	-0.299	-0.219	0.925	0.524	-0.401
DEU	1.126	-0.438	-0.493	-0.055	0.557	0.517	-0.04
DNK	1.925	-0.536	-0.355	0.181	0.463	0.357	-0.106
ESP	0.782	-0.348	-0.236	0.112	0.694	0.709	0.015
FIN	1.043	-0.417	-0.193	0.224	0.593	0.628	0.035
FRA	0.896	-0.376	-0.395	-0.019	0.628	0.790	0.162
GBR	0.477	-0.102	-0.161	-0.059	0.902	0.810	-0.092
IRL	0.321	-0.264	-0.193	0.071	0.734	0.562	-0.172
ITA	-	-0.278	-0.282	-0.004	0.723	0.727	0.004
JPN	0.713	-0.200	-0.157	0.043	0.812	0.898	0.086
KOR	2.914	-0.687	-0.393	0.294	0.368	0.532	0.164
NLD	0.644	-0.318	-0.307	0.011	0.672	0.731	0.059
NOR	1.004	-0.292	-0.081	0.211	0.704	0.034	-0.67
SWE	0.329	-0.008	-0.009	-0.001	1.015	0.882	-0.133
USA	0.699	-0.144	-0.033	0.111	0.841	0.765	-0.076
UE-12	0.599	-0.215	-0.249	-0.034	0.798	0.679	-0.119
Whole sample	0.800	-0.267	-0.223	0.044	0.745	0.636	-0.109

Notes: ϕ is the intratemporal elasticity of substitution between traded goods and non traded goods. We denote by superscripts "predict" and "FMOLS" the numerically computed values and fully modified OLS estimates taken from Table 3, respectively; columns (4) and (7) show the difference between FMOLS estimates and predicted values for percentage changes in the relative wage and the relative price of non tradables.

A Data for Empirical Analysis

Coverage: Our sample consists of a panel of 18 countries: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Germany (DEU), Denmark (DNK), Spain (ESP), Finland (FIN), France (FRA), the United Kingdom (GBR), Ireland (IRL), Italy (ITA), Japan (JPN), Korea (KOR), the Netherlands (NLD), Norway (NOR), Sweden (SWE), and the United States (USA). The period is running from 1970 to 2007, except for Japan (1974-2007).

Sources: We use the EU KLEMS [2011] database (the March 2011 data release) for all countries of our sample with the exceptions of Canada and Norway. For these two countries, sectoral data are taken from the Structural Analysis (STAN) database provided by the OECD [**?**]. Both the EU KLEMS and STAN databases provide annual data at the ISIC-rev.3 1-digit level for eleven industries.

The eleven industries are split into tradables and non tradables sectors. To do so, we adopt the classification proposed by De Gregorio et al. [1994]. Following Jensen and Kletzer [2006], we have updated this classification by treating "Financial Intermediation" as a traded industry. We construct traded and non traded sectors as follows (EU KLEMS codes are given in parentheses):

- **Traded Sector**: "Agriculture, Hunting, Forestry and Fishing" (AtB), "Mining and Quarrying" (C), "Total Manufacturing" (D), "Transport, Storage and Communication" (I) and "Financial Intermediation" (J).
- **Non Traded Sector**: "Electricity, Gas and Water Supply" (E), "Construction" (F), "Wholesale and Retail Trade" (G), "Hotels and Restaurants" (H), "Real Estate, Renting and Business Services" (K) and "Community Social and Personal Services" (LtQ).

Once industries have been classified as traded or non traded, for any macroeconomic variable X, its sectoral counterpart X^j for $j = T, N$ is constructed by adding the X_k of all sub-industries k classified in sector $j = T, N$ as follows $X^j = \sum_{k \in j} X_k$. In the following, we provide details on data construction (mnemonics are in parentheses):

- **Relative wage of non tradables**, Ω, is calculated as the ratio of the nominal wage in the non traded sector W^N to the nominal wage in the traded sector W^T, i.e., $\Omega = W^N/W^T$. The sectoral nominal wage W^j for sector $j = T, N$ is calculated by dividing labor compensation in sector j (LAB) by total hours worked by persons engaged (H_EMP) in that sector.
- **Relative price of non tradables**, P, corresponds to the ratio of the value added deflator of non traded goods P^N to the value added deflator of traded goods P^T, i.e., $P = P^N/P^T$. The sectoral value-added deflator P^j for sector $j = T, N$ is calculated by dividing value added at current prices by value added at constant prices in sector j. Series for sectoral value added at current prices (VA) (constant prices (VA_QI) resp.) are constructed by adding value at current (constant resp.) prices of all sub-industries in sector $j = T, N$.
- **Relative productivity of tradables**, A^T/A^N, is calculated as the ratio of traded real labor productivity A^T to the non traded real labor productivity A^N. To measure real labor productivity in sector $j = T, N$, we divide value-added at constant prices in sector j (VA_QI) by total hours worked by persons engaged (H_EMP) in that sector.

To empirically assess the role of labor market regulation in the determination of the relative price and relative wage responses to higher productivity growth in tradables relative to non tradables, we use a number of indicators which capture the extent of rigidity of labor markets. We detail below the sources:

- **Employment protection legislation**, denoted by EPL_{it} in country i at time t, is an index available on an annual basis developed by the OECD which is designed as a multi-dimensional indicator of the strictness of a comprehensive set of legal regulations governing hiring and firing employees on regular contracts. Source: OECD Labour Market Statistics database. Data coverage: 1985-2007 (1990-2007 for KOR). Because the legal protection for workers with temporary contracts has been eased in most European countries, we follow Boeri and Van Ours [2006] and construct an alternative index in order to have a more accurate measure of employment protection. This indicator, denoted by EPL_{it}^{adj} in country i at time t, is computed by adjusting EPL with the share of permanent workers in the economy (share_{perm}) according to $\text{EPL}^{adj} = \text{EPL} \times \text{share}_{perm}$. Source for share_{perm}: OECD Labour Market Statistics database. Data coverage: 1985-2007 (1990-2007 for KOR).
- The generosity of the unemployment benefit scheme, r_{it} in country i at time t, is commonly captured by the **unemployment benefit replacement rate**. the replacement rate measure is defined as the average of the net unemployment benefit (including social assistance and housing benefit) replacement rates for two earnings levels and three family situations. Source: OECD, Benefits and Wages Database. Data coverage: 2001-2007. In order to have longer time

series, we calculated r over the period running from 1970 to 2000, by using the growth rate of the historic OECD measure of benefit entitlements which is defined as the average of the gross unemployment benefit replacement rates for two earnings levels, three family situations and three durations of unemployment. Source: OECD, Benefits and Wages Database. Data coverage: 1970-2001 for all countries while data are unavailable for Korea.

- The worker bargaining power is measured by the **collective bargaining coverage**, BargCov_{it}, which corresponds to the employees covered by collective wage bargaining agreements as a proportion of all wage and salary earners in employment with the right to bargaining. Source: Data Base on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts, 1960-2009 (ICTWSS), version 3.0, Jelle Visser [2009]. Data coverage: 1970-2007 for AUS, AUT, CAN, DEU, DNK, FIN, GBR, IRL, ITA, JPN, SWE and USA, 1970-2005 for NLD and NOR, 1970-2002 for BEL and FRA, 1977-2004 for ESP and 2002-2006 for KOR.

B Data for Calibration

B.1 Non Tradable Share

Table 7 shows the non-tradable content of labor, consumption, government spending, and gives the share of government spending on the traded and non traded goods in the sectoral output. The last column of Table 7 also shows the ratio of traded real labor productivity to the non traded real labor productivity, A^T/A^N. Our sample consists of 18 OECD countries mentioned in section A, including 12 European countries plus Australia, Canada, Korea, Japan, Norway, the United-States. Our reference period for the calibration corresponds to the period 1990-2007. The choice of this period has been dictated by data availability.

To calculate the non-tradable share of employment we split the eleven industries into traded and non-traded sectors by adopting the classification proposed by De Gregorio et al. [1994] and updated by Jensen and Kletzer [2006] (Source: EU KLEMS [2011]). The non-tradable share of labor, shown in column 1 of Table 7 averages to 66%.

To split consumption expenditure (at current prices) into consumption in traded and non traded goods, we made use of the Classification of Individual Consumption by Purpose (COICOP) published by the United Nations (Source: United Nations [2011]). Among the twelve items, the following ones are treated as consumption in traded goods: "Food and Non-Alcoholic Beverages", "Alcoholic Beverages Tobacco and Narcotics", "Clothing and Footwear", "Furnishings, Household Equipment", "Transport", "Miscellaneous Goods and Services". The remaining items are treated as consumption in non traded goods: "Housing, Water, Electricity, Gas and Fuels", "Health", "Communication", "Education", "Restaurants and Hotels". Because the item "Recreation and Culture" is somewhat problematic, we decided to consider it as both tradable (50%) and non tradable (50%) with equal shares. Data coverage: 1990-2007 for AUS, AUT, CAN, DNK, FIN, FRA, GBR, ITA, JPN, KOR, NLD, NOR, and USA, 1991-2007 for DEU, 1993-2007 for SWE, 1995-2007 for BEL and ESP and 1996-2007 for IRL. Note that the non-tradable share of consumption shown in column 2 of Table 7 averages to 42%, in line with the share reported by Stockman and Tesar [1995].

Sectoral government expenditure data (at current prices) were obtained from the Government Finance Statistics Yearbook (Source: IMF [2011]) and the OECD General Government Accounts database (Source: OECD [2011b]). Adopting Morshed and Turnovsky's [2004] methodology, the following four items were treated as traded: "Fuel and Energy", "Agriculture, Forestry, Fishing, and Hunting", "Mining, Manufacturing, and Construction", "Transport and Communications". Items treated as non traded are: "Government Public Services", "Defense", "Public Order and Safety", "Education", "Health", "Social Security and Welfare", "Environment Protection", "Housing and Community Amenities", "Recreation Cultural and Community Affairs". Data coverage: 1990-2007 for BEL, DNK, FIN, GBR, IRL, ITA, JPN, NOR and USA, 1990-2006 for CAN, 1991-2007 for DEU, 1995-2007 for AUT, ESP, FRA, NLD and SWE and 2000-2007 for KOR (data are not available for AUS). The non-tradable component of government spending shown in column 3 of Table 7 averages to 90%. The proportion of government spending on the traded and non traded good (i.e., G^T/Y^T and G^N/Y^N) are shown in columns 5 and 6 of Table 7. They average 5% and 29%, respectively.

B.2 Elasticity of Substitution in consumption (ϕ)

To estimate the elasticity of substitution in consumption ϕ between traded and non traded goods, we first derive a testable equation by inserting the optimal rule for intra-temporal allocation of consumption (13) into the goods market equilibrium which gives $\frac{C^T}{C^N} = \frac{Y^T - NX - G^T - I^T}{Y^N - G^N - I^N} = \left(\frac{\varphi}{1-\varphi}\right) P^{\phi}$ where $NX \equiv \dot{B} - r^{\star} B$ is net exports, I^j and G^j are investment in physical capital and government spending in sector j, respectively. Isolating $\left(Y^T - NX\right)/Y^N$ and taking logarithm yields

$\ln\left(\frac{Y^T-NX}{Y^N}\right) = \alpha + \phi p$ where α is a term composed of (logged) ratios of G^T (G^N) and I^T (I^N) to $Y^T - NX$ (Y^N), and of a preference parameter φ. Adding an error term μ, we estimate ϕ by running the regression of the (logged) output of tradables adjusted with net exports at constant prices in terms of output of non tradables on the (logged) relative price of non tradables:

$$\ln\left(\frac{Y^T - NX}{Y^N}\right)_{i,t} = f_i + f_t + \alpha_i t + \phi_i \ln P_{i,t} + \mu_{i,t}, \tag{54}$$

where f_i and f_t are the country fixed effects and time dummies, respectively. Because the term α is composed of ratios and hence may display a trend over time, we add country-specific trends, as captured by $\alpha_i t$.

Instead of using time series for sectoral value added, we can alternatively make use of series for sectoral labor compensation. Multiplying both sides of $\frac{(Y^T-NX)(1-\upsilon_{G^T}-\upsilon_{V^T})}{Y^N(1-\upsilon_{G^N}-\upsilon_{V^N})} = \left(\frac{\varphi}{1-\varphi}\right)P^{\phi}$ by $\frac{P^T}{P^N}$ and then by ω^T/ω^N with $\omega^j = \frac{W^jL^j}{P^jY^j}$, denoting by $\gamma^T = \left(W^TL^T - \omega^TP^TNX\right)$ (with $\omega_T \equiv \frac{W^TL^T}{P^TY^T}$) and $\gamma^N = W^NL^N$, and taking logarithm yields $\ln\left(\frac{\gamma^T}{\gamma^N}\right) = \eta + \phi \ln P$ where η is a term composed of both preference (i.e., φ) and production (i.e., θ^j) parameters, and (logged) ratios of G^T (G^N) and I^T (I^N) to $W^TL^T - \omega^TP^TNX$ (W^NL^N). We estimate ϕ by exploring alternatively the following empirical relationship:

$$\ln\left(\gamma^T/\gamma^N\right)_{i,t} = g_i + g_t + \eta_i t + \phi_i \ln P_{i,t} + \zeta_{i,t}, \tag{55}$$

where g_i and g_t are the country fixed effects and time dummies, respectively, and we add country-specific trends, as captured by $\eta_i t$, because η is composed of ratios that may display a trend over time.

Time series for sectoral value added at constant prices, labor compensation, and the relative price of non tradables are taken from EU KLEMS [2011] (see section A). Net exports correspond to the external balance of goods and services at current prices taken from OECD Economic Outlook Database. To construct time series for net exports at constant prices NX, data are deflated by the traded value added deflator of traded goods P_t^T.

Since the LHS term of (54) and the relative price of non tradables display trends, we ran unit root and then cointegration tests. Having verified that these two assumptions are empirically supported, we estimate the cointegrating relationships by using fully modified OLS (FMOLS) procedure for cointegrated panel proposed by Pedroni [2000], [2001]. FMOLS estimates are reported in the second and the third column of Table 8, considering eq. (54). Estimates of ϕ are reported in column 2 of Table 8 when calibrating the model for each country. As a reference model, we consider eq. (54); exploring the empirical relationship (54) gives an estimate for the whole sample of 0.800 which is smaller than one, in line with estimates documented by cross-section studies, notably Stockman and Tesar [1995] who find a value for ϕ of 0.44 and Mendoza [1995] who reports an estimate of 0.74. As shown in column 2 of Table 8, estimate of ϕ for Belgium is not statistically significant and thus we take consistent estimate obtained when exploring the empirical relationship (55) for this economy. Because estimates for Italy is negative by using alternatively eq. (54) or eq. (55), estimate for ϕ for this country is left blank and ϕ is set to our panel data estimation for EU-12, i.e., 0.599, when calibrating the model for each country.

C Data for Calibration: Labor Market

We now describe the data employed to calibrate the model, focusing on labor market. We use two calibrations aimed at capturing the the U.S. and European labor markets.

- Sectoral unemployment rate denoted by u^j ($j = T, N$): Sectoral unemployment rate is the number of unemployed workers U^j in sector j as share of the labor force $F^j \equiv L^j + U^j$ in this sector, in %. LABORSTA database from ILO provides series for unemployed workers by economic activity for fourteen OECD countries over eighteen of our sample. The longest available period ranges from 1987 to 2007. On average, our data covers 12.5 years per country. Series cover 18 sectors, according to ISIC Rev.3 classification.

  Sectors have been aggregated into tradables (Agriculture; Hunting and Forestry; Fishing; Mining and Quarrying; Manufacturing; Transport, Storage and Communications; Financial Intermediation) and non-tradables (Electricity, Gas and Water Supply; Construction; Wholesale and Retail Trade, Repair of Motor Vehicles, Motorcycles and Personal and Household Goods; Hotels and Restaurants; Real Estate, Renting and Business Activities; Public Administration and Defense, Compulsory Social Security; Education; Health and Social Work; Other Community, Social and Personal Service Activities; Households with Employed Persons; Extra-Territorial Organizations and Bodies). Note that unemployment in the following

Table 7: Data to Calibrate the Two-Sector Model (1990-2007)

Countries	Non tradable Share			G^j/Y^j			Relative Productivity
	Labor	Consumption	Gov. Spending	G/Y	G^T/Y^T	G^N/Y^N	A^T/A^N
AUS	0.68	0.43	n.a.	0.18	n.a.	n.a.	1.30
AUT	0.64	0.42	0.90	0.19	0.05	0.27	1.05
BEL	0.68	0.42	0.91	0.22	0.06	0.30	1.28
CAN	0.69	0.43	0.91	0.20	0.05	0.30	1.32
DEU	0.65	0.40	0.91	0.19	0.05	0.27	1.00
DNK	0.68	0.42	0.94	0.26	0.05	0.36	1.17
ESP	0.66	0.46	0.88	0.18	0.06	0.24	1.18
FIN	0.63	0.43	0.89	0.22	0.06	0.34	1.47
FRA	0.69	0.40	0.94	0.23	0.05	0.31	1.05
GBR	0.70	0.40	0.93	0.20	0.04	0.29	1.54
IRL	0.62	0.43	0.89	0.17	0.04	0.28	1.83
ITA	0.63	0.37	0.91	0.19	0.05	0.27	1.00
JPN	0.64	0.43	0.86	0.16	0.06	0.22	0.96
KOR	0.58	0.44	0.76	0.12	0.06	0.18	1.53
NLD	0.70	0.40	0.90	0.23	0.07	0.32	1.38
NOR	0.66	0.39	0.88	0.21	0.06	0.34	1.44
SWE	0.68	0.45	0.92	0.27	0.06	0.39	1.42
USA	0.73	0.51	0.90	0.16	0.05	0.20	1.12
Mean	0.66	0.42	0.90	0.20	0.05	0.29	1.28

Notes: G^j/Y^j is the share of government spending in good j in output of sector j

Table 8: Estimates of the Elasticity of Substitution in Consumption between Tradables and Non Tradables (ϕ)

Country	$\hat{\phi}_i^{DOLS}$ eq. (54)	$\hat{\phi}_i^{FMOLS}$ eq. (54)	$\hat{\phi}_i^{DOLS}$ eq. (55)	$\hat{\phi}_i^{FMOLS}$ eq. (55)
AUS	0.081 (0.74)	0.295^a (3.09)	0.011 (0.08)	0.375^b (2.39)
AUT	0.574 (1.62)	1.019^a (2.99)	0.910^a (3.77)	1.414^a (4.98)
BEL	−0.268 (−1.58)	0.034 (0.17)	0.393^a (3.41)	0.749^a (4.60)
CAN	0.308^b (2.04)	0.439^a (3.75)	0.332^b (2.18)	0.569^a (4.94)
DEU	0.976^a (3.46)	1.126^a (2.99)	1.190^a (4.34)	1.363^a (3.47)
DNK	1.243 (1.24)	1.925^a (2.76)	1.698^b (2.35)	1.320^a (2.73)
ESP	0.527^a (3.31)	0.782^a (4.71)	0.177 (0.90)	0.355^c (1.71)
FIN	1.556^a (10.13)	1.043^a (9.30)	2.061^a (8.62)	1.412^a (8.45)
FRA	0.880^a (4.75)	0.896^a (6.29)	1.169^a (4.46)	1.048^a (5.58)
GBR	0.688^a (8.76)	0.477^a (9.57)	1.424^a (14.39)	1.183^a (15.03)
IRL	0.074 (0.28)	0.321 (1.48)	0.485 (0.89)	0.126 (0.28)
ITA	-0.365^a (−3.44)	−0.260 (−1.50)	-0.427^a (−3.04)	−0.206 (−1.17)
JPN	0.832^a (3.96)	0.713^a (3.25)	0.681^a (4.52)	0.655^a (4.55)
KOR	0.626 (0.52)	2.914^a (4.16)	1.006 (1.26)	2.237^a (4.60)
NLD	0.832^a (2.65)	0.644^c (1.93)	0.523^c (1.92)	0.412 (1.10)
NOR	1.138^a (7.26)	1.004^a (9.81)	2.080^a (14.42)	2.056^a (13.51)
SWE	0.364^b (2.24)	0.329^a (3.52)	1.073^a (5.85)	0.915^a (7.16)
USA	0.486 (1.37)	0.699^a (3.27)	0.571 (0.90)	0.804^b (2.07)
EU-12	0.590^a (9.65)	0.599^a (11.84)	0.890^a (26.17)	0.832^a (16.18)
Whole sample	0.586^a (11.63)	0.800^a (16.86)	0.853^a (24.52)	0.933^a (28.55)

Notes: Data coverage: 1970-2007 (except Japan: 1974-2007). All regressions include country fixed effects, time dummies and country specific trends. ^{a}, ^{b} and ^{c} denote significance at 1%, 5% and 10% levels. Heteroskedasticity and autocorrelation consistent t-statistics are reported in parentheses.

categories, 'Not classifiable by economic activity' and 'Unemployed seeking their first job' has been split between tradables and non-tradables according to the shares of total employment between tradables and non-tradables, by year. Average EU-10 unemployment rate shown in Table 9 is the unweighted sum of ten EU members' unemployment rates. Source: LABORSTA database from the International Labour Organization (ILO).

- Job finding rate denoted by m^j $(j = T, N)$: This parameter has been estimated at a sectoral level by adopting the methodology proposed by Shimer [2012]. As Shimer [2012], we ignore movements in and out of the overall labor force. Since we compute the job finding rate for the traded and the non traded sector, we have to further assume that labor force is fixed at a sectoral level, i.e., we ignore reallocation of labor across sectors. More details on the model as well as the derivations of the results can be found below.

- Labor market tightness denoted by θ^j $(j = T, N)$: This variable is calculated as employment vacancies on the number of unemployed, by sector. While series for unemployed workers by economic activity are taken from LABORSTA (ILO), series for job vacancies at a sectoral level taken from various databases, as detailed below.

  Once industries have been classified as traded or non traded, series for employment vacancies are constructed by adding job openings of all sub-industries in sector $j = T, N$. The same logic applies to calculate unemployed workers in sector j. The labor market tightness θ^j is the ratio of job vacancies V^j to unemployed workers U^j in sector j.

$$\theta^j = \frac{\sum_{i=1}^{N_j} V_i^j}{\sum_{i=1}^{N_j} U_i^j} = \frac{V^j}{U^j},$$

  where i are industries classified in sector j and N_j is the number of industries in sector $j = T, N$.

  Eurostat provides series for continental European countries that cover 15 sectors, according to NACE 1-digit classification. Sectors have been aggregated into tradables (Agriculture, hunting and forestry; Financial intermediation; Fishing; Manufacturing; Mining and quarrying; Transport, storage and communication) and non tradables (Construction; Education; Electricity, gas and water supply; Health and social work; Hotels and restaurants; Other community, social and personal service activities; Public administration and defense; Compulsory social security; Real estate, renting and business activities; Wholesale and retail trade, repair of motor vehicles, motorcycles and personal and household goods). For continental European countries, the longest available period ranges from 2002 to 2007.

  BLS provides series for the US which cover 18 sectors according to industrial classification. Sectors have been aggregated into tradables (Durable goods manufacturing; Finance and insurance; Information; Mining and logging; Nondurable goods manufacturing; Professional and business services; Transportation, warehousing, and utilities) and non-tradables (Accommodation and food services; Arts, entertainment, and recreation; Construction; Educational services; Federal Health care and social assistance; Other services; Real estate and rental and leasing; Retail trade; State and local; Wholesale trade). For the US, the longest available period ranges from 2002 to 2007.

  OFS provides series for the UK that cover 19 sectors, according to SIC 2007 classification. Sectors have been aggregated into tradables (Financial and insurance activities; Information and communication; Manufacturing; Mining and quarrying; Transport and storage) and non tradables (Accomodation and food service activities; Administrative and support service activities; Arts, entertainment and recreation; Construction; Education; Electricity, gas, steam and air conditioning supply; Human health and social work activities; Other service activities; Public administration and defense; Compulsory social security; Real estate activities; Water supply, sewerage, waste and remediation activities; Wholesale and retail trade; repair of motor vehicles and motor cycles). Note that the sector "Professional, scientific and technical activities" has been evenly split across tradables and non-tradables. For the UK, the longest available period ranges from 1988 to 2007.

  Source: Eurostat database for continental European countries, LABSTAT database from the U.S. Bureau of Labor Statistics for the US, Labour Market Statistics from the Office for National Statistics for the UK.

- Unemployment benefit net replacement rate denoted by r: The net replacement rate measure is defined as the average of the net unemployment benefit (including social assistance and housing benefit) replacement rates for two earnings levels, three family situations. Average EU-12 unemployment benefit replacement rate shown in Table 9 is the unweighted sum of twelve EU members' replacement rates. Source: OECD, Benefits and Wages Database.

- Firing cost denoted by x: the last column of Table 9 is a measured of the strictness of legal protection against dismissals captured by the firing tax x in our model; it is calculated as the sum of the average advance notice and average severance payment after 4 and 20 years of employment (Source: Aleksynska and Schindler [2011]); x is expressed in monthly salary equivalents and is averaged over the period 1980-2005.

  gives the severance pay for redundancy dismissal after 20 years of continuous employment redundancy. The period is running from 2006 to 2013. Source: Historical data, Doing Business Database.

Coverage: Series of employment and unemployment by economic activity provided by ILO are not available for France, the Netherlands, Norway; while such data are available for Korea, unemployment by duration provided by the OECD is not available and thus makes impossible the estimates of the monthly job finding and job destruction rates. For these four countries, we proceeded as follows:

- Job finding rate denoted by m: Monthly job finding rates come from Hobijn and Sahin [2009] who hgive average values for France (1975-204), the Netherlands (1983-2004), Norway (1983-2004). For Korea, we average the job finding rates taken from Chang et al. [2004] over 1993-1994.
- Unemployment rate denoted by u: Unemployed (workers as share of the labor force), in %: France (1975-204), Korea (1993-1994), the Netherlands (1983-2004), Norway (1983-2004).
- Job separation rate denoted by s: Monthly job job separation rates are computed so as to be consistent with the steady-state unemployment rate given by $u = \frac{s}{s+m}$.

Table 9: Data to Calibrate the Labor Market

Country	Period	u^T	u^N	u	m^T	s^T	m^N	s^N	Period	θ^T	θ^N	Period	θ	r	x
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AUS	95-07	0.072	0.062	0.065	0.304	0.0236	0.278	0.0184				80-07	0.13	52.4	1.9
AUT	94-07	0.037	0.044	0.042	0.126	0.0048	0.123	0.0057	04-05	0.17	0.27	80-07	0.18	52.8	6.6
BEL	01-07	0.077	0.079	0.078	0.067	0.0056	0.064	0.0055				82-03	0.05	65.2	5.7
CAN	87-07	0.082	0.084	0.083	0.269	0.0241	0.269	0.0247						52.9	2.8
DEU	95-07	0.101	0.091	0.094	0.067	0.0075	0.062	0.0062	06-07	0.21	0.40	80-07	0.09	60.6	3.4
DNK	94-04	0.064	0.061	0.062	0.245	0.0167	0.247	0.0161						78.2	4.5
ESP	92-07	0.147	0.161	0.156	0.097	0.0167	0.094	0.0181				80-04	0.03	47.2	9.4
FIN	91-07	0.087	0.118	0.107	0.137	0.0130	0.135	0.0180	02-07	0.21	0.2	81-07		65.1	3.9
FRA	75-04	n.a.	n.a.	0.081	0.067	0.0059	0.067	0.0059				89-07	0.07	51.8	3.7
GBR	88-07	0.073	0.066	0.068	0.163	0.0129	0.161	0.0114	01-07	0.30	0.48	80-07	0.24	58.3	2.9
IRL	86-97	0.130	0.154	0.144	0.048	0.0071	0.045	0.0082						58.2	2.0
ITA	93-07	0.094	0.098	0.097	0.062	0.0065	0.059	0.0064						10.1	1.7
JPN	03-07	0.033	0.033	0.033	0.171	0.0058	0.165	0.0056	0.64			80-07	0.27	50.1	3.8
KOR	92-07	0.041	0.027	0.035	0.262	0.0112	0.262	0.0072	0.90					37.5	13.0
NLD	83-04	n.a.	n.a.	0.064	0.047	0.0032	0.047	0.0032						68.2	3.0
NOR	83-04	n.a.	n.a.	0.045	0.305	0.0143	0.305	0.0143				80-07	0.18	53.5	2.0
SWE	95-07	0.056	0.060	0.059	0.233	0.0138	0.231	0.0148	05-07	0.17	0.17	82-07	0.19	54.9	4.8
USA	03-07	0.048	0.053	0.052	0.444	0.0224	0.440	0.0246	01-07	0.43	0.65	01-07	0.59	26.1	0.0
Average EU-12		0.087	0.093	0.091	0.124	0.0118	0.122	0.0125		0.21	0.30		0.12	55.9	4.3
Average OECD		0.079	0.083	0.081	0.174	0.0148	0.170	0.0154		0.24	0.34		0.18	52.4	4.2

Notes: Regarding sectoral unemployment rates, job finding and separation rates for DNK, the period 1994-2007 has to be read 1994-1998 and 2002-2004; u^j is the sectoral unemployment rate (source: ILO); m^j and s^j are the monthly job finding and job destruction rate in sector $j = T, N$, respectively (source: ILO); the monthly job destruction rate has been estimated by adopting the methodology developed by Shimer [2012] except for FRA, NLD, NOR and KOR; θ^j is the labor market tightness in sector j (source: Eurostat for European countries and Bureau of Labor Statistics for the U.S.); r is the average net unemployment benefit replacement rate over the period 1980-2007 (source: OECD Benefits and Wages Database); x is the firing cost expressed in monthly salary equivalents and is averaged over the period 1980-2005 (source: Fondazione De Benedetti).

References

Aleksynska, Mariya and Martin Schindler (2011) Labour Market Regulation in Low-, Middle* and High-Income Countries: A New Panel Database. *IMF working paper.*

Altissimo, Filippo, Pierpaolo Benigno and Diego Rodriguez Palenzuela (2011) Inflation Differentials in a Currency Area: Facts, Explanations and Policy. *Open Economies Review*, 22, 189-233.

Andolfatto, D. (1996) Business Cycles and Labor-Market Search. *American Economic Review* 86(1), pp. 112-132.

Artuç, Erhan, Shubham Chaudhuri, and John McLaren (2010) Trade Shocks and Labor Adjustment: A Structural Empirical Approach. *American Economic Review*, 100(3), pp. 1008-45,

Balassa, Bela (1964) The Purchasing Power Parity Doctrine: a Reappraisal. *Journal of Political Economy*, 72, pp. 584-596.

Barnichon, Regis (2012) Vacancy Posting, Job Separation and Unemployment Fluctuations. *Journal of Economic Dynamics and Control*, 36(3), pp. 315-330.

Bems, Rudolfs and K. Jonsson Hartelius (2006) Trade Deficits in the Baltic States: How Long will the Party Last? *Review of Economic Dynamics*, 4, pp. 179-209.

Bergin Paul R., Reuven Glick and Alan M. Taylor (2006) Productivity, Tradability, and the Long-Run Price Puzzle. *Journal of Monetary Economics*, vol. 53(8), 2041-2066.

Boeri and Van Ours (2008) The Economics of Imperfect Labor Markets. Second edition. Princeton University Press.

Breitung Jörg (2000) The Local Power of Some Unit Root Tests for Panel Data, in B. Baltagi (ed.), Advances in Econometrics, vol. 15: Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Amsterdam: JAI Press, 161-178.

Brock, Ellen and Sabien Dobbelaere (2006) Has International Trade Affected Workers' Bargaining Power? *Review of World Economics*, 142(2), pp 233-266.

Cahuc, Pierre, Christian Gianella, Dominique Goux and Jacques Mairesse (1998) Equalizing Wage Differences and Bargaining Power. *Discussion Paper INSEE* No. 98-05.

Cahuc, Pierre, Fabien Postel-Vinay, and Jean-Marc Robin (2006) Wage Bargaining with On-the-Job Search: Theory and Evidence. *Econometrica*, 74(2), pp. 323-364.

Canzoneri, Matthew B., Robert E. Cumby and Behzad Diba (1999) Relative Labor Productivity and the Real Exchange Rate in the Long Run: Evidence for a Panel of OECD Countries. *Journal of International Economics*, vol. 47, 245-266.

Chang, Yongsung, Jaeryang Nam, and Changyong Rhee (2004) Trends in Unemployment Rates in Korea: A Search-Matching Model Interpretation. *Journal of the Japenese and the International Economies*, 18(2), pp. 241-263.

Cordoba (de), Gonzalo Fernandez and Timothy J. Kehoe (2000) Capital Flows and Real Exchange Rate Fluctuations Following Spain's Entry into the European Community. *Journal of International Economics*, 51(1), 49-78.

Crépon, Bruno, Rozen Desplatz and Jacques Mairesse (1999) Estimating price cost margins, scale economies and workers' bargaining power at the firm level. *Discussion Paper INSEE No.* 99-17.

Davis Steven J. and John C. Haltiwanger (1999) Gross job flows, Handbook of Labor Economics, in: O. Ashenfelter and D. Card (ed.), volume 3, Chapter 41, pages 2711-2805, Elsevier.

De Gregorio, Jose, Alberto Giovannini and Holger C. Wolf (1994) International Evidence on Tradables and Nontradables Inflation. *European Economic Review*, 38, pp. 1225-1244.

Dix-Carneiro, Rafael (2014) Trade Liberalization and Labor Market Dynamics. *Econometrica*, 82(3), pp. 825-885.

Dix-Carneiro, Rafael, and Brian Kovak (2015) Trade Reform and Regional Dynamics: Evidence from 25 Years of Brazilian Matched Employer-Employee Data. NBER Working Paper No. 20908

Domeij, David, and Martin Flodén (2006) The Labor-Supply Elasticity and Borrowing Constraints: Why Estimates are Biased. *Review of Economic Dynamics* 9, 242-262.

European Union KLEMS (2011) Growth and Productivity Accounts.

Fiorito, Riccardo and Giulio Zanella (2008) Labor Supply Elasticities: Can Micro Be Misleading for Macro? *Quaderni del Diparmento de Economia Politica* No. 547.

Ghironi, Fabio and Marc J. Melitz (2005) International Trade and Macroeconomic Dynamics with Heterogenous Firms. *Quarterly Journal of Economics*, 120(3), pp. 865-915.

Hadri, Kaddour (2000) Testing for Unit Roots in Heterogeneous Panel Data. *Econometrics Journal*, 3, pp. 148-161.

Haefke, Christian and Michael Reiter (2011) What Do Participation Fluctuations Tell Us About Labor Supply Elasticities? *IZA Discussion Paper*, No. 6039.

Heijdra, Ben J., and Jenny E. Ligthart (2002) The Hiring Subsidy cum Firing Tax in a Search Model of Unemployment. *Economics Letters*, 75, pp. 97-108.

Heijdra, Ben J., and Jenny E. Ligthart (2009) Labor Tax Reform, Unemployment and Search. *International Tax and Public Finance*, 16, pp. 82-104.

Hobijn, Bart and Aysegül Sahin (2009) Job-Finding and Separation Rates in the OECD. *Economics Letters*, 104(3), pp. 107-111.

Horvath, Michael (2000) Sectoral Shocks and Aggregate Fluctuations. *Journal of Monetary Economics*, 45, pp. 69-106.

Hosios, Arthur J. (1990) On the Efficiency of Matching and Related Models of Search and Unemployment. *Review of Economic Studies*, 57(2), pp. 279-98.

International Monetary Fund (2011), *Government Finance Statistics Yearbook*, IMF, Washington D.C.

Im, Kyung So, Hashem M. Pesaran and Yongcheol Shin (2003) Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics*, 115, pp. 53-74.

Jensen, Bradford J., and Lori G. Kletzer, (2006) Offshoring White-Collar Work, in Susan M. Collins and Lael Brainard, eds., *Brookings Trade Forum* 2005, Offshoring White-Collar Work. Brookings Institution: Washington, DC, pp. 75-134.

Kakkar, Vikas (2003) The Relative Price of Nontraded Goods and Sectoral Total Factor Productivity: an Empirical Investigation. *The Review of Economics and Statistics*, 85(2), pp. 444-452.

Kambourov, Gueorgui (2009) Labour Market Regulations and the Sectoral Reallocation of Workers: The Case of Trade Reforms. *The Review of Economic Studies*, 76, pp. 1321-1358.

Kehoe, Patrick, Virgilu Midrigan and Elena Pastorino (2014) Debt Constraints and Unemployment. Mimeo.

Kennan, John K., and James W. Walker (2011) The Effect of Expected Income on Individual Migration Decisions. *Econometrica*, 79(1), pp. 211-251.

Kim, Kunhong, and Young Sik Kim (2006) How Important is the Intermediate Input Channel in Explaining Sectoral Employment Comovement over the Business Cycle? *Review of Economic Dynamics*, 9, pp. 659-682.

Kuroda, Sachiko and Isamu Yamamoto (2007) Estimating Frisch Labor Supply Elasticity in Japan. *Imes Discussion Paper Series* No. 2007-E-5.

Lane, Philip R., and Gian Maria Milesi-Ferretti (2002) External Wealth, the Trade Balance, and the Real Exchange Rate. *European Economic Review*, 46(6), pp. 1049-1071.

Lane, Philip R., and Gian Maria Milesi-Ferretti (2004) The Transfer Problem Revisited: Net Foreign Assets and Real Exchange Rates. *The Review of Economics and Statistics*, 86(4), pp. 841-857.

Lee, Donghoon and Kenneth I. Wolpin (2006) Intersectoral Labor Mobility and the Growth of the Service Sector. *Econometrica*, 74, pp. 1-46.

Levin Andrew, Chien-Fu Lin and Chia-Shang James Chu (2002) Unit Root Test in Panel Data: Asymptotic and Finite Sample Properties. *Journal of Econometrics*, 108, pp. 1-24.

Maddala, Gangadharrao S. and Shaowen Wu (1999) A Comparative Study of Unit Root Tests with Panel Data and a New Test. *Oxford Bulletin of Economics and Statistics*, 61, pp. 631-652.

Mark, Nelson C. and Donggyu Sul (2003) Vector Estimation by Panel DOLS and Long-run Money Demand. *Oxford Bulletin of Economics and Statistics*, 65(5), pp. 655-680.

Mendoza, Enrique, G. (1995) The Terms of Trade, Real Exchange Rate and Economic Fluctuations. *International Economic Review*, 36, pp. 101-137.

Merz, Monika, (1995) Search in the Labor Market and the Real Business Cycle. *Journal of Monetary Economics* 36(2), pp. 269-300.

Morshed, Mahbub A. K. M., and Stephen J. Turnovsky (2004) Sectoral Adjustment Costs and Real Exchange Rate Dynamics in a Two-sector Dependent Economy. *Journal of International Economics*, 63, pp. 147-177.

Nickell, Stephen, Luca Nunziata and Wolfgang Ochel (2005) Unemployment in the OECD since the 1960s: What do we Know? *Economic Journal*, 115, pp. 1-27

Organization for Economic Cooperation and Development (2011a), *Input-Output Database*, OECD, Paris.

Organization for Economic Cooperation and Development (2011b), *National Accounts: General Government Accounts*, OECD, Paris.

Organization for Economic Cooperation and Development (2008c), *Annual National Accounts*, OECD, Paris.

Pedroni, Peter (1999) Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors. *Oxford Bulletin of Economics and Statistics*, 61, pp. 653-670.

Pedroni, Peter (2000) Fully Modified OLS for Heterogeneous Cointegrated Panels. *Advances in Econometrics*, vol. 15, edited in B. Baltagi: Nonstationary Panels, Panel Cointegration and Dynamic Panels, 93-130.

Pedroni, Peter (2001) Purchasing Power Parity Tests in Cointegrated Panels. *The Review of Economics and Statistics*, 83(4), pp. 727-731.

Pedroni, Peter (2004) Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. *Econometric Theory*, 20, pp. 597-625.

Pesaran, Hashem M. and Ron P. Smith (1995) Estimating Long-run Relationships from Dynamic Heterogeneous Panels. *Journal of Econometrics*, 68, pp. 79-113.

Pesaran, Hashem M., Yongcheol Shin and Ron P. Smith (1999) Pooled Mean Group Estimation of Dynamic Heterogeneous Panels.*Journal of the American Statistical Association*, 94, pp. 621-634.

Petrongolo, Barbara and Christopher A. Pissarides. (2001) Looking Into the Black Box: A Survey of the Matching Function. *Journal of Economic Literature*, 39(2), pp. 390-431.

Samuelson Paul A. (1964) Theoretical Notes on Trade Problems. *Review of Economics and Statistics*, 46, pp. 145-164.

Schmillen, Achim (2011) Are Wages Equal Across Sectors of Production? A Panel Data Analysis for Tradable and Non-Tradable Goods. OEI Working Paper No. 285.

Schubert, Stefan (2013) Unemployment Dynamics in a Short-Run Two Sector Model of a Tourism Exporting Small Open Economy. *Tourism Economics*, 19(5), pp. 1049-1076.

Sheng, Yu, and Xinpeng Xu (2011) Real Exchange Rate, Productivity and Labor Market Rigidities. *Journal of International Money and Finance*, 30, pp. 587-603.

Shi, Kang (2011) Sectoral Labor Adjustment and Monetary Policy in a Small Open Economy. *Journal of Macroeconomics*, 33(4), pp. 634-643.

Shi, Shouyong, and Quan Wen (1999) Labor Market Search and the Dynamic Effects of Taxes and Subsidies. *Journal of Monetary Economics*, 43, 457-495.

Shimer, Robert (2005) The Cyclical Behavior of Equilibrium Unemployment and Vacancies. *American Economic Review* 95(1), pp. 25-49.

Shimer, Robert (2012) Reassessing the Ins and Outs of Unemployment. *Review of Economic Dynamics*, 15(2), pp. 127-148.

Stockman Alan C. and Linda L. Tesar (1995) Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements. *American Economic Review* 85(1), pp. 168-185.

Turnovsky, Stephen J. (1997) *International Dynamic Macroeconomics*, MIT Press, Cambrige, MA.

United Nations Statistics Division (2011) Classification of Individual Consumption by Purpose. United Nations, New York.

Veracierto, Marcelo (2008) Firing Costs And Business Cycle Fluctuations. *International Economic Review*, vol. 49(1), pages 1-39.

Visser, Jelle (2009), ICTWSS Database, Database on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts in 34 countries between 1960 and 2007, Institute for Advanced Labour Studies, AIAS, University of Amsterdam, Amsterdam. http://www.uva-aias.net/207

TECHNICAL CHANGE BIASED TOWARD THE TRADED SECTOR AND LABOR MARKET FRICTIONS

TECHNICAL APPENDIX

NOT MEANT FOR PUBLICATION

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A Data Description

A.1 Data: Source and Construction

Coverage: Our sample consists of a panel of 18 countries: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Germany (DEU), Denmark (DNK), Spain (ESP), Finland (FIN), France (FRA), the United Kingdom (GBR), Ireland (IRL), Italy (ITA), Japan (JPN), Korea (KOR), the Netherlands (NLD), Norway (NOR), Sweden (SWE), and the United States (USA). The period is running from 1970 to 2007, except for Japan (1974-2007). These countries have the most extensive coverage of variables of our interest.

Sources: We use the EU KLEMS [2011] database (the March 2011 data release) for all countries of our sample with the exceptions of Canada and Norway. For these two countries, sectoral data are taken from the Structural Analysis (STAN) database provided by the OECD [**?**]. Both the EU KLEMS and STAN databases provide annual data at the ISIC-rev.3 1-digit level for eleven industries.

The eleven 1-digit ISIC-rev.3 industries are split into tradables and non tradables sectors. To do so, we adopt the classification proposed by De Gregorio et al. [1994] who treat an industry as traded when it exports at least 10% of its output. Following Jensen and Kletzer [2006], we have updated the classification suggested by De Gregorio et al. [1994] by treating "Financial Intermediation" as a traded industry. Jensen and Kletzer [2006] use the geographic concentration of service activities within the United States to identify which service activities are traded domestically. The authors classify activities that are traded domestically as potentially traded internationally. The idea is that when a good or a service is traded, the production of the activity is concentrated in a particular region to take advantage of economies of scale in production.

Jensen and Kletzer [2006] use the two-digit NAICS (North American Industrial Classification System) to identify tradable and non tradable sectors. We map their classification into the NACE-ISIC-rev.3 used by the EU KLEMS database. The mapping was clear for all sectors except for "Real Estate, Renting and Business Services". According to the EU KLEMS classification, the industry labelled "Real Estate, Renting and Business Services" is an aggregate of five sub-industries: "Real estate activities" (NACE code: 70), "Renting of Machinery and Equipment" (71), "Computer and Related Activities" (72), "Research and Development" (73) and "Other Business Activities" (74). While Jensen and Kletzer [2006] find that industries 70 and 71 can be classified as tradable, they do not provide information for industries 72, 73 and 74. We decided to classify "Real Estate, Renting and Business Services" as non tradable but conduct a robustness check by contrasting our empirical findings when "Real Estate, Renting and Business Services" is non traded with those when "Real Estate, Renting and Business Services" is traded.

Traded Sector comprises the following industries: Agriculture, Hunting, Forestry and Fishing; Mining and Quarrying; Total Manufacturing; Transport, Storage and Communication; and Financial Intermediation.

Non Traded Sector comprises the following industries: Electricity, Gas and Water Supply; Construction; Wholesale and Retail Trade; Hotels and Restaurants; Real Estate, Renting and Business Services; and Community Social and Personal Services.

Relevant to our work, the EU KLEMS and STAN database provides series, for each industry and year, on value added at current and constant prices, permitting the derivation of sectoral deflators of value added, as well as details on labor compensation and employment data, allowing the construction of sectoral wage rates. We describe below the construction for the data employed in Section 2 (mnemonics are given in parentheses):

- Sectoral value-added deflator P_t^j for $j = T, N$: value added at current prices (VA) over value added at constant prices (VA_QI) in sector j. Source: EU KLEMS database. The relative price of non tradables P_t corresponds to the ratio of the value added deflator of non traded goods to the value added deflator of traded goods: $P_t = P_t^N / P_t^T$.
- Sectoral labor L_t^j for $j = T, N$: total hours worked by persons engaged (H_EMP) in sector j. Source: EU KLEMS database.
- Sectoral nominal wage W_t^j for $j = T, N$: labor compensation in sector j (LAB) over total hours worked by persons engaged (H_EMP) in that sector. Source: EU KLEMS database. The relative wage, Ω_t is calculated as the ratio of the nominal wage in the non traded sector W^N to the nominal wage in the traded sector: $\Omega_t = W_t^N / W_t^T$.

Summary statistics of the data used in the empirical analysis are displayed in Table 11. As shown in the first three columns, all countries of our sample experience technological change biased toward the traded sector, an appreciation in the relative price of non tradables and a decline in the ratio of the non traded wage relative to the traded wage.

Because data source and construction are heterogenous across variables as a result of different nomenclatures, Table 11 provides a summary of the classification adopted to split value added and its demand components as well intro traded and non traded goods.

A.2 Data: Source and Construction

To empirically assess the role of labor market institutions in the determination of the relative wage response to higher productivity growth in tradables relative to non tradables, we use three indicators aimed at capturing the stringency of labor market regulation. We detail below the construction and the source of these three indicators:

- The difficulty of redundancy is measured by the **employment protection legislation** index, EPL_{it} in country i at time t, provided by OECD which captures the strictness of legal protection against dismissals for permanent workers. Source for EPL_{it}: OECD Labour Market Statistics database. Data coverage: 1985-2007 (1990-2007 for KOR). This index can be misleading since regulation was eased for temporary contracts (in Spain) while the regulation for workers with permanent contracts hardly changed. To have a more accurate measure of legal protection against dismissals, we construct a new index denoted by EPL^{adj}_{it} in country i at time t by adjusting EPL_{it} for regular workers with the share share^{perm}_{it} of permanent workers in the economy, i.e., $\text{EPL}^{adj} = \text{EPL}_{it} \times \text{share}^{perm}_{it}$. Source for share^{perm}_{it}: OECD Labour Market Statistics database. Data coverage: 1985-2007 (1990-2007 for KOR).
- The generosity of the unemployment benefit scheme, r_{it} in country i at time t, is commonly captured by the **unemployment benefit replacement rate**. It is worthwhile noticing that the unemployment benefit rates are very similar across counties when considering short-term unemployment (less than one year) but display considerable heterogeneity for long-term unemployment. To have a more accurate measure of the generosity of the unemployment benefit scheme, we calculate r as the average of the net unemployment benefit (including social assistance and housing benefit) replacement rates for two earnings levels and three family situations. Source: OECD, Benefits and Wages Database. Data coverage: 2001-2007. In order to have longer time series, we calculated r over the period running from 1970 to 2000, by using the growth rate of the historic OECD measure of benefit entitlements which is defined as the average of the gross unemployment benefit replacement rates for two earnings levels, three family situations and three durations of unemployment. Source: OECD, Benefits and Wages Database. Data coverage: 1970-2001 for all countries while data are unavailable for Korea.
- The worker bargaining power is measured by the **collective bargaining coverage**, BargCov_{it}, which corresponds to the employees covered by collective wage bargaining agreements as a proportion of all wage and salary earners in employment with the right to bargaining. Source: Data Base on Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts, 1960-2010 (ICTWSS), version 3.0, Jelle Visser [2009]. Data coverage: 1970-2007 for AUS, AUT, CAN, DEU, DNK, FIN, GBR, IRL, ITA, JPN, SWE and USA, 1970-2005 for NLD and NOR, 1970-2002 for BEL and FRA, 1977-2004 for ESP and 2002-2006 for KOR.

Summary statistics of the labor market regulation indicators used in the empirical analysis are displayed in Table 11.

A.3 Calibration of the Labor Market

To calibrate the labor market for the traded and the non traded sector, we need to estimate the job finding and the job destruction rate for each sector. To do so, we apply the methodology developed by Shimer [2012] who assume that the labor force is fixed. Applying the same logic to our two-sector model, we need to impose that the labor force F^j is fixed at a sectoral level. The implication of such an assumption is twofold. First, we explicitly assume that there are no movements into and out of the labor force. Second, we assume that there are no movements between the traded and the non traded sectors. Reassuringly, Shimer [2012] shows that a two-state model where workers simply transition between employment and unemployment, shows that a two-state model does a good job of capturing unemployment fluctuations. Because the reallocation of labor across sectors is relatively low, the second assumption should not substantially affect the results.

The presentation below borrows heavily from Elsby, Hobijn, and Sahin [2013]. We assume that during period t, all unemployed workers find a job according to a Poisson process with arrival rate $m^j(t) = -ln\left(1 - M^j(t)\right)$ and all employed workers lose their job according to a Poisson process with arrival rate $s^j(t) = -ln\left(1 - S^j(t)\right)$. We refer to $m^j(t)$ and $s^j(t)$ as the job finding and job destruction rates in sector j and to $M^j(t)$ and $S^j(t)$ as the corresponding probabilities.

The evolution over time of the unemployed workers, which we denote by $U^j(t)$, can be written as:

$$\dot{U}^j(t) = s^j(t)L^j(t) - m^j(t)U^j(t), \tag{56}$$

Table 10: Construction of Variables and Data Sources

Variable	Countries covered	Period	Construction and aggregation	Database
Value added Y^T & Y^N (constant prices)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	T: Agriculture, Mining, Manufacturing, Transport, Finance Intermediation N: Electricity, Construction, Trade, Hotels, Real Estate, Personal Services	EU KLEMS
Value added $P^T Y^T$ & $P^N Y^N$ (current prices)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	T: Agriculture, Mining, Manufacturing, Transport, Finance Intermediation N: Electricity, Construction, Trade, Hotels, Real Estate, Personal Services	EU KLEMS
Labor L^T & L^N (total hours worked by persons engaged)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	T: Agriculture, Mining, Manufacturing, Transport, Finance Intermediation N: Electricity, Construction, Trade, Hotels, Real Estate, Personal Services	EU KLEMS
Labor compensation LAB^T & LAB^N (current prices)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	T: Agriculture, Mining, Manufacturing, Transport, Finance Intermediation N: Electricity, Construction, Trade, Hotels, Real Estate, Personal Services	EU KLEMS
Consumption C^T & C^N (constant prices)	BEL (95-07), DEU (91-07), DNK, ESP (95-07), FIN (75-07), FRA, ITA, GBR (90-07), IRL (96-07) JPN (80-07), KOR, NLD (80-07), SWE (93-07), USA	1970-2007	T: Food, Beverages, Clothing, Furnishings, Transport, Recreation, Other N: Housing, Health, Communication, Education, Restaurants, Recreation (Recreation is defined as 50% tradable and 50% non tradable)	COICOP
Government spending $P^T G^T$ & $P^N G^N$ (current prices)	BEL, DEU (91-07), DNK, ESP (95-07), FIN, FRA (95-07), GBR, IRL, ITA, JPN, KOR (00-07), NLD (95-07), SWE (95-07), USA	1990-2007	T: Energy, Agriculture, Manufacturing, Transport N: Public Services, Defense, Safety, Education, Health, Welfare, Housing, Environment, Recreation	OECD-FMI
Trade balance NX (constant prices)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN, KOR, NLD, SWE, USA	1970-2007	External balance of goods and services at current prices (source: OCDE) over price of traded goods (P^T)	authors' calculations
Price P^T & P^N (value added deflator)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	Value added at current prices ($P^j Y^j$) over value added at constant prices (Y^j)	authors' calculations
Relative Price P (index 1995=100)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	Value added deflator of non traded goods (P^N) over value added deflator of traded goods (P^T)	authors' calculations
Wage W^T & W^N (nominal and per hour)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	Labor compensation (LAB^j) over total hours worked by persons engaged (L^j)	authors' calculations
Relative Wage Ω (index 1995=100)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	Nominal wage in non tradables (W^N) over nominal wage in tradables (W^T)	authors' calculations
Sectoral Productivity A^T & A^N (index 1995=100)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN (74-07), KOR, NLD, SWE, USA	1970-2007	Measured by labor productivity $A^j = Y^j/L^j$ θ^j: labor share in value added averaged over the period 1970-2007	authors' calculations
Relative Productivity (index 1995 =100)	BEL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, JPN (74-07), KOR, NLD, ESP, SWE, USA	1970-2007	computed as the ratio A^T/A^N	authors' calculations

Table 11: Summary Statistics per Country

Countries	Variables					
	$\hat{p}$	$\hat{\omega}$	$\hat{a}^T - \hat{a}^N$	r	BargCov	EPL^{adj}
	(1)	(2)	(3)	(4)	(5)	(6)
AUS	0.91	-0.27	1.83	0.50	0.71	1.21
AUT	1.97	-0.72	2.89	0.50	0.97	2.48
BEL	2.26	-0.04	2.53	0.67	0.94	1.65
CAN	0.54	-0.42	1.55	0.54	0.36	0.81
DEU	0.85	-0.62	1.62	0.72	0.69	2.36
DNK	0.78	-0.91	2.21	0.61	0.82	1.93
ESP	2.62	-0.97	3.67	0.41	0.76	2.04
FIN	2.56	-0.78	4.22	0.59	0.86	2.02
FRA	2.14	-0.98	2.68	0.47	0.85	2.11
GBR	1.57	-0.50	2.31	0.63	0.45	1.02
IRL	2.55	-0.88	4.37	0.54	0.58	1.32
ITA	2.02	-0.92	3.05	0.08	0.83	2.53
JPN	2.60	-0.44	2.68	0.51	0.24	1.49
KOR	3.35	-2.15	6.49	0.38	0.11	1.98
NLD	1.86	-0.39	2.38	0.67	0.85	2.60
NOR	-0.37	-0.39	1.96	0.43	0.70	2.06
SWE	2.34	-0.11	2.76	0.48	0.89	2.31
USA	1.74	-0.23	2.64	0.26	0.20	0.24
Average	1.74	-0.23	2.64	0.26	0.20	0.24

Notes: $\hat{p}$ is the relative price of non tradables average growth rate, $\hat{\omega}$ is the relative wage of non tradables average growth rate and $(\hat{a}^T - \hat{a}^N)$ is the average growth rate of the labor productivity differential between tradables and non tradables. Data coverage for $\hat{p}$, $\hat{\omega}$ and $(\hat{a}^T - \hat{a}^N)$ is 1970-2007 (1974-2007 for Japan). r is the unemployment benefit replacement rate. Data coverage: 1970-2000 (2001-2007 for KOR). BargCov is the collective bargaining coverage. Data coverage: 1970-2007 for AUS, AUT, CAN, DEU, DNK, FIN, GBR, IRL, ITA, JPN, SWE and USA, 1970-2005 for NLD and NOR, 1970-2002 for BEL and FRA, 1977-2004 for ESP and 2002-2006 for KOR. EPL^{adj} is the employment protection legislation index adjusted with the share of permanent workers in the economy. Data coverage: 1985-2007 (1990-2007 for KOR).

or alternatively by using the fact that $L_j(t) = F^j - U^j(t)$

$$\dot{U}^j(t) = s^j(t)\left(F^j - U^j(t)\right) - m^j(t)U^j(t), \tag{57}$$

where $s^j(t)$ is the monthly rate of inflow into unemployment, $m^j(t)$ is the monthly outflow rate from unemployment, and t indexes months.

Collecting terms, assuming that the job destruction rate and the job finding rate are constant within years and solving eq. (57), pre-multiplying by $e^{-(m+s)\tau}$, and integrating over the time interval $[t-12, t]$, leads to the temporal path for unemployed workers:

$$U^j(t) = \psi^j(t)\tilde{u}^j(t)F^j(t) + (1-\psi(t))\,U^j(t-12), \tag{58}$$

where $\tilde{u}^j$ is the long-run unemployment rate in sector j:

$$\tilde{u}^j(t) = \frac{s^j(t)}{s^j(t) + m^j(t)}, \tag{59}$$

and ψ^j is the annual rate of convergence to the long-run sectoral unemployment rate:

$$\psi^j(t) = 1 - e^{-\left(s^j(t)+m^j(t)\right)12}. \tag{60}$$

To infer the monthly outflow probability $M^j(t)$ and then the monthly job finding rate $m^j(t)$, we follow Shimer [2012] and write the dynamic equations of sectoral unemployment and sectoral short term unemployment, i.e.,

$$\dot{U}^j(t+d) = s^j(t)L^j(t) - m^j(t)U^j(t),, \tag{61a}$$

$$\dot{U}^{j,<d}(t+d) = s^j(t)L^j(t) - m^j(t)U^{j,<d}(t), \tag{61b}$$

where $L^j(t)$ is employment is sector j and $U^{j,<d}$ denotes short-term unemployment, i.e., the stock of unemployed workers who are employed at some time $\tau \in]t, t+d]$ but lose their job and thus are

unemployed at time $t+\tau$; hence, by construction, $U^{j,<d}(t)=0$ since all short-term unemployed workers were employed at time t. Combining (61a) and (61b) to eliminate $s^j(t)L^j(t)$ leads to a dynamic equation relating changes of unemployment to changes of short-term unemployment:

$$\dot{U}^j(t+d)=\dot{U}^{j,d}(t+d)-m^j(t)\left(U^j(t)-U^{j,<d}(t)\right). \tag{62}$$

Solving eq. (62) above by integrating over $[t-d,t]$, and using the fact that at time t, short-term unemployment is such that $U^{j,<d}(t)=0$ leads to:

$$U^j(t+d)=U^{j,<d}(t+d)+e^{m^j(t)\,.d}U^j(t).$$

Inserting $e^{-m^j(t)\,.d}=\left(1-M^{j,<d}(t)\right)$ where $M^{j,<d}$ is the probability that an unemployed worker exits unemployment within d months, one obtains:

$$U^j(t+d)-U^j(t)=U^{j,d}(t+d)-M^{j,<d}(t)U^j(t) \tag{63}$$

Eq. (63) states that the change of unemployment in sector j is equal to the inflows into unemployment $U^{j,d}(t+d)$ of workers who were employed at time t but are unemployed at time $t+d$ less the number of unemployed workers who find a job $M^{j,<d}(t)U^j(t)$. Solving (63) for $M^{j,<d}(t)$, it is possible to write the probability that an unemployed worker exits unemployment within d months as

$$M^{j,<d}(t)=1-\left[\frac{U^j(t+d)-U^{j,d}(t+d)}{U^j(t)}\right]. \tag{64}$$

The probability of finding a job within d months given by eq. (64) can be mapped as the monthly job finding rate for unemployment duration $d=1,3,6,12$:

$$m^{j,<d}(t)=-\frac{1}{d}\ln\left(1-M^{j,<d}(t)\right). \tag{65}$$

Data are available on annual basis to compute series for sectoral unemployment $U^j(t)$; setting $d=12$ into eq. (64) leads to the probability of

$$M^{j,<12}(t)=1-\left[\frac{U^j(t+12)-U^{j,<12}(t+12)}{U^j(t)}\right]. \tag{66}$$

To estimate the monthly job finding rate $m^{j,<12}(t)$, we use data from the Labor Force Statistics Database provided by the OECD. This dataset contains data on the share of the five durations of unemployment among total unemployment: less than 1 month, >1 month and <3 months,>3 months and <6 months,>6 months and <1 year, 1 year and over. Define the number of unemployed persons that has been unemployed in month t for less than a month as $U_1(t)$, more than one but less than three months as $U_3(t)$, more than three but less than six months as $U_6(t)$, more than six but less than twelve months $U_{12}(t)$, and more than 12 months as $U_\infty(t)$. For clarity purposes, we remove the superscript j and will introduce it again when necessary. The mapping of the definition of short-term unemployment into the data implies $U^{<12}(t)=U_1(t)+U_3(t)+U_6(t)+U_{12}(t)$. Using the fact that $U(t)=U^{<12}(t)+U_\infty(t)$, eq. (66) can be rewritten as follows:

$$1-M^{j,<12}(t)=\frac{U^j_\infty(t)}{U^j(t-12)}, \tag{67}$$

where $U_\infty(t)$ corresponds to unemployed workers in month t for more than 12 months. Applying the same logic as before (see eq. (65)) and setting $d=12$, the monthly job finding rate is:

$$m^{j,<12}(t)=-\frac{\ln\left(U^j_\infty(t)\right)-\ln\left(U^j(t-12)\right)}{12}. \tag{68}$$

Since series for unemployment by duration are expressed in percentage, we define $\omega_\infty(t)$ the share of unemployment for 1 year and over among total unemployment as follows:

$$\omega_\infty(t)=\frac{U_\infty(t)}{U(t)}. \tag{69}$$

Since this share is not available by economic activity, we assume that $\omega_\infty(t)$ is identical across sectors.

$$\omega_\infty(t)=\omega^T_\infty(t)=\omega^N_\infty(t) \tag{70}$$

An alternative way to estimate the monthly job finding rate is to use the duration of unemployment lower than one month. In this configuration, the probability of finding a job can be rewritten as follows:

$$M^{j,<1}(t)=1-\left[\frac{U^j(t)-U^{j,1}(t)}{U^j(t-1)}\right]$$

or alternatively by using the definition of unemployment by duration:

$$1 - M^{j,<1}(t) = \frac{U_3^j(t) + U_6^j(t) + U_{12}^j(t) + U_\infty^j(t)}{U^j(t-1)}. \tag{71}$$

Since $U^j(t-1)$ corresponds to monthly unemployment, we have to convert annual data on a monthly basis:

$$U^j(t-1) = \left(U^j(t-12)\right)^{1/12} \left(U^j(t)\right)^{11/12}. \tag{72}$$

The monthly job finding rate is:

$$m^{j,<1}(t) = -\ln\left(U_3^j(t) + U_6^j(t) + U_{12}^j(t) + U_\infty^j(t)\right) - \ln\left(U^j(t-1)\right) \tag{73}$$

where the construction of $U^j(t-1)$ is given by eq. (72). The job destruction rate can be estimated by solving this equation:

$$U^j(t) = \psi^j(t)\frac{s^j(t)}{s^j(t) + m^{j,<1}(t)}\left(U^j(t) + L^j(t)\right) + (1 - \psi(t))\, U^j(t-1), \tag{74}$$

where $U^j(t-1)$ is given by eq. (72) and ψ^j is the monthly rate of convergence to the long-run sectoral unemployment rate:

$$\psi^j(t) = 1 - e^{-\left(s^j(t) + m^j(t)\right)}. \tag{75}$$