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Abstract

This paper sets up a general oligopolistic equilibrium model with multi-product firms and union wage setting in a subset of industries. By claiming a wage premium, labor unions enforce a decline in firm scale and scope and thus dampen industrial output, with negative feedback effects on the competitive wage and positive ones on firm scale and scope in non-unionized sectors. In this setting, a decline in union density raises labor demand and thus wages in non-unionized as well as unionized industries. This induces a general decline in firm scale and scope, with the respective reduction being more pronounced in non-unionized industries. Aside from analyzing the consequences of deunionization in a closed economy, we also shed light on how multi-product firms respond to a country's movement from autarky to free trade with a symmetric partner country. Access to international trade stimulates labor demand and raises the competitive as well as the union wage, thereby lowering firm scope in all industries. Since the labor market distortion becomes less severe, unionized and non-unionized firms become more similar in the size of their product range. While scope effects are unambiguous, adjustments in firm scale turn out to be less clearcut and *inter alia* depend on the degree of product differentiation.

JEL codes: F12, F16, J51, L13
Keywords: Multi-product firms, General oligopolistic equilibrium, Labor unions, International trade

1 Introduction

Empirical studies highlight the omnipresence of multi-product firms (MPFs). For instance, Bernard, Redding, and Schott (2010) document their dominant role in US manufacturing industries, while Goldberg, Khandelwal, Pavcnik, and Topalova (2008) show that the respective findings are not a peculiarity of developed countries. In view of these observations it is not surprising that the determinants and consequences of MPFs have reached the center stage of economic research. In recent years, attention has been given to the question how MPFs absorb macroeconomic shocks, with international trade being the main shock of interest. By simultaneously accounting for adjustments in both firm scale and scope, this literature has significantly improved our knowledge about how firms respond to macroeconomic changes. However, being concerned with the product market side of the economy, existing studies model factor markets in a rudimentary way. In particular, they assume perfectly competitive labor markets and therefore end up with identical wage payments of all producers. This assumption seems to be restrictive as it is an empirical fact that firms pay differing wages, and wages themselves are a key cost factor and thus an important determinant of both firm scale and scope in models of MPFs.

Shedding light on the role of labor market imperfection for firm scale and scope is the aim of this paper. For this purpose, we set up a general oligopolistic equilibrium (GOLE) model with MPFs along the lines of Eckel and Neary (2010) and enrich this framework by introducing a simple model of union wage setting. In the Eckel and Neary (2010) framework, there is a continuum of industries and a small (exogenous) number of firms competing in quantities within each of these industries. Firms employ labor to produce a range of differentiated product varieties. They have a core competence in one of these varieties which they produce at the lowest marginal cost. By expanding the scope of their product range, firms start manufacturing varieties with a larger distance to their core competence and thus higher marginal production costs.[1] With respect to modeling union wage setting, we rely on a similar framework as Bastos and Kreickemeier (2009). In particular, we assume that labor unions are active in a subset of industries and unilaterally set wages there, while in the rest of the economy firms pay the competitive wage.

The asymmetry of sectors with respect to their labor market institutions is a key aspect of our analysis. It allows us to study the consequences of union wage setting on firm scale and scope and it provides novel insights on how labor market imperfections in certain industries feed back on firm organization in the rest of the economy. Setting a markup on the competitive wage, labor unions enforce a reduction in the output and employment level of unionized firms. While this effect is

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[1] Abstracting from any additional costs of introducing a new variety the model captures the idea of flexible manufacturing, which is a widely used concept of representing MPFs (see Milgrom and Roberts, 1990; Eaton and Schmitt, 1994; Norman and Thisse, 1999; Eckel, 2009). While there are many alternative ways of modeling MPFs (see, for instance, Arkolakis and Muendler, 2007; Feenstra and Ma, 2008; Nocke and Yeaple, 2008; Bernard, Redding, and Schott, 2009; Mayer, Melitz, and Ottaviano, 2010), there are good reasons for relying on the Eckel and Neary (2010) approach when accounting for union wage setting. With oligopolistic competition between a small number of competitors and linear demand in each industry, our model is related to a large and well-established literature on unionized oligopoly. Thus, we can directly compare our results with findings from this literature in order to highlight whether and how previous insights on the interplay between labor market and product market imperfections have to be modified if one accounts for multi- instead of single-product firms.

present in any model of unionized oligopoly, there is an additional adjustment margin in a setting with MPFs. By raising marginal production costs, unions reduce the incentive of firms to operate a wide product range and, hence, they also lower firm scope. Furthermore, union wage setting lowers aggregate employment *ceteris paribus* and thus induces an adjustment in the competitive wage, which must fall in order to clear the labor market in a general equilibrium environment. This decline in the competitive wage raises firm scale and scope in non-unionized industries.

With these insights on the basic mechanics of the model at hand, we can apply our theoretical vehicle to analyze in more detail how previous insights from the literature need to be modified if one takes into account union wage setting in the presence of MPFs. To highlight the relevance of our model, we focus on two specific research questions that have sparked considerable interest in academic circles and, at the same time, are relevant for policy makers who aim at introducing measures of deregulation in product and/or labor markets. The first question we are interested in is how firms absorb changes in labor market institutions. From an empirical point of view, the probably most notable change in labor market institutions is the significant decline in union coverage. This *deunionization* process is a worldwide phenomenon which has been observed in all industrialized economies over the last four decades – although, of course, to a different extent. For instance, as documented by OECD (2004), in the US union density fell from 27% to 13% over the period 1970 to 2000, while in Germany the decline of union density was much less pronounced: it fell from 32% to 25% over the same period.

From Bastos and Kreickemeier (2009) we know that in an otherwise similar framework with single product firms (SPFs), deunionization raises the competitive as well as the union wage and thus lowers scale of both unionized and non-unionized firms. Since the union wage increases less than proportionally, deunionization lowers the scale differential between the two types of producers. In this paper, we show that firm-level adjustments become more sophisticated if firms produce more than just a single variety and that the endogeneity of the product range leads to further interesting results upon how firms respond to changes in labor market institutions. To be more specific, deunionization induces an increase in the competitive as well as the union wage, similar to the model with SPFs. However, in a setting with MPFs the associated cost increase renders production of those varieties that have the largest distance to a firm's core competence unattractive, so that firms reduce the scope of their product range and thus shrink at the extensive margin. Both the cost increase and the shortening of the product range induce a decline in total firm scale, while the output reduction for a single variety is the stronger, the further away it is from a firm's core competence. Furthermore, by focusing on the production of high-competence, i.e. low-cost, varieties, all firms (except for the newly deunionized ones) can produce a higher level of output with a given level of labor input and thus are more productive on average.[2] A further notable difference between our setup and the one with SPFs arises with respect to the impact of deunionization on the total number of product varieties that are available for consumers. While in a model with an exogenous number

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[2]For further discussion on how to measure labor productivity in a setting with MPFs see Eckel and Neary (2010). For our purpose, relying on the rudimentary measure of (unweighted) output per worker is meaningful, as this measure allows us to present the main insights from our analysis in the simplest possible way.

of SPFs the number of available product varieties stays constant by construction, in our framework with MPFs deunionization also impacts the total number of available varieties, with the sign of the respective effect depending on the prevailing labor market institutions. To be more specific, if the share of unionized sectors shrinks in a country with a low union density, the increase in the number of varieties produced by newly deunionized MPFs dominates the decline in the number of varieties produced by all other MPFs and, hence, the total number of varieties increases. The opposite is true in countries with high union density. Finally, by weakening the labor market distortion deunionization lowers the union wage premium and thus firms become more similar in both scale and scope if union density falls.

In a second application of our model, we investigate how firm scale and scope are affected if a country opens up for free trade with a symmetric partner country. As outlined by Brander (1981), a movement from autarky to trade raises competition in an oligopolistic market and thus provides a stimulus for the production of all firms *ceteris paribus*. In a general equilibrium environment with factor market clearing, this induces an increase in the competitive wage, which counteracts the partial equilibrium production stimulus. As outlined by Neary (2009), in a model with SPFs, symmetric industries, and no labor market distortions, the two effects cancel and thus firm scale remains unaffected by the trade shock.[3] In an otherwise identical model with MPFs, firms lower their scope in response to a higher competitive wage, thereby leaving more labor for employment in activities that are closer to the firms' core competences. To put it in the words of Eckel and Neary (2010) firms are *leaner and meaner* in the open economy and they experience a productivity surge as their total output increases for a given level of labor input. This points to a new channel through which gains from trade can materialize, one that is specific to models of MPFs.

By extending the Eckel and Neary (2010) framework to one with labor market imperfections, we further enrich the picture of possible firm-level adjustments to globalization. As in textbook models of unionized oligopoly with SPFs, trade exerts a union-disciplining effect and thus lowers union wage claims *ceteris paribus* (Huizinga, 1993; Sørensen, 1993).[4] Hence, both scale and scope effects of trade are more pronounced in unionized industries, so that economic activity shifts towards these sectors. All other things equal, this lowers production in non-unionized industries and the shift effect may actually be strong enough to dominate the output stimulus from being more focused on the production of high-competence varieties. Hence, labor market imperfections render firm-level adjustments to international trade more sophisticated and less clearcut than one might have expected from the analysis in Eckel and Neary (2010).

Aside from looking at pure level effects, we also study the differential impact that trade exerts on unionized and non-unionized firms. In this respect, we show that trade weakens the labor market distortion and thus lowers the union wage premium. This effect is instrumental for a reduction in the scope differential between the two types of producers. Similarly, the decline in the union wage

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[3]In such a *featureless economy* trade only affects the distribution of economic rents in the society: by raising the competitive wage, workers gain at cost of firm owners.

[4]Bastos and Kreickemeier (2009) show that his partial equilibrium argument does not necessarily imply a lower absolute level of union wages in a general equilibrium environment. In fact, the increase in the competitive wage counteracts the partial equilibrium impact effect and it may dominate for sufficiently high levels of union density.

premium also reduces the domestic output differential of local producers. However, this effect is counteracted by a widening of the output gap at the extensive margin as, after a country's opening up for trade, firms start exporting and the respective exports are larger for non-unionized than for unionized firms. Which of these two effects dominates is not clearcut in general and depends on the degree of product differentiation. Smaller degrees of product differentiation reinforce the pro-competitive effect of trade and thus amplify the union-disciplining effect of foreign competition. This strengthens the negative impact of trade on the domestic production gap between unionized and non-unionized producers, so that the scale differential decreases for small degrees of product differentiation. On the contrary, for high degrees of product differentiation it is the output expansion effect in the export market that dominates so that the firm scale differential increases in response to trade.

The remainder of the paper is organized as follows. In Section 2 we introduce the main assumptions, describe the basic model structure, and characterize the autarky equilibrium. After a brief discussion on how union wage setting affects firm scale and scope, we study how MPFs respond to a decline in union density. In Section 3 we characterize the equilibrium in an open economy with free trade between two symmetric countries and compare the outcome in the open economy with the one in the closed economy in order to shed light on how trade affects union wage setting as well as firm scale and scope in the presence of labor market imperfection. Section 4 concludes with a brief summary of the most important results.

2 MPFs and imperfect labor markets: The closed economy

The country under consideration hosts a continuum of industries, with an oligopolistic market structure and a small (exogenous) number n of firms in each of these industries.[5] The industries are identical in all respects except for the prevailing labor market institutions. While firms in a subset of industries are exposed to union wage-setting, firms in the rest of the economy pay the competitive wage.

2.1 Preferences and consumer demand

There exists a representative consumer, whose preferences are represented by a two-tier quasi-homothetic utility function. The upper tier is an additive function of a continuum of sub-utilities,

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[5]The assumption of an exogenous firm number can be motivated by a Ricardo-Viner approach with an exogenous industry-level capital stock K and a capital input requirement of k for setting up a firm and providing the relevant headquarters services. The number of firms is then determined by $n = K/k$. By imposing the assumption of an exogenous firm number, we restrict our attention to short-run equilibria (see Leahy and Neary, 2010). In the long-run, firm owners can shift their capital endowment towards those industries that offer the highest return to their investment. Even though a detailed analysis of such long-run adjustments is beyond the scope of our analysis, we will at least briefly discuss how such an extension impacts our results in the conclusions section.

each of them corresponding to one industry $z \in [0, 1]$:

$$U[u\{z\}] = \int_0^1 u\{z\} \, dz. \tag{1}$$

Each sub-utility is a quadratic function of consumption levels $q(i, z)$, $i \in [1, N(z)]$, where $N(z)$ is the measure (or, in the interest of a more accessible interpretation, the *number*, henceforth) of differentiated varieties produced in industry z. To be more specific, we assume

$$u\{z\} = a \int_0^{N(z)} q(i, z) di - \frac{1}{2} b \left[(1 - \rho) \int_0^{N(z)} q(i, z)^2 di + \rho \left(\int_0^{N(z)} q(i, z) di \right)^2 \right], \tag{2}$$

where a, b denote non-negative preference parameters with the usual interpretation and ρ is an inverse measure of product differentiation, which is assumed to lie between 0 and 1.[6]

Aggregate demand in this setting is determined by maximizing utility of the representative consumer subject to her budget constraint

$$\int_0^1 \int_0^{N(z)} p(i, z) q(i, z) di \, dz \leq I, \tag{3}$$

where $p(i, z)$ denotes prices for variety i in industry z and I is aggregate income of the economy. This gives

$$p(i, z) = \frac{1}{\lambda} \left(a - b[(1 - \rho) q(i, z) + \rho \int_0^{N(z)} q(i, z) di] \right), \tag{4}$$

where λ is the representative consumer's marginal utility of income. As it has become standard in the literature, we choose the marginal utility of income as the numéraire and set λ equal to one. Due to this normalization all nominal variables are measured relative to the representative consumer's marginal utility of income. Since λ is not the price of a consumption good, the respective values have to be interpreted with care (see Neary, 2009, for further discussion).

From Eq. (4) we can infer insights upon the role of preference parameter ρ in our setting. As mentioned above, ρ is a measure of product differentiation and lies in interval $[0, 1]$. If $\rho = 1$ products are homogeneous (perfect substitutes), so that the price is linear in total industry consumption: $p(i, z) = a - b \int_0^{N(z)} q(i, z) di$. In the other limiting case with $\rho = 0$, goods are perfectly differentiated in the perception of consumers, so that the price for each variety only depends on consumption of

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[6]The preferences in Eqs. (1) and (2) are the same as in Eckel and Neary (2010). They combine the continuum-quadratic approach to symmetric horizontal product differentiation of Ottaviano, Tabuchi, and Thisse (2002) with the preference specification in Neary (2009). By formulating the respective preferences of the representative consumer, we have presumed that the following two conditions are fulfilled for any individual consumer: participation in the market for any good i and non-satiation in the consumption of these goods. Clearly, both of these conditions depend on endogenous variables. However, under the additional assumption of identical consumer preferences, we know from previous work that these conditions are fulfilled if a lump-sum tax-transfer system redistributes a sufficient level of income from rich to poor agents. Being not interested in income distribution or individual welfare levels *per se*, we can thus safely assume that the two conditions are fulfilled throughout our analysis.

this variety but is independent of the consumption of all other varieties in this industry. In the latter case, indirect demand is given by $p(i,z) = a - bq(i,z)$.

2.2 Technology, production, and profit maximization

As outlined in the introductory section, we associate MPFs with the idea of flexible manufacturing, and thus assume that firms can expand their product range "with only a minimum of adaptation" (Eckel and Neary, 2010, p.192). The costs of adaptation are modeled by higher labor requirements for producing a unit of output of a firm's non-core competence product, and the respective adaptation costs are assumed to be monotonically increasing in the distance between a specific product to the firm's core competence variety. However, adding a new variety to the product range does not alter the costs of producing other varieties nor does it involve any fixed costs. To put it formally, we denote marginal production costs of firm $j = 1, ..., n$ in industry z for producing variety i by $c_j(i,z) = \gamma_j(i)w_j(z)$, with $\gamma_j(i)$ being the constant labor input coefficient for producing variety i and $w_j(z)$ being the wage rate in industry z. We associate firm j's core competence with variety $i = 0$ and capture flexible manufacturing by assuming $\partial c_j(i,z)/\partial i = \partial\gamma_j(i)/\partial i \times w_j(z) > 0$. While the main mechanisms of our analysis do not hinge on a specific functional form of $\gamma_j(i)$, we impose the additional assumption $\gamma_j(i) = e^i$ in the interest of analytical tractability.[7] Finally, we assume that product ranges are firm-specific, implying that each firm has its own core competence and produces its own set of varieties.

Although the technology assumptions considered here are the same as in Eckel and Neary (2010), there remains an important difference between the two settings. While Eckel and Neary (2010) abstract from labor market imperfections and assume that all firms pay the common competitive wage rate, we allow for sectoral differences in labor market institutions and thus end up with industry-specific wage rates. Hence, in contrast to Eckel and Neary (2010) marginal production costs in our model comprise both a product-specific component, $\gamma_j(i)$, and a sector-specific one, $w_j(z)$.

Considering the technology assumptions above and denoting by $\delta_j(z)$ the scope of the product range, profits of firm j in industry z are given by

$$\Pi_j(z) = \int_0^{\delta_j(z)} \left[p_j(i,z) - c_j(i,z) \right] x_j(i,z) di, \tag{5}$$

where $x_j(i,z)$ denotes output of variety i. Considering the market clearing condition $x_j(i,z) = q_j(i,z)$ and maximizing j's profits in (5) with respect to $x_j(i,z)$ gives

$$x_j(i,z) = \frac{a - c_j(i,z) - b\rho(X_j(z) + Y(z))}{2b(1 - \rho)}, \tag{6}$$

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[7]With this additional assumption, the output across the different varieties within MPFs is highly skewed in the distance to a firm's core competence. This is consistent with the empirical findings in Goldberg, Khandelwal, Pavcnik, and Topalova (2008) and Bernard, Redding, and Schott (2010).

with $X_j(z) = \int_0^{\delta_j(z)} x_j(i,z)di$ denoting firm scale and $Y(z) = \int_0^{N(z)} x(i,z)di$ being industry-wide output of all n producers. The negative impact of industry output $Y(z)$ on firm j's profit-maximizing output of variety i captures the fact that under Cournot competition (and linear demand) output levels are strategic substitutes. Furthermore, the additional negative impact of this firm's own total output $X_j(z)$ reflects the cannibalization effect, i.e. under Cournot competition MPFs internalize that increasing output of a certain variety lowers prices for this as well as all other varieties in the firm's product range. Both of these effects do exist if and only if $\rho > 0$, i.e. if products are not perfectly differentiated (see above).

Furthermore, maximizing profits (5) with respect to $\delta_j(z)$ yields firm j's optimal product range

$$\delta_j(z) = \ln\left[\frac{a - b\rho(X_j(z) + Y(z))}{w_j(z)}\right]. \tag{7}$$

Comparing Eqs. (6) and (7), we see that firms add new varieties to their product portfolio until the marginal costs of the last variety $\delta_j(z)$ equals the marginal revenue of this variety at zero output. Using the latter insight in Eq. (6), we can derive a second expression for optimal output of variety i, by expressing the respective output level of this variety in terms of the difference between its own marginal cost and that of the marginal variety:[8]

$$x_j(i,z) = \frac{w_j(z)[e^{\delta_j(z)} - e^i]}{2b(1-\rho)}. \tag{6'}$$

Integrating output $x_j(i,z)$ over all varieties i, finally gives total output, i.e. the scale, of firm j:

$$X_j(z) = \frac{w_j(z)}{2b(1-\rho)}\left[e^{\delta_j(z)}\big(\delta_j(z) - 1\big) + 1\right], \tag{8}$$

which, all other things equal, increases in the firm's product range $\delta_j(z)$ and, for a given scope, increases in wage rate $w_j(z)$. The latter may be surprising at a first glance. However, we know from above that any firm produces zero output of its marginal product variety, while an increase in the wage rate raises the production cost differential of any two varieties. Hence, keeping firm scope constant, an increase in $w_j(z)$ unambiguously raises output of all interior varieties, i.e. of all varieties $i < \delta_j(z)$, with the respective output expansion being the more pronounced, the closer a variety is to the firm's core competence.

2.3 Union wage setting and the labor market

Regarding factor endowments, we assume that the country under consideration is populated by L workers, each of them supplying one unit of labor. Workers are mobile across sectors, with sectors

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[8]We can write the first-order condition for the profit-maximizing output of variety i as $d\Pi_j(z)/dx_j(i,z) = p_j(i,z) - c_j(i,z) - b[(1-\rho)x_j(i,z) + \rho X_j(z)] = 0$, which implies that $p_j(i,z) - c_j(i,z) > 0 \; \forall i$. Furthermore, the first-order condition for optimal firm scope is given by $d\Pi_j(z)/d\delta_j(z) = [p_j(i,z) - c_j(\delta_j(z),z)]x_j(\delta_j(z),z) = 0$ which, given our insights above, implies $x_j(\delta_j(z),z) = 0$. Evaluating (6) at $i = \delta_j(z)$ and subtracting the resulting expression from $x_j(i,z)$, then gives Eq. (6').

differing in the prevailing labor market institutions. To be more specific, we apply the labor market model of Bastos and Kreickemeier (2009) and assume that a subset of industries is unionized, while in the rest of the economy, the labor market is perfectly competitive. Without loss of generality, we order industries such that unions are active in all sectors with $z \leq \widetilde{z}$. Provided that unions are only active in a subset of industries, i.e. $\widetilde{z} < 1$, involuntary unemployment does not materialize in this setting, as workers who do not find a job in unionized industries will move to non-unionized industries, and the competitive wage will fall until all workers can find employment there. With respect to wage setting in industries $z \in [0, \tilde{z}]$, we consider sector-level unions which unilaterally set wages that are binding for all workers of the respective industry, while, at the same time, leaving the right-to-manage employment to firms. Unions are utilitarian and have an objective function of the form[9] $\Omega(z) = [w(z) - w^c]nl(z)$, where w^c is the economy-wide competitive wage and $w(z)$, $l(z)$ are union wage claims and firm-level labor demand in unionized industry z, respectively.

Differences in the labor market institutions generate asymmetries between unionized and non-unionized industries. However, there prevails no asymmetry of sectors within these two subgroups of industries. Due to this feature of our model, we can introduce superscripts u and c to refer to unionized and non-unionized industries, respectively, and can suppress sector index z from now on. Then, substituting $l(z) = \int_0^{\delta(z)} \gamma(i,z)x(i,z)di$ and $x(i,z)$ from (6′) into union objective Ω, we obtain

$$\Omega = \frac{n}{4b(1-\rho)}[w^u - w^c]w^u[e^{\delta^u} - 1]^2. \tag{9}$$

Comparing the objective function in (9) with the respective objective function in Bastos and Kreickemeier (2009) provides insights on how the problem for the labor union changes if firms produce more than just a single product variety. With MPFs having the right-to-manage employment, they simultaneously adjust firm scale and scope to changes in union wage claims, and they do so in a non-trivial way because of the oligopolistic structure in the product market. It is the adjustment in firm scope, which differentiates our analysis from Bastos and Kreickemeier (2009), and it is this aspect which is in the center of our interest. However, it is also this additional adjustment margin which renders a formal characterization of equilibrium and a discussion of comparative-static experiments difficult. In order to present our main insights in the simplest possible way, we therefore reduce complexity and consider a benchmark scenario with $\rho = 0$ in the next subsection. As outlined above, with $\rho = 0$ there is no strategic interaction of firms in the product market and widening the product range does not cannibalize a firm's output in its other varieties. A detailed discussion of the more sophisticated model variant with $\rho > 0$ is postponed to Subsection 2.5.

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[9]Since all firms within a particular industry are symmetric and unions are organized at the industry level, we suppress firm indices from now on in order to simplify notation.

2.4 A benchmark model of MPFs with perfectly differentiated goods

If $\rho = 0$, firms behave as monopolists with respect to each of their varieties. In this case, Eqs. (6) and (7) simplify to

$$x(i, z) = \frac{a - c(i, z)}{2b}, \qquad \delta(z) = \ln\left[\frac{a}{w(z)}\right], \tag{10}$$

respectively, and the union objective can be rewritten as

$$\Omega = \frac{n}{4b}[w^u - w^c]w^u\left[\frac{a}{w^u} - 1\right]^2. \tag{11}$$

Maximizing union objective (11) with respect to w^u gives the union wage claim as an implicit function of the competitive wage, w^c:

$$w^u = \frac{1}{2}\left[\frac{a}{\omega} + w^c\right], \tag{12}$$

where $\omega \equiv w^u/w^c$ denotes the union wage premium. It is easily shown that $\omega > 1$, implying that firms in unionized industries are smaller in both scale and scope than their counterparts in non-unionized industries (see Eq. (10)). However, this result has to be interpreted with care – in particular, when contrasting it with real-world evidence – because we have focused on labor market institutions as the only source of asymmetry in our model, thereby abstracting from other reasons of cross-sectoral differences in firm characteristics, as, for instance, exogenous differences in labor productivity or firm organization.

For a better understanding of how flexible manufacturing affects union wage setting, it is meaningful to compare Eq. (12) to the union wage claim in an otherwise identical model with SPFs. Imposing the additional assumption that labor productivity in the SPF model is equal to one, as for the core-competence variety in our setting, we obtain $w^u = a/2 + w^c/2$ (see Bastos and Kreickemeier, 2009). In view of $\omega > 1$, it is thus immediate that union wage claims are lower if firm scope is endogenous. MPFs respond to higher union wage claims with a reduction in scale and a shortening of their product range. However, a shortening of the product range implies that firms stop manufacturing those products with the highest labor input coefficients and, all other things equal, the employment reduction in response to a higher union wage claim is therefore more pronounced in a model with flexible manufacturing than in an otherwise identical model with SPFs and exogenous firm scope. This renders excessive wage claims less attractive from the perspective of unions.

So far, we have treated the competitive wage, w^c, as an exogenous variable and, hence, have looked at our model from a partial equilibrium perspective. To solve for the general equilibrium outcome, we apply the labor market clearing condition, $L = \int_0^1 \int_0^{\delta(z)} nx(i, z)e^i di dz$ and endogenously determine the competitive wage. Straightforward calculations give

$$L = \frac{n}{4b}\left[\tilde{z}w^u\left(e^{\delta^u} - 1\right)^2 + (1 - \tilde{z})w^c\left(e^{\delta^c} - 1\right)^2\right], \tag{13}$$

with the left-hand side of this equation representing exogenous labor supply and the right-hand side representing economy-wide labor demand. Even in the parsimonious benchmark model, we cannot explicitly solve for the equilibrium competitive wage. However, we can show that labor demand is a negative function of the competitive wage and that Eq. (13) has a unique solution in w^c.[10]

Together, Eqs. (10), (12) and (13) determine firm size and scope in general equilibrium, and we can use the respective equations for investigating how firm-level adjustments respond to a decline in union density as observed in the industrialized world over the last four decades. In our setting, we can associate a decline in union density with a fall in the share of unionized industries, $\widetilde{z}$. Since non-unionized firms employ more workers than unionized ones, a fall in $\widetilde{z}$ provides an employment stimulus in the newly deunionized industries and thus raises economy-wide labor demand. With labor demand now exceeding labor supply, the competitive wage must increase in order to restore the labor market equilibrium. According to (12), a higher competitive wage induces higher union wage claims and, hence, labor costs increase in all industries, except for the newly deunionized ones. The cost increase prompts firms to use their labor input more productively, thereby inducing a shortening of their product range (see (10)). At the same time, firms reduce the output of each interior variety, and they do so more than proportionally for varieties that are further away from their core competence. Hence, all MPFs (except for the newly deunionized ones) end up with smaller scale and scope, but also operate at a higher labor productivity.

By construction, this productivity increase does not materialize in models with SPFs, provided that output of a specific variety is linear in labor input (see Bastos and Kreickemeier, 2009). However, the productivity stimulus is not the only aspect that differentiates the MPF model considered here from an otherwise identical framework with SPFs. By lowering the scope of MPFs in all industries in which the labor market institution does not change, deunionization *ceteris paribus* reduces the total number of varieties that are available to consumers. This effect is counteracted by an expansion in the product range of newly deunionized firms, and the relative strength of the two effects depends crucially on the degree of labor market imperfection. To be more specific, we find that the latter (former) effect dominates, so that the total number of product varieties goes up (down) in response to deunionization, if the share of unionized sectors has been small (large) prior to the fall in union density (see the appendix). This is intuitive, as the negative scope effect of a given wage increase is less pronounced *ceteris paribus* for high initial wage levels, while wages w^u, w^c are the higher, the smaller is $\tilde{z}$ prior to the deunionization process. Such adjustments in the number of available product varieties, which may be an important channel through which welfare effects of deunionization materialize, are absent in models of SPFs, at least as long as the number of competitors is held constant.

Aside from studying pure level effects, we can also shed light on the differential impact a decline

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[10]Substituting $e^{\delta(z)} = a/w(z)$ into $f(z) \equiv w(z) \left(e^{\delta(z)} - 1 \right)^2$ and differentiating the resulting expression with respect to $w(z)$, gives $df(z)/dw(z) < 0$. In view of $dw^u/dw^c > 0$, this proves that the right-hand side of (13) is decreasing in w^c. Furthermore, noting from Eq. (12) that $w^u = 0$ if $w^c = 0$ and $w^u = a$ if $w^c = a$, it is immediate that the right-hand side of (13) approaches infinity if $w^c \to 0$, while it falls to zero if $w^c \to a$. Putting together, this proves existence and uniqueness of the labor market equilibrium.

in $\widetilde{z}$ exerts on unionized and non-unionized firms. From inspection of (12), we can conclude that a higher competitive wage, while triggering higher union wage claims, reduces the union wage premium ω. This fall in ω is instrumental for rendering firms more similar in both scale and scope. Formally, this can be shown by looking at the two differentials $\Delta \equiv \delta^c - \delta^u$ and $\Xi \equiv X^c - X^u$. Regarding the scope differential, we can note from Eq. (10) that $\Delta = \ln(\omega)$, which definitely falls when ω goes down. Furthermore, we can express the scale differential as $\Xi = (w^c/2b) [\omega(2\omega - 1)\ln(\omega) - \omega + 1]$.[11] Hence, there are two counteracting effects of deunionization on the firm scale differential. On the one hand, by driving up the competitive wage, a decline in $\widetilde{z}$ magnifies the output differential for a given ω. To understand this effect, it is useful to note that $\delta^c = \ln(\omega(2\omega - 1))$ and $\delta^u = \ln(2\omega - 1)$. Hence, by holding ω constant, we hold firm scope in both unionized and non-unionized sectors constant. However, from our discussion at the end of Subsection 2.2 we know that, for a given firm scope, an increase in the wage rate unambiguously increases the output of all interior varieties, and, by operating a larger product range, this effect is more pronounced in non-unionized firms. On the other hand, a decline in ω renders firms more similar in scope. This lowers the firm scale differential *ceteris paribus*. In our model, it is this second effect that dominates so that, similar to an otherwise identical model with SPFs, a decline in union density makes non-unionized and unionized producers more similar in firm scale.[12]

This completes our discussion of the benchmark model. In a next step, we analyze to what extent our insights from above need to be modified when accounting for a more general setting with partial differentiation of consumer goods and oligopolistic competition in the product market.

2.5 A sophisticated model of MPFs with partially differentiated goods

In this subsection, we extend the previous model to one with $\rho > 0$. Accounting for symmetry of firms within industries and using (8) in (7) gives

$$e^{\delta(z)} = \frac{a/w(z) - \phi}{1 + \phi\delta(z) - \phi},\tag{14}$$

where $\phi \equiv \rho(n+1)/[2(1-\rho)]$ is a measure of product market competition, which positively depends on the number of competitors, n, and negatively depends on the degree of product differentiation, as captured by the inverse of ρ. Eq. (14) establishes a negative relationship between wage rate $w(z)$

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[11]Using (10) in (8), and substituting the resulting expression for X^c and X^u, respectively, gives $\Xi = [w^c/(2b)] [(a/w^c)\ln(\omega) - \omega + 1]$. Then, using $a/w^c = \omega(2\omega - 1)$, according to (12), we end up with the respective expression for Ξ in the main text.

[12]Totally differentiating Ξ with respect to w^c and accounting for $d\omega/dw^c = -(\omega/w^c)[(2\omega - 1)/(4\omega - 1)]$, according to (12), we can calculate

$$\frac{d\Xi}{dw^c} = -\frac{(\omega - 1)(4\omega^2 + 2\omega - 1)}{4\omega - 1} < 0.$$

and firm scope $\delta(z)$.[13] Together (8) and (14) determine firm scale $X(z)$ as an implicit function of $w(z)$. As outlined at the end of Subsection 2.2, a sectoral wage increase exerts two opposing effects on firm scale. On the one hand, there is a positive scale effect of an increase in $w(z)$ for given firm scope while, on the other hand, the shortening of the product range that is triggered by an increase in $w(z)$ lowers firm scale. As pointed out above, it is the second effect that dominates in our setting so that firm scale falls along with firm scope when the sectoral wage rate increases.[14]

These implications of higher wages for firm scale and scope are taken into account by labor unions, which in the more sophisticated model variant with partially differentiated goods maximize an objective function of the form

$$\Omega = \frac{n}{4b(1-\rho)}[w^u - w^c]w^u \left[\frac{a/w^u - \phi}{1 + \phi\delta^u - \phi} - 1 \right]^2, \tag{15}$$

according to (9) and (14). Totally differentiating the latter with respect to w^u and setting the resulting expression equal to zero allows us to derive the union wage claim as an implicit function of the competitive wage w^c:

$$w^u = \frac{1}{2}w^c + \frac{a}{[1 + \phi\delta^u][e^{\delta^u} - 1]} \left[1 - \frac{w^c}{w^u} \right]. \tag{16}$$

Eqs. (14) and (16) establish a system of two equations, which together determine the equilibrium levels of w^u and δ^u (for a given w^c). If $\rho = 0$, we have $\phi = 0$ and (14) and (16) reduce to the respective expressions in (10) and (12). As outlined in Subsection 2.4, firms behave as monopolists in the production of all of their varieties, and the number of competitors turns out to be irrelevant for union wage claims in this case. Things are different if $\rho > 0$. While similar to the benchmark model higher union wage claims reduce industry-wide labor demand, the respective employment decline is less pronounced if $\rho > 0$. The reason is the following: By reducing output of a certain variety, the firm reduces its negative demand externality on all other varieties produced in the respective industry. This feedback effect is the stronger, the more firms are active in the respective industry, so that the number of competitors is a crucial determinant of the union wage claim if $\rho > 0$. Furthermore, with the negative employment response to a given wage increase being less pronounced, union wage claims must be higher than in the benchmark model.[15]

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[13]Applying the implicit function theorem to (14) gives

$$\frac{d\delta(z)}{dw(z)} = -\frac{1}{w(z)} \frac{e^{\delta(z)}[1 + \phi\delta(z) - \phi] + \phi}{e^{\delta(z)}[1 + \phi\delta(z)]} < 0.$$

[14]Substituting (14) into (8) and differentiating the resulting expression with respect to $w(z)$ gives

$$\frac{dX(z)}{dw(z)} = -\frac{e^{\delta(z)} - 1}{2b(1-\rho)[1 + \phi\delta(z)]} < 0.$$

[15]The mechanisms here differ significantly from those in a setting with SPFs. Since a cannibalization effect does not materialize if firms are confined to produce just a single variety, the union wage claim is invariant to the number of producers – provided that unions are organized at the sector level (see Bastos and Kreickemeier, 2009, and the

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With these insights regarding the role of ρ for union wage setting at hand, we are well equipped to characterize the general equilibrium outcome in the more sophisticated model variant. For this purpose, we substitute $x(i, z)$ from Eq. (6') into the labor market clearing condition $L = \int_0^1 \int_0^{\delta(z)} nx(i, z)e^i didz$ in order to arrive at

$$L = \frac{n}{4b(1 - \rho)} \left[\tilde{z}w^u \left(e^{\delta^u} - 1 \right)^2 + (1 - \tilde{z})w^c \left(e^{\delta^c} - 1 \right)^2 \right]. \tag{13'}$$

Together with Eqs. (8), (14) – separately for unionized and non-unionized industries – and (16) this gives a system of six equations, which jointly determine the autarky level of the six endogenous variables w^c, w^u, δ^c, δ^u, X^c and X^u.

We complete the discussion of the more sophisticated model variant by investigating to what extent our insights from the comparative-static exercise on firm-level adjustments to changes in labor market institutions need to be modified if one considers partial differentiation of consumer goods. As in the benchmark model with $\rho = 0$, a decline in union density, i.e. a reduction in $\tilde{z}$, gives an employment stimulus in the newly deunionized industries and, hence, the competitive wage must increase in order to restore the labor market equilibrium. This increase in the competitive wage induces higher union wage claims, so that all firms, except for the newly deunionized ones, experience a production cost increase if $\tilde{z}$ declines. As a consequence, firm scale and scope fall in all sectors in which labor market institutions do not change. Since this reasoning applies for any possible ρ, we can conclude that the comparative static effects of deunionization on firm scale and scope in the benchmark model are robust to changes in the degree of product differentiation. Unfortunately, with respect to the impact of deunionization on the scale and scope differentials between unionized and non-unionized firms or the total number of product varieties we were not able to show that the insights from the benchmark scenario survive in the more sophisticated model when allowing for arbitrary levels of ρ. However, with all variables of interest being continuously differentiable in ρ, we can at least conclude that the respective insights from Subsection 2.4 are robust to small changes in ρ. Hence, the parsimonious framework in the previous subsection is a suitable benchmark for our analysis as long as the degree of product differentiation is sufficiently high. This completes our discussion of the closed economy.

3 MPFs and labor market imperfection in an open economy

It is the purpose of this section to shed light on firm level adjustments if the country under consideration opens up to trade. Thereby, we consider trade between two fully symmetric economies and abstract from the existence of any impediments of shipping goods across borders.[16] Product

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cited literature there).

[16]While the model allows in principle for considering such trade impediments, doing so would complicate the analysis enormously. For instance, one could allow for iceberg transport costs. In this case, MPFs would choose different scale and scope for the domestic and the export market and, hence, we would end up with four scale and scope variables instead of just two variables, as in the closed economy. Alternatively, one might assume that only a subset of sectors has access to the export market (see, for instance, Epifani and Gancia, 2009; Kreickemeier and

markets are segmented and labor is not allowed to move across borders. In the interest of readability, we do not repeat all the steps of the formal analysis in Section 2, but instead stick to an informal discussion of the trade effects on firm scale and scope in the main text of our paper. A characterization of the open economy equilibrium and formal details on the effects of a country's movement from autarky to trade can be found in the appendix. Similar to the closed economy, we start our analysis by first looking at the benchmark model with $\rho = 0$ and briefly discuss the more sophisticated model with $\rho > 0$ afterwards.

If $\rho = 0$, opening up for trade does not change a firm's competitive environment and leaves the partial equilibrium outcome unaffected. However, there are general equilibrium effects, because firms start to serve foreign consumers in the open economy and thus expand production and labor demand at the extensive margin. To restore the labor market equilibrium, the competitive wage must increase and unions respond to this increase in w^c by raising their wage claims. The surge in factor costs causes a shortening of the product range of all competitors and firm scope falls in unionized as well as non-unionized industries. With respect to firm scale, we can note that the increase in factor costs lowers the output of firms for the domestic market. However, in the open economy firms additionally serve foreign consumers and this expansion at the extensive margin dominates the output reduction, so that firm scale unambiguously increases in all industries when a country opens up for trade. This effect is intuitive, as the decline in firm scope leaves more labor for employment in the firms' high-competence varieties which means that resources are used more productively and firm scale can expand in the open economy. This outcome is in line with the key finding of Eckel and Neary (2010) that firms become *leaner and meaner* when a country opens up for trade, thereby generating productivity gains which refer to a new channel through which gains from trade can materialize, a channel that is not present is textbook models of trade with SPFs.

In order to determine how trade affects relative firm performance, it is worth noting that union wage claims, while stimulated by the surge in the competitive wage, increase less than proportionally, so that the union wage premium, ω, shrinks when the country opens up for trade with a symmetric partner country. The fall in the wage differential reduces the cost disadvantage of unionized firms, thereby lowering the differential in firm scope across industries, i.e. Δ is lower in the open than in the closed economy. The fall in the union wage premium is also instrumental for a decline of the output differential in the domestic market. However, with market-specific output being larger in non-unionized sectors, firms in these industries experience a more than proportional output increase from exporting. It is this second effect that dominates in our model, so that the firm scale differential, Ξ, is magnified in the open economy if $\rho = 0$.[17]

Meland, 2010). However, if a subset of both unionized and non-unionized industries is exposed to trade, we again end up with four variables for firm scale and scope, similar to the case of iceberg transport costs. To present the main insights of our analysis in the simplest possible way, we have decided to keep the number of scale and scope variables small and thus abstract from any trade impediments.

[17]While the focus in this section is on firm-level variables, it is also possible to determine the impact of trade on the total number of available product varieties. In this respect, we can distinguish two effects. On the one hand, trade lowers firm scope of all producers, which lowers the number of available product varieties *ceteris paribus*. On the other hand, trade provides access to foreign product varieties, which raises the basket of available consumer goods. With $\rho = 0$ it is the second effect that dominates, so that in this case the number of available consumer goods

While in the benchmark scenario with $\rho = 0$, trade does not change the competitive environment of firms in the product market, but fosters competition for scarce labor and thus impacts the general equilibrium outcome through adjustments in the competitive wage, there are pro-competitive effects at work if one allows for partial differentiation of consumer goods. In fact, these pro-competitive effects materialize along multiple lines. On the one hand, trade fosters product market competition and thus reduces profits *ceteris paribus*. While in a model with SPFs this does not exert a direct effect on union wage setting, it induces a fall in firm scope and thus gives room for higher union wage claims in our setting. On the other hand, trade changes the labor market environment. While sector-level unions unilaterally set industry-wide wage standards in the closed economy, they have to account for the outcome of union wage setting in the foreign economy when the opening up for trade exposes domestic producers to international competition. All other things equal, this gives rise to a union-disciplining effect and induces a fall in union wage claims. Hence, in the partial equilibrium there are now two counteracting effects of trade on union wage setting, while in the general equilibrium there is an additional positive effect due to a labor demand stimulus and a higher competitive wage.

Clearly, for small levels of ρ, it is the general equilibrium effect that dominates and thus union wages unambiguously increase as in the benchmark model. Also our findings regarding the trade effects on firm size and scope as well as the differentials of these variables remain unaffected when ρ increases from zero to a small positive level. However, things become more complicated if we allow for high values of ρ and thus consider parameter configurations for which the partial equilibrium effects on union wage setting are strong. Since we are not able to derive sharp analytic results for small degrees of product differentiation, we have conducted a series of numerical simulation exercises in order to shed light on how our results from the benchmark model are affected by an increase of ρ from zero to a large positive value. Table 1 summarizes the main findings of these exercises for a relatively small degree of product differentiation, $\rho = 0.8$.[18] First of all, we can conclude from the second column of the table that for high values of ρ union wage claims may actually fall in response to trade liberalization. But this can only happen if the share of unionized industries is sufficiently small. An intuition for the role of $\tilde{z}$ in determining the impact of trade on union wage claims can be found in Bastos and Kreickemeier (2009). As shown in their study on SPFs, a higher $\tilde{z}$, while not directly affecting the strength of the (partial equilibrium) impact effect on union wage setting in a given industry, implies that this impact effect is relevant for a larger share of sectors, thereby reinforcing the labor demand stimulus of trade and thus the general equilibrium feedback effect through adjustments in w^c. From this we can deduce that a positive effect of trade on union wage claims is the more likely, the larger is the share of unionized industries $\tilde{z}$.

Columns 4 and 5 of Table 1 present numerical results for the impact of trade on firm scope, and these results indicate that all firms shorten their product range in response to trade, irrespective

	$w_t^u - w_a^u$	$w_t^c - w_a^c$	$\delta_t^u - \delta_a^u$	$\delta_t^c - \delta_a^c$	$D_t^u - D_a^u$	$D_t^c - D_a^c$	$X_t^u - X_a^u$	$X_t^c - X_a^c$
$\widetilde{z} = 0.1$	-0.17	5.55	-0.02	-0.06	-0.61	-1.96	0.67	0.02
$\widetilde{z} = 0.3$	0.24	6.78	-0.03	-0.07	-0.73	-2.29	0.66	-0.16
$\widetilde{z} = 0.5$	0.90	8.50	-0.03	-0.08	-0.91	-2.72	0.61	-0.42

Notes: D denotes domestic firm-level output and subscripts a, t refer to autarky and trade variables, respectively. Parameter values are $a = 100$, $b = 1$, $\rho = 0.8$, $n = 5$, $L = 20$.

Table 1: Trade Effects on wages, scope and scale for different values of trade union presence

of the prevailing labor market institutions. The negative effect of trade on firm scope is more pronounced in non-unionized industries, so that, in line with our benchmark model, firms become more similar in this dimension. Furthermore, from inspection of columns 6 and 7, we can conclude that the findings from our benchmark model regarding the impact of trade on domestic output (D) also remain unaffected if one considers positive (and relatively high) values of ρ: All firms reduce their domestic output level in response to trade. However, this does not mean that firm scale falls as well, as firms get access to the export market and thus increase output at the extensive margin. From columns 8 and 9 we see that, in contrast to the benchmark model, the expansion at the extensive margin needs not be strong enough to dominate the output decline at the intensive margin so that the total impact on firm scale is not clearcut in general if ρ is sufficiently large. To be more specific, the numerical results indicate that firm scale definitely increases in unionized industries, while it may increase or fall in non-unionized sectors. In our simulation exercise, firm scale increases in non-unionized industries if union density is low, while it declines if $\widetilde{z}$ is sufficiently large.

To get an intuition for the role of $\widetilde{z}$ in determining the impact of trade on firm scale, it is useful to distinguish two effects. On the one hand, trade induces a general decline in firm scope which leaves more labor for producing high-competence varieties and thus stimulates firm scale in all industries. On the other hand, the wage differential between unionized and non-unionized industries shrinks, which implies that production shifts towards unionized sectors. The stronger the latter effect is, the more likely is a negative firm scale effect of trade in non-unionized industries. From inspection of columns 2 and 3 of Table 1, we can infer that the reduction in the wage differential is more pronounced for high levels of union density. Hence, the second effect dominates if $\widetilde{z}$ is sufficiently large. Finally, for all parameter configurations in Table 1, the scale differential between unionized and non-unionized industries shrinks in response to a country's movement from autarky to trade, which constitutes a further important difference to our benchmark model.

The above discussion highlights the role of labor market institutions for firm-level adjustments to a country's movement from autarky to trade. While in a setting with perfect labor markets MPFs shorten their product range and increase the scale of output in response to trade, our analysis makes clear that these firm-level effects may change significantly when labor market distortions are

taken into account, with the degree of product differentiation being an important determinant of how labor market institutions impact the adjustment of MPFs. Our findings therefore suggest that shedding light on how product differentiation and labor market institutions interact is a prerequisite for drawing a comprehensive picture of firm-level adjustments to international trade.

4   Concluding remarks

We have set up a general oligopolistic equilibrium model of MPFs and labor market imperfections due to union wage-setting in a subset of industries. We have used this setting to tackle two questions that have sparked considerable interest of economists in recent years and are of relevance for policy makers alike. The first question we are interested in deals with firm-level (and related economy-wide) adjustments to declines in union density, a phenomenon that has been observed in all industrialized countries over the last four decades. Associating a decline in union density with a reduction in the share of unionized industries, we have shown that deunionization raises both the competitive and the union wage and thus renders a shortening of the product range attractive for MPFs. In addition to the decline in firm scope, the cost increase lowers total output of all interior varieties, so that firm scale decreases in unionized as well as non-unionized industries. With firms concentrating on high-competence varieties, deunionization therefore leads to an increase in labor productivity of all firms (except for the newly deunionized ones). Aside from this productivity gain, consumers can benefit from an increase in the number of varieties if union density has already been low prior to the deunionization process. This differentiates our setting from an otherwise identical model with SPFs, where such productivity and variety effects do not exist. The second question we tackle in this paper is the impact of trade on firm scale and scope. In this respect, the main insight from our analysis is that, while firms become leaner and meaner as in models of MPFs without labor market frictions, the additional labor force that has been set free by the decline in firm scope is not equally allocated to unionized and non-unionized industries and thus it is not guaranteed that all firms actually increase their scale when being exposed to international trade. To be more specific, with labor market institutions being industry-specific, the firm-level effects of trade depend on a non-trivial interplay of product differentiation and union density.

   While we hope that our analysis contributes to a better understanding of how MPFs adjust their scale and scope in response to macroeconomic shocks, it is clear that, in the interest of analytical tractability we had to impose several simplifying assumptions which limit the practical relevance of our results. Most notable in this respect is the assumption of an exogenous and equal number of competitors within each industry. This assumption closes one important adjustment margin and restricts our analysis to a short-run perspective. In the long run, it is plausible that firm owners de-invest their capital stock and search for the best investment opportunities in the whole economy. If there are no extra costs of moving capital across sectors, firm owners will adjust their investment strategy in the long run until the return to their investment is the same in all industries. In comparison to our short-run model with an exogenous and equal number of competitors in all

industries, this induces a movement of producers towards non-unionized industries. Since non-unionized firms are larger than unionized ones, this gives a labor demand stimulus, thereby raising the competitive as well as the union wage. Hence, compared to our short-run model firm scale and scope shrink in both unionized and non-unionized industries if capital is mobile across industries (at least as long as products are sufficiently differentiated).

A further extension of our model which is worthwhile to consider is one that allows for analyzing the consequences of marginal trade liberalization. Since the introduction of trade impediments would significantly complicate our analysis, such a modification is beyond the scope of this paper. However, we can follow Eckel and Neary (2010) and associate marginal steps of trade liberalization with an increase in the number of trading partners. In the case of perfect product differentiation, opening up for trade with an additional (symmetric) partner country reinforces the respective effects identified in the previous section. While this result can be extended to sufficiently high degrees of (partial) product differentiation, determining the respective effects for arbitrary levels of ρ is not a trivial task and, hence, we leave a more detailed discussion of this issue open for future research.

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Appendix

Deunionization and the number of product varieties in the benchmark scenario

The total number of product varieties is given by $N \equiv \tilde{z}N^u + (1 - \tilde{z})N^c = \tilde{z}n\delta^u + (1 - \tilde{z})n\delta^c$. Differentiating the latter with respect to $\tilde{z}$, we obtain

$$\frac{dN}{d\tilde{z}} = n \left\{ \ln\left(\frac{1}{\omega}\right) - \frac{dw^c}{d\tilde{z}} \left[\tilde{z}\frac{1}{w^u}\frac{a + w^u}{4w^u - w^c} + (1 - \tilde{z})\frac{1}{w^c} \right] \right\}, \tag{17}$$

according to (10). Totally differentiating (13) and accounting for $a/w^u = 2\omega - 1$, $a/w^c = \omega(2\omega - 1)$ from (12), we can calculate

$$\frac{dw^c}{d\tilde{z}} = w^c \frac{4\omega(\omega - 1)^2 - [\omega(2\omega - 1) - 1]^2}{8\tilde{z}\omega^3(4\omega - 1)^{-1}(\omega - 1) + (1 - \tilde{z})[(\omega(2\omega - 1))^2 - 1]}. \tag{18}$$

Substituting the latter into (17), we get

$$\frac{dN}{d\tilde{z}} = n \left\{ \ln\left(\frac{1}{\omega}\right) - \frac{\left\{4\omega(\omega - 1)^2 - [\omega(2\omega - 1) - 1]^2\right\}\left[2\tilde{z}\omega(4\omega - 1)^{-1} + (1 - \tilde{z})\right]}{8\tilde{z}\omega^3(4\omega - 1)^{-1}(\omega - 1) + (1 - \tilde{z})[(\omega(2\omega - 1))^2 - 1]} \right\}. \tag{19}$$

Evaluating $dN/d\tilde{z}$ at $\tilde{z} = 0$ gives

$$\left.\frac{dN}{d\tilde{z}}\right|_{\tilde{z}=0} = n \left[\ln\left(\frac{1}{\omega}\right) - \frac{4\omega(\omega - 1)^2 - [\omega(2\omega - 1) - 1]^2}{[(\omega(2\omega - 1))^2 - 1]} \right], \tag{20}$$

which is negative for any $\omega > 1$. Evaluating $dN/d\tilde{z}$ at $\tilde{z} = 1$ gives

$$\left.\frac{dN}{d\tilde{z}}\right|_{\tilde{z}=1} = n \left[\ln\left(\frac{1}{\omega}\right) - \frac{\omega - 1}{\omega} + \frac{[\omega(2\omega - 1) - 1]^2}{4\omega^2(\omega - 1)} \right], \tag{21}$$

which is positive for any $\omega > 1$. This proves the respective statement in the main text. *QED*

Deunionization in a sophisticated model with $\rho > 0$

In a first step, we show that $dw^u/dw^c > 0$ still holds in the more general setting with $\rho > 0$. For this purpose, we can define the implicit function

$$\Gamma(w^c, w^u) \equiv w^u - \frac{1}{2}w^c - \frac{a}{(1 + \phi\delta^u)(e^{\delta^u} - 1)}\left[1 - \frac{w^c}{w^u}\right] = 0, \tag{22}$$

according to (16). Partially differentiating $\Gamma(\cdot)$ with respect to w^c and accounting for $a/w^u = e^{\delta^u}(1 + \phi\delta^u - \phi) + \phi$, according to (14), we obtain

$$\frac{\partial\Gamma(\cdot)}{\partial w^c} = \frac{(e^{\delta^u} + 1)(1 + \phi\delta^u) - 2\phi(e^{\delta^u} - 1)}{2(1 + \phi\delta^u)(e^{\delta^u} - 1)}, \tag{23}$$

which is positive.[19] Partially differentiating $\Gamma(\cdot)$ with respect to w^u gives

$$\frac{\partial \Gamma(\cdot)}{\partial w^u} = 1 - \frac{w^c}{w^u} \frac{a/w^u}{(1 + \phi\delta^u)(e^{\delta^u} - 1)} + \left(1 - \frac{w^c}{w^u}\right) \frac{a\left[e^{\delta^u}\left(1 + \phi\delta^u\right) + \phi\left(e^{\delta^u} - 1\right)\right]}{(1 + \phi\delta^u)^2\left(e^{\delta^u} - 1\right)^2} \frac{d\delta^u}{dw^u}. \tag{24}$$

Noting

$$\frac{d\delta(z)}{dw(z)} = -\frac{1}{w(z)} \frac{e^{\delta(z)}\left(1 + \phi\delta(z) - \phi\right) + \phi}{e^{\delta(z)}(1 + \phi\delta(z))} \tag{25}$$

from FN 13 and substituting $a/w^u = e^{\delta^u}(1 + \phi\delta^u - \phi) + \phi$, we can further calculate

$$\frac{\partial \Gamma(\cdot)}{\partial w^u} = -\left[(\alpha^2\beta - 1) - \frac{w^c}{w^u}(\alpha^2\beta - \alpha)\right], \tag{26}$$

with

$$\alpha \equiv \frac{e^{\delta^u}\left(1 + \phi\delta^u\right) - \phi\left(e^{\delta^u} - 1\right)}{(e^{\delta^u} - 1)(1 + \phi\delta^u)}, \qquad \beta \equiv \frac{e^{\delta^u}\left(1 + \phi\delta^u\right) + \phi\left(e^{\delta^u} - 1\right)}{e^{\delta^u}(1 + \phi\delta^u)} > 1. \tag{27}$$

Hence, $\alpha > 1$, which is equivalent to $1 - \phi(e^{\delta^u} - \delta^u - 1) > 0$, is sufficient for $\partial\Gamma(\cdot)/\partial w^u < 0$. Using (14) together with (16), we can conclude that $1 - \phi(e^{\delta^u} - \delta^u - 1) > 0$ is equivalent to $\omega > 1$, so that $\partial\Gamma(\cdot)/\partial w^u < 0$ and, by applying the implicit function theorem to (22), also $dw^u/dw^c > 0$ are immediate.

In a second step, we differentiate $f(z) \equiv w(z)[e^{\delta(z)} - 1]^2$ with respect to $w(z)$. Accounting for (37), this gives

$$\frac{df(z)}{dw(z)} = -\frac{e^{\delta(z)} - 1}{1 + \phi\delta(z)}\left[(e^{\delta(z)} + 1)(1 + \phi\delta(z)) - 2\phi(e^{\delta(z)} - 1)\right], \tag{28}$$

which is negative (see (23) and FN 19). On the one hand, this implies $w^u(e^{\delta^u} - 1)^2 < w^c(e^{\delta^c} - 1)^2$, so that the right-hand side of (13$'$) unambiguously falls in $\tilde{z}$, when holding wages constant. On the other hand, combining $df(z)/dw(z) < 0$ with $dw^u/dw^c > 0$, we can conclude that the right-hand side of (13$'$) determines a negative relationship between economy-wide labor demand and the competitive wage w^c. Putting together, we get $dw^c/d\tilde{z} < 0$, $dw^u/d\tilde{z} < 0$, which in view of $d\delta(z)/dw(z) < 0$ (see above), implies $d\delta^c/d\tilde{z} > 0$, $d\delta^u/d\tilde{z} > 0$. Finally, accounting for $dX(z)/dw(z) < 0$ (see FN 14), we also get $dX^c/d\tilde{z} > 0$ and $dX^u/d\tilde{z} > 0$. This completes the proof. *QED*

Characterization of the open economy equilibrium: the case of $\rho = 0$

Since with $\rho = 0$ there is no competition in the product market, the relationship between $w(z)$ and $\delta(z)$ in the open economy, remains to be given by the respective autarky relationship in (10). Similarly, union wage setting is not affected either and remains to be given by (12) in the open

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[19]It is immediate that the denominator of this expression is positive, while the numerator is strictly increasing in δ^u and equals 2 at $\delta^u = 0$.

economy. However, trade raises competition for scarce labor and thus impacts the labor market clearing condition, which in the open economy is given by

$$L = \frac{\hat{n}}{4b} \left[\tilde{z} w^u \left(e^{\delta^u} - 1 \right)^2 + (1 - \tilde{z}) w^c \left(e^{\delta^c} - 1 \right)^2 \right] \tag{29}$$

instead of (13), where $\hat{n} \equiv 2n$. Finally, with firms serving two instead of just a single market total firm output is now given by $X(z) = 2D(z)$, where $D(z)$ equals local output in (8), when setting $\rho = 0$.

Trade effects in the benchmark model with $\rho = 0$

Comparing the open economy equilibrium in the last subsection with the respective equilibrium under autarky, we see that trade provides a labor demand stimulus and thus raises the competitive wage. Hence, in view of (10) and (12), it is immediate that w^u is larger, while δ^c, δ^u are smaller in the open than in the closed economy. Furthermore, noting from Subsection 2.4 that an increase in w^c lowers ω, it is also immediate that the scope differential $\Delta = \delta^c - \delta^u = \ln(\omega)$ falls when a country opens up for free trade. To determine the scale effects, we can combine (8) and (10), in order to arrive at

$$X_a(z) = \frac{w_a(z)}{2b} \left[\frac{a}{w_a(z)} \left(\ln \left(\frac{a}{w_a(z)} \right) - 1 \right) + 1 \right], \tag{30}$$

where subscript a refers to an autarky variable. Similarly, we obtain

$$D(z) = \frac{w(z)}{2b} \left[\frac{a}{w(z)} \left(\ln \left(\frac{a}{w(z)} \right) - 1 \right) + 1 \right] \tag{31}$$

for a firm's domestic output in the open economy (see above). Recollecting from the analysis in Subsection 2.4 that the right hand-side of (30) is strictly decreasing in $w(z)$ and noting from above that a movement from autarky to free trade raises both the competitive and the union wage, it is immediate that $D(z) < X_a(z)$.

To determine the impact of trade on total firm scale $X(z)$, we can make use of the following fact: The impact of trade on $X(z)$ is qualitatively the same as the impact of trade on $Y(z) \equiv \hat{n} X(z)$, where $\hat{n} = n$ under autarky and $\hat{n} = 2n$ under free trade. Put differently, we can infer the impact of a country's opening up for free trade on firm scale from differentiating $Y(z)$ with respect to $\hat{n}$. Accounting for (29) and (30), we can calculate

$$\frac{dY(z)}{d\hat{n}} = \frac{1}{2b} \left\{ a \left[\ln \left(\frac{a}{w(z)} \right) - 1 \right] + w(z) - w(z) \left(\frac{a}{w(z)} - 1 \right) \frac{\hat{n}}{w(z)} \frac{dw(z)}{d\hat{n}} \right\}. \tag{32}$$

Distinguishing between non-unionized and unionized industries, accounting for $a/w^c = \omega(2\omega - 1)$

and $a/w^u = 2\omega - 1$, according to (12), and using $dw^c/d\hat{n} = (w^c/\hat{n}) \times \gamma(\omega)/\zeta(\omega)$, with

$$\gamma(\omega) \equiv 4\tilde{z}\omega(\omega - 1)^2 + (1 - \tilde{z})\Big[\omega(2\omega - 1) - 1\Big]^2, \tag{33}$$

$$\zeta(\omega) \equiv 4\tilde{z}\omega(\omega - 1)^2 \frac{2\omega^2}{4\omega^2 - 5\omega + 1} + (1 - \tilde{z})\Big[\omega(2\omega - 1) - 1\Big]^2\left[\frac{\omega(2\omega - 1) + 1}{\omega(2\omega - 1) - 1}\right], \tag{34}$$

the latter can be rewritten as

$$\frac{dY^c}{d\hat{n}} = \frac{w^c}{2b}\left\{\omega(2\omega - 1)\Big[\ln\big(\omega(2\omega - 1)\big) - 1\Big] + 1 - \Big[\omega(2\omega - 1) - 1\Big]\frac{\gamma(\omega)}{\zeta(\omega)}\right\}, \tag{35}$$

$$\frac{dY^u}{d\hat{n}} = \frac{w^c}{2b}\left\{\omega(2\omega - 1)\Big[\ln\big(2\omega - 1\big) - 1\Big] + \omega - \frac{4(\omega - 1)\omega^2}{4\omega - 1}\frac{\gamma(\omega)}{\zeta(\omega)}\right\}, \tag{36}$$

respectively. It is tedious but straightforward to show that the right-hand sides of (35) and (36) are positive, implying that $dY^c/dn > 0$, $dY^u/dn > 0$.[20] This implies that a movement from autarky to trade raises firm scale in unionized as well as non-unionized industries.

In a final step, we look at the impact of trade on firm size differential Ξ. Noting that, with a constant number of competitors in either country, changes in Ξ are qualitatively the same as changes in $\Psi \equiv Y^c - Y^u$, we can infer insights on the respective effects, by determining the sign of

$$\frac{d\Psi}{d\hat{n}} = \frac{w^c}{2b}\left\{\omega(2\omega - 1)\ln(\omega) - (\omega - 1) - \frac{(\omega - 1)\left(4\omega^2 + 2\omega - 1\right)}{4\omega - 1}\frac{\gamma(\omega)}{\zeta(\omega)}\right\}. \tag{37}$$

It is tedious but straightforward to show that the sign of the latter is positive, implying that the firm size differential increases when a country moves from autarky to free trade. This completes the proof. *QED*

Characterization of the open economy equilibrium: the case of $\rho > 0$

In this subsection, we summarize the six equation that characterize the open economy equilibrium in the sophisticated model variant with $\rho > 0$.[21] In this case, firm scale and scope in non-unionized and unionized industries are given by

$$X^c = \frac{w^c}{b(1 - \rho)}\Big[e^{\delta^c}(\delta^c - 1) + 1\Big], \qquad X^u = \frac{w^u}{b(1 - \rho)}\Big[e^{\delta^u}(\delta^u - 1) + 1\Big], \tag{38}$$

$$\delta^c = \ln\left[\frac{a/w^c - \phi(2n + 1)/(n + 1)}{1 + \phi(\delta^c - 1)(2n + 1)/(n + 1)}\right], \quad \delta^u = \ln\left[\frac{a/w^u - \phi(2n + 1)/(n + 1)}{1 + \phi(\delta^u - 1)(2n + 1)/(n + 1)}\right], \tag{39}$$

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[20]Further details of the proof have been deferred to a technical supplement, which is available upon request.

[21]We do not present derivation details here, as the respective calculations are tedious. Instead, we refer the interested reader to a technical supplement, which is available upon request.

where $\phi = \rho(n+1)/[2(1-\rho)]$ (see Subsection 2.5). Furthermore, the outcome of union wage setting is given by

$$w^u = w^c \left(\frac{1}{2} \frac{(e^{\delta^u} - 1)}{1 - e^{\delta^u} + H(\delta^u)} + 1 \right),$$

(40)

where

$$H(\delta^u) \equiv \frac{(1 + \phi\delta^u)\left[e^{\delta^u}(1 + \phi\delta^u - \phi) + \phi\right] - \phi^2\delta^u \left[n/(n+1)\right]^2 \left[e^{\delta^u}(\delta^u - 1) + 1\right]}{(1 + \phi\delta^u)^2 - \left[\phi\delta^u[n/(n+1)]\right]^2}.$$

Finally, labor market clearing in the open economy requires

$$L = \frac{n}{2b(1-\rho)} \left[\tilde{z}w^u \left(e^{\delta^u} - 1\right)^2 + (1 - \tilde{z})w^c \left(e^{\delta^c} - 1\right)^2 \right].$$

(41)

Supplement
(not intended for publication)

The impact of trade on total firm output

The fist part of the supplement aims at providing further derivation details for the impact of an increase in $\hat{n}$ on Y^c, Y^u, and Ψ. Let us first consider Y^c. From (35), we can conclude that $dY^c/d\hat{n} > 0$ holds if

$$\left[\omega(2\omega - 1)\Big(\ln\left(\omega(2\omega - 1)\right) - 1 \Big) + 1\right] \zeta(\omega) > [\omega(2\omega - 1) - 1]\,\gamma(\omega), \tag{S1}$$

where $\zeta(\omega)$, $\gamma(\omega)$ are given by (33) and (34), respectively. Using straightforward calculations, we can conclude that $dY^c/d\hat{n} > 0$ if $T_1 + T_2 > 0$, with

$$T_1 \equiv -\frac{4\widetilde{z}\omega(2\omega - 1)(\omega - 1)^2}{4\omega^2 - 5\omega + 1}\left[2\omega^3\Big(3 - \ln\left(\omega(2\omega - 1)\right)\Big) - 5\omega^2 - 2\omega + 1\right],$$

$$T_2 \equiv \frac{(1 - \widetilde{z})\,[\omega(2\omega - 1) - 1]^2}{\omega(2\omega - 1) - 1}\left\{\left[\omega(2\omega - 1)\Big(\ln\left(\omega(2\omega - 1)\right) - 1\Big) + 1\right]\left[\omega(2\omega - 1) + 1\right] - \left[\omega(2\omega - 1) - 1\right]^2\right\}.$$

The positive sign of $dY^c/d\hat{n} > 0$ can then be inferred from $T_1 > 0$ and $T_2 > 0$.[22]

Let us now consider the impact of $\hat{n}$ on Y^u. From (36), we can conclude that $dY^u/d\hat{n} > 0$ holds if

$$\left[\omega(2\omega - 1)\Big(\ln(2\omega - 1) - 1 \Big) + \omega\right] \zeta(\omega) > \frac{4(\omega - 1)\omega^2}{4\omega - 1}\gamma(z). \tag{S2}$$

Equivalently, we can state that $dY^u/d\hat{n} > 0$ holds if $T_3 + T_4 > 0$, with

$$T_3 \equiv [(2\omega - 1)[\ln(2\omega - 1) - 1] + 1]\frac{\omega}{\omega - 1} - 2(\omega - 1),$$

$$T_4 \equiv [(2\omega - 1)[\ln(2\omega - 1) - 1] + 1]\frac{\omega(2\omega - 1) + 1}{\omega(2\omega - 1) - 1} - \frac{4\omega(\omega - 1)}{4\omega - 1},$$

It can be shown that, for any $\omega > 1$, $T_3 > 0, T_4 > 0$, so that $dY^u/d\hat{n} > 0$ is immediate.

In a final step, we now look at the impact of an increase in $\hat{n}$ on Ψ. From (37) it follows that $d\Psi/d\hat{n} > 0$ if

$$\omega(2\omega - 1)\ln(\omega) - (\omega - 1) > \frac{(\omega - 1)\left(4\omega^2 + 2\omega - 1\right)}{4\omega - 1}\frac{\gamma(\omega)}{\zeta(\omega)}. \tag{S3}$$

Noting

$$\text{sgn}\left[\frac{d\big(\gamma(\omega)/\zeta(\omega)\big)}{d\widetilde{z}}\right] = \text{sgn}\left[\frac{\omega(2\omega - 1) + 1}{\omega(2\omega - 1) - 1} - \frac{2\omega^2}{4\omega^2 - 5\omega + 1}\right] = 1, \tag{S4}$$

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[22]While we have shown the positive signs of T_1, T_2 analytically, the respective signs can also be verified with any standard mathematics software package.

and accounting for

$$\frac{\gamma(\omega)}{\zeta(\omega)}\bigg|_{\tilde{z}=1} = \frac{4\omega^2 - 5\omega + 1}{2\omega^2}, \tag{S5}$$

we can further conclude that

$$2\omega^2 \big[\omega(2\omega - 1)\ln(\omega) - (\omega - 1)\big] > (\omega - 1)^2 \left(4\omega^2 + 2\omega - 1\right) \tag{S6}$$

is sufficient for $d\Psi/d\hat{n} > 0$. This completes the respective proof. *QED*

Characterization of the open economy equilibrium: the case of $\rho > 0$

In the open economy, a firm's domestic output is given by:

$$D(z) = \frac{w(z)}{2b(1-\rho)}\left[\frac{a}{w(z)}(\ln(w(z)) - 1) + 1\right]. \tag{S7}$$

Accounting for symmetry and recollecting that we abstract from any trade impediments, firm scale $X(z)$ equals $2D(z)$. This establishes the respective scale expressions in (38). Furthermore, with two fully symmetric countries, domestic output and total scale of a foreign firm are given by:

$$D^*(z) = \frac{w^*(z)}{2b(1-\rho)}[e^{\delta^*(z)}(\delta^*(z) - 1) + 1], \tag{S8}$$

$X^*(z) = 2D^*(z)$, respectively, where an asterisk denotes foreign variables. Total sector output in the open economy is then given by $Y(z) = nD(z) + nD^*(z)$. Substituting the latter together with (S7) and (S8) into (7) – with $D(z)$ assuming the role of $X(z)$ in the open economy – we get

$$e^{\delta(z)} = \frac{1}{w(z)}\frac{a - w(z)\phi - w^*(z)\phi[n/(n+1)][e^{\delta^*(z)}(\delta^*(z) - 1) + 1]}{1 + \phi\delta(z) - \phi}, \tag{S9}$$

$$e^{\delta^*(z)} = \frac{1}{w^*(z)}\frac{a - w^*(z)\phi - w(z)\phi[n/(n+1)][e^{\delta(z)}(\delta(z) - 1) + 1]}{1 + \phi\delta^*(z) - \phi} \tag{S10}$$

for domestic and foreign firms' scope, respectively. In the case of symmetry, with $\delta^u = \delta^{u*}$ and $w^u = w^{u*}$, Eq. (S9) can be simplified to (39).

Proceeding as in the closed economy, we can now determine the union objective in Home, which in the open economy is given by

$$\Omega = \frac{nw^u(w^u - w^c)}{2b(1-\rho)}[e^{\delta^u} - 1]^2. \tag{S11}$$

By maximizing objective Ω the domestic union sets wage w^u according to the first order condtion

$$\frac{d\Omega}{dw^u} = \frac{n(e^{\delta^u} - 1)}{2b(1-\rho)}\left[(2w^u - w^c)(e^{\delta^u} - 1) + 2w^u(w^u - w^c)e^{\delta^u}\frac{d\delta^u}{dw^u}\right] = 0. \tag{S12}$$

II

Applying the implicit function theorem to system (S9), (S10), we can calculate

$$\frac{d\delta^u}{dw^u} = -\frac{1}{w^u} \frac{\left[e^{\delta^u}(1 + \phi\delta^u - \phi) + \phi\right](1 + \phi\delta^{u*}) - \phi^2[n/(n+1)]^2\left[e^{\delta^u}(\delta^u - 1) + 1\right]\delta^{u*}}{e^{\delta^u}\left[(1 + \phi\delta^u)(1 + \phi\delta^{u*}) - \phi^2\delta^u\delta^{u*}[n/(n+1)]^2\right]}.$$

And evaluating the latter expression at $\delta^u = \delta^{u*}$ (symmetry), we get

$$\frac{d\delta^u}{dw^u} = -\frac{1}{w^u} \frac{\left[e^{\delta^u}(1 + \phi\delta^u - \phi) + \phi\right](1 + \phi\delta^u) - \phi^2[n/(n+1)]^2\left[e^{\delta^u}(\delta^u - 1) + 1\right]\delta^u}{e^{\delta^u}\left[(1 + \phi\delta^u)^2 - (\phi\delta^u)^2[n/(n+1)]^2\right]}. \tag{S13}$$

Substituting (S13) into (S12), we obtain after tedious but straightforward calculations:

$$w^u = w^c \frac{(1/2)\left(1 - e^{\delta^u}\right) + H(\delta^u)}{1 - e^{\delta^u} + H(\delta^u)}, \tag{S14}$$

where $H(\delta^u)$ is defined in analogy to the appendix. Eq. (S14) can be easily transformed into Eq. (40).

Finally, combining Eqs. (13), (13′), and (29), we can write the full employment condition as in (41). Putting all elements together, we therefore arrive at the open economy equilibrium as characterized by (38)-(41). This completes the proof. *QED*