Centre de Recherche en Economie Publique et de la Population

CREPP WP No 2011/11

International Trade with Endogenous Mode of Competition in General Equilibrium

Peter Neary
Joe Tharakan

September 2011

CREPP - Centre de recherche en Economie Publique et de la Population
Boulevard du Rectorat 7 (B31)
4000 Liège Belgium

CREPP Working Paper Series

INTERNATIONAL TRADE WITH ENDOGENOUS MODE OF COMPETITION IN GENERAL EQUILIBRIUM *,†

J. Peter Neary
University of Oxford and CEPR

Joe Tharakan
Université de Liege, CORE and CEPR

July 18, 2011

Abstract

This paper endogenizes the extent of intra-sectoral competition in a multi-sectoral general-equilibrium model of oligopoly and trade. Firms choose capacity followed by prices. If the benefits of capacity investment in a given sector are below a threshold level, the sector exhibits Bertrand behaviour, otherwise it exhibits Cournot behaviour. By endogenizing the threshold parameter in general equilibrium, we show how exogenous shocks such as globalization and technological change alter the mix of sectors between "more" and "less" competitive, or Bertrand and Cournot, and affect the relative wages of skilled and unskilled workers, even in a "North-North" model with identical countries.

JEL: F10, F12, L13

Keywords: Bertrand and Cournot competition; GOLE (General Oligopolistic Equilibrium); Kreps-Scheinkman; market integration; trade, technology and wages.

---

*Addresses for Correspondence: Neary: Department of Economics, University of Oxford, Manor Road Building, Oxford, OX1 3UQ, U.K.; tel.: (+44) 1865-271085; e-mail: peter.neary@economics.ox.ac.uk; Tharakan: Department of Economics, Université de Liège, 7, bd du Rectorat B31, B-4000 Liège, Belgium; tel.: (+32) 43663121; e-mail: j.tharakan@ulg.ac.be.

†The first version of this paper formed part of the International Trade and Investment Programme of the Geary Institute at University College Dublin. For helpful comments and suggestions we are very grateful to Banu Demir, Jonathan Eaton, Bob Staiger, Xavier Wauthy and a referee, and to participants in presentations at ETSG, ERWIT, Nottingham, NUI Maynooth, UCD, WZB (Berlin) and Zurich. Support from the Irish Research Council for the Humanities and Social Sciences and from the EU Commission under research contract HPRN-CT-2000-00069 is gratefully acknowledged.

1 Introduction

One of the oldest themes in international economics is that larger or more open economies are likely to be more competitive. This notion has been formalized in a variety of ways. Partial-equilibrium models of oligopoly have shown that trade liberalization or increases in market size generate a competition effect which reduces output and profit margins of incumbent firms and may make it harder for them to sustain collusion in repeated interactions.[1] Krugman (1979) showed that competition effects can also arise in a general-equilibrium model with differentiated products, free entry and general additively-separable demands. However, most subsequent studies of trade in general equilibrium have used the Dixit-Stiglitz model of monopolistic competition with CES preferences, which implies that firms' price-cost margins, and hence the degree of competition in the economy, are independent of market size. Melitz (2003) introduces firm heterogeneity into such a framework, and shows that trade liberalization favours more efficient firms at the expense of less efficient ones. However, this is a selection effect rather than a competition effect, since in the Melitz model each individual firm always has the same mark-up. Melitz and Ottaviano (2008) show that this can be relaxed in a model with a quadratic demand system similar to the one we use in this paper. However, since they assume that preferences are quasi-linear, they do not model the impact on factor markets. Much remains to be done to understand the implications of allowing firm mark-ups and the degree of competition to be endogenous in a general-equilibrium model.

In this paper we provide a new explanation of how exogenous shocks such as growth or trade liberalization can lead to changes in the degree of competitive behaviour throughout the economy. We do this by embedding a model of firm behaviour along the lines of Kreps and Scheinkman (1983) in a framework of general oligopolistic equilibrium presented in Neary (2003a, 2007). In the model of Kreps and Scheinkman, as simplified and reduced to an equilibrium in pure strategies by Maggi (1996), firms producing differentiated products first invest in capacity and then set their output prices. Although firms always compete in a Bertrand manner in the second stage of the game, the outcome may or may not resemble that of a one-stage Bertrand game. It will do so if the cost savings from prior investment in capacity are below a threshold level.[2] By contrast, if the cost savings exceed the threshold, then the outcome is "as if" the firms were playing a one-stage Cournot game. Since it is well-known that, other things equal, Bertrand behaviour is more competitive than Cournot (implying higher output and lower mark-ups), this model implies that the nature of technology in a sector is an independent determinant of the extent of competition there.[3]

All previous applications of this approach have considered only a single sector in partial equilibrium.[4] Moreover, they have assumed that the crucial threshold parameter is exogenous. By contrast, a major contribution of our paper is to show that it is endogenous in general equilibrium. As in previous work, the threshold parameter depends on a *technological* component, which varies across sectors. In addition, it depends on a *cost* component, which is linked to economy-wide factor prices. This is because investing in capacity installation is assumed to require a different factor mix from routine production. Specifically, we assume that investment uses skilled workers while production uses unskilled. (Our results are qualitatively unchanged as long as capacity installation uses skilled labour more intensively than production.) This assumption is supported by much of the empirical literature on technology, trade and wages, where the distinction between production and non-production workers is assumed to coincide with that between unskilled and skilled workers. See for example Berman, Bound and Griliches (1994), Hanson and Harrison (1999), Feenstra (2003, p. 101) and Bernard et al. (2008). Its implications have also been explored in a

[1] Brander (1981) is an early example of the former; Rotemberg and Saloner (1989) and Fung (1992) illustrate the latter.

[2] Strictly speaking, in sectors below the threshold level in which the equilibrium level of investment in capacity is strictly positive, the outcome is a "quasi-Bertrand" one, as we explain in Section 4.

[3] This underlies one of Maggi's key results: the greater the cost savings from investing in capacity, the more the outcome resembles that of a less competitive Cournot game, and hence the more likely an export subsidy is to be optimal.

[4] The Kreps-Scheinkman model has been further explored by Davidson and Deneckere (1986), Friedman (1988), Madden (1998), and Boccard and Wauthy (2000), and has been applied to trade issues by Venables (1990) and Ben-Zvi and Helpman (1992) as well as by Maggi.

number of other theoretical studies.[5]

An immediate implication of this view of the technology of production is that shocks to an equilibrium, such as trade liberalization, affect factor prices and therefore alter the cost component of the threshold parameter. As a result, such shocks change the mix of sectors between "more" and "less" competitive, or, equivalently, between those exhibiting Bertrand and Cournot behaviour. The model thus suggests a new mechanism whereby exogenous changes can affect the degree of competition in an economy. It also throws new light on the impact of trade liberalization and technological change on the relative wages of skilled and unskilled workers.

To set the scene, we begin by considering the model in the absence of oligopolistic interaction. Section 2 examines the case of a closed economy where each of a continuum of sectors has only a single firm. We show how the level of investment in capacity is chosen and in Section 3 illustrate the determination of equilibrium. Section 4 extends this model to an integrated world economy with home and foreign firms active in each sector, and explains how the mix between "Bertrand" and "Cournot" sectors is determined. Section 5 considers the effects of shocks to the initial equilibrium. Finally, Section 6 compares the autarky and free-trade equilibria, and shows how opening up such a world to trade affects the degree of competition and the distribution of income, even though the two countries in our "North-North" model are identical.

2 Autarky with Monopoly in General Equilibrium

2.1 Technology

We consider an economy with a continuum of sectors indexed by z, which varies along the unit interval: $z \in [0, 1]$. Until Section 4 we focus on the autarky equilibrium, in which there is a single firm in each sector. Each firm takes two decisions: how much to invest in capacity, and how much output to produce. We follow Maggi (1996) in assuming that capacity is not a rigid constraint on output: firms can produce beyond capacity though they incur higher marginal costs when they do so. In addition, we extend Maggi's framework to allow for the possibility that firms may not invest in capacity at all, choosing instead to incur the penalty of producing above capacity on all units they produce. We consider how a firm chooses its optimal capacity in the next sub-section. In the remainder of this one, we explain our second main departure from Maggi: the links between technology and factor demands which allow us to embed the model in general equilibrium.

As already discussed, production and capacity installation require different factors of production, unskilled and skilled labour respectively. Factor markets are economy-wide, so all sectors face the same factor prices: w for unskilled labour and r for skilled labour. The skilled labour requirement for a unit of capacity is the same across all sectors, equal to δ.[6] By contrast, sectors differ in their technologies for production. For all units up to capacity the unskilled labour requirement in sector z is $\gamma(z)$; while each unit of production above capacity requires $\theta(z)$ additional unskilled workers. Hence, letting $q(z)$ and $k(z)$ denote the levels of output and capacity in sector z, respectively, total costs can be written as:

$$C(z) = r\delta k(z) + \begin{cases} w\gamma(z)q(z) & \text{if} \quad q(z) \le k(z) \\ w\gamma(z)q(z) + w\theta(z)\left[q(z) - k(z)\right] & \text{if} \quad q(z) > k(z) \end{cases} \tag{1}$$

[5] This assumption of non-homotheticity in production has been made in some models of trade under monopolistic competition. Lawrence and Spiller (1983) distinguish between physical capital and labour (rather than skilled and unskilled labour) and assume that they are exclusively used in fixed and variable costs respectively. Flam and Helpman (1987) allow for differences in the ratio of skilled to unskilled labour between fixed costs (which they interpret as R&D costs incurred in product development) and variable costs. Forslid and Ottaviano (2003) show that the core-periphery new economic geography model can be solved analytically when the geographically mobile factor is used exclusively in fixed costs and the immobile factor in variable costs.

[6] Assuming that δ is common across sectors can be rationalized in terms of a competitive sector supplying capacity-installation services, as in Mussa (1978), though without costs of adjustment. Relaxing this assumption complicates the model considerably without yielding additional insight.

Without loss of generality, we order the sectors such that $\theta(z)$ rises (or at least does not fall) with z. Thus:

$$\theta'(z) \geq 0 \tag{2}$$

In addition, we will sometimes assume that $\gamma(z)$ falls (or at least does not rise) with z; this is not essential for our results, though it helps with the interpretation of the model. In diagrams and simulations it is convenient to specialize to the case where both $\gamma(z)$ and $\theta(z)$ are linear in z: $\gamma(z) = \gamma_0 - \gamma_1 z$, where $\gamma_0 \geq \gamma_1 \geq 0$; and $\theta(z) = \theta_0 + \theta_1 z$, where $\theta_0 \geq 0$ and $\theta_1 \geq 0$.[7]

To interpret these assumptions about factor requirements, note from (1) that firms in effect have a choice between two technologies: an unskilled-labour-intensive technology for units produced above capacity, and a skilled-labour-intensive technology for units produced at or below capacity. The parameter $\theta(z)$ measures the penalty which a firm in sector z incurs for saving on skilled labour by producing above capacity. Maggi (1996) interprets this as either a cost of outsourcing or a premium that must be paid to unionized workers to induce them to work overtime. More generally, we can view it as a measure of the firm's cost of producing with the unskilled-labour-intensive technology. This means that low-z sectors have less incentive to hire skilled workers. Hence we define sectors with low values of z as relatively unskilled-labour-intensive. Conversely, sectors with high values of z have the opposite configuration and so are relatively skilled-labour-intensive. Note that this definition coincides with one that focuses on a sector's unskilled labour requirements $\gamma(z)$ in the case where $\gamma(z)$ is strictly decreasing in z. We can also interpret differences between sectors in terms of labour productivity. For sectors which *do* invest in capacity, unskilled labour productivity is just $\gamma(z)^{-1}$, so if $\gamma(z)$ is decreasing in z then unskilled labour is more productive in less unskilled-labour-intensive sectors. Similar assumptions have been made in other recent papers. For example, Costinot and Vogel (2010) assume that high-skill workers have a comparative advantage in sectors with high skill intensities; while Harrigan and Reshef (2010) assume that there is a positive correlation between firms' skill intensity and their productivity.[8]

2.2 Capacity Choice

When will a firm invest in capacity? Consider the marginal costs which it incurs depending on its choice of capacity and output.[9] In the absence of uncertainty and with no threat of entry, a firm will never choose to hold excess capacity, since it incurs a cost of $r\delta$ per unit on the excess capacity, but has no resulting output available for sale. If it produces above capacity (whether its capacity is positive or zero), its marginal cost is $c^N(z)$; while if it invests and produces at capacity, its marginal cost (including the cost of capacity itself) is $c^K(z)$; where the marginal costs are defined as follows:

$$\text{(i)} \quad c^N(z) \equiv w\{\gamma(z) + \theta(z)\} \qquad \text{(ii)} \quad c^K(z) \equiv w\gamma(z) + r\delta \tag{3}$$

The marginal cost $c^N(z)$ consists of the core cost of hiring unskilled workers, $w\gamma(z)$, plus the additional cost of producing above capacity, $w\theta(z)$. By contrast, the marginal cost $c^K(z)$ consists of the core cost of unskilled workers, $w\gamma(z)$, plus the cost of a unit of capacity, $r\delta$, equal to the skilled wage times the number of skilled workers needed to produce the unit.

[7] When both γ' and θ' are zero (corresponding to $\gamma_1 = \theta_1 = 0$ when the functions are linear), all sectors are identical. This very special case is called the "featureless economy" in Neary (2003b) and will not be considered further.

[8] The same need not be true for sectors which do *not* invest in capacity and so do not use skilled labour, however. Employment of unskilled workers in such sectors equals $[\gamma(z) + \theta(z)]\, q(z)$, so unskilled labour productivity equals $[\gamma(z) + \theta(z)]^{-1}$. Hence, unskilled labour can be either more or less productive in less unskilled-labour-intensive sectors depending on whether $\gamma(z) + \theta(z)$ is increasing or decreasing in z, in other words, depending on whether or not the increase in θ as z rises is sufficient to offset the decrease in γ.

[9] In the case where the firm invests in capacity, Maggi distinguishes between short-run and long-run marginal cost. In our notation, short-run marginal cost equals $w\gamma(z)$ when $q(z) \leq k(z)$, and $w\{\gamma(z) + \theta(z)\}$ when $q(z) > k(z)$; while long-run marginal cost equals $w\gamma(z) + r\delta$. However, when the firm does not invest in capacity, the distinction between short-run and long-run marginal cost is moot. Moreover, in the present case of a single monopoly firm, decisions on capacity and output are in effect contemporaneous, so there is no distinction between short- and long-run in either the time or stage dimension.

The monopoly firm's decision is now very simple:[10] if $c^N(z)$ is less than $c^K(z)$, then the firm will choose not to invest in capacity; while if $c^N(z)$ is greater than $c^K(z)$, then it will invest in capacity.[11] As already noted, it will never choose to produce below capacity. Nor when $c^N(z) > c^K(z)$ will it produce above capacity, since it could produce the same output at lower cost by investing more in capacity. Hence the capacity investment choice the firm faces is all-or-nothing, and depends on the relative magnitude of $c^N(z)$ and $c^K(z)$.

Comparing the two marginal costs, $c^N(z)$ and $c^K(z)$, the decision to invest in an extra unit of capacity reflects a trade-off between the additional cost $r\delta$ and the benefit of saving $w\theta(z)$ on the unit of output produced. Hence the marginal sector which is indifferent between investing in capacity and not is the one for which $c^N(z)$ and $c^K(z)$ are equal; i.e., it is the sector indexed by $\tilde{z}$, the solution to the equation:

$$r\delta = w\theta(\tilde{z}) \tag{4}$$

Provided we assume that $\theta(z)$ is strictly increasing in z, this equation must have a unique solution. However, the value of $\tilde{z}$ need not lie strictly between zero and one. If it does, then some sectors (those for which $z > \tilde{z}$) invest in capacity while others (those for which $z \leq \tilde{z}$) do not. If, instead, the value of $\tilde{z}$ which satisfies (4) lies outside these admissible bounds, then the effective value of $\tilde{z}$ must take on one or other boundary value. At one extreme, if the relative cost of skilled labour is so high or extra capacity is so unproductive that $r\delta$ exceeds $w\theta(z)$ for all $z \in [0, 1)$, then no sectors invest in capacity and $\tilde{z}$ equals one. At the other extreme, if capacity is relatively cheap so $r\delta$ is less than $w\theta(z)$ for all $z \in (0, 1]$, then all sectors invest in capacity and $\tilde{z}$ equals zero. In most of the paper we concentrate on the case where $\tilde{z}$ lies strictly between zero and one, since this gives the richest set of outcomes. Other cases will be mentioned in passing.

Note the comparative statics implications of (4). Both an increase in the skill premium r/w and a fall in the productivity of skilled workers (i.e., a rise in δ) are associated with a rise in $\tilde{z}$. Each of these shocks makes investing in capacity less attractive, and so fewer sectors choose to do so in equilibrium. In this case we can say that the extensive margin of capacity investment rises.

2.3 Preferences

Consumer preferences take a continuum quadratic form as in Neary (2003a), extended to allow for differentiated products within sectors. There are $\bar{L}$ identical households, each with additively separable preferences over their consumption of all goods:

$$U[\{x(z)\}] = \int_0^1 u\{x(z)\}dz \tag{5}$$

where the sub-utility functions are quadratic. Note that there is no numéraire or outside good: preferences are not quasi-linear, so the demands for all goods are affected by changes in income. In the monopoly case, we do not need to distinguish between different varieties, and so $u\{x(z)\}$ is simply $ax(z) - \frac{b}{2}x(z)^2$, with $a > 0$ and $b > 0$. In Sections 4 and 5 we allow for duopoly, so the sub-utility functions become:[12]

$$u\{x(z)\} = a[x_1(z) + x_2(z)] - \frac{b}{2}\left[x_1(z)^2 + x_2(z)^2 + 2ex_1(z)x_2(z)\right] \tag{6}$$

Here $x_i(z)$ is the individual's demand for variety i in sector z; and e, which is positive and strictly less than one ($0 \leq e < 1$), is an inverse measure of product differentiation, ranging from zero (the case of unrelated

[10] We will see in Section 4 that the same conclusions follow in the duopoly case, though the argument is more subtle.

[11] Maggi considered only the latter case, where $c^N(z) < c^K(z)$. In the knife-edge case where the two marginal costs coincide, so $c^N(z) = c^K(z)$, we assume that the firm does not invest in capacity.

[12] Our treatment of differentiated product demand within each sector follows Dixit (1981) and Vives (1985).

goods) to one (the case of identical products). With varieties $x_1(z)$ and $x_2(z)$ produced by rival firms in duopoly, e will also serve as a measure of the intensity of competition within sectors.

Each household maximizes utility subject to the budget constraint:

$$\int_0^1 [p_1(z)x_1(z) + p_2(z)x_2(z)]\, dz \leq I \tag{7}$$

where I is the household's income. This yields inverse demand functions for each good as follows:

$$p_i(z) = \frac{a}{\lambda} - \frac{b}{\lambda}[x_i(z) + e x_j(z)] \qquad i,j = 1,2; \quad i \neq j \tag{8}$$

Here λ is the household's marginal utility of income, which depends on income and on the distribution of prices:

$$\lambda = \frac{\alpha \mu_1^p - I}{\beta(\mu_2^p - e\nu^p)} \tag{9}$$

where μ_1^p and μ_2^p denote respectively the first and second moments of the distribution of prices and ν_p denotes the (uncentred) covariance of prices across sectors. (Details are given in the Appendix.) Aggregating over all $\bar{L}$ households and imposing market clearing (so the total quantity sold by firm i in sector z, $q_i(z)$, equals $\bar{L}x_i(z)$, for all i, z) yields the market inverse demand functions:

$$p_i(z) = \hat{a} - \hat{b}[q_i(z) + e q_j(z)] \qquad i,j = 1,2; \quad i \neq j \tag{10}$$

where $\hat{a} \equiv a/\lambda$ and $\hat{b} \equiv b/\lambda\bar{L}$. Because of λ, the demand functions are highly non-linear in prices. However, λ depends only on economy-wide variables and not directly on variables in sector z. Hence, firms in sector z take $\hat{a}$ and $\hat{b}$ as given in their decision-making, so from the perspective of individual sectors the demand functions are linear.

2.4 Factor markets

We assume that each of the $\bar{L}$ households supplies one unit of unskilled labour and s units of skilled labour, and that wage flexibility brings about full employment of both factors. Equilibrium in the market for unskilled workers therefore requires that total supply $\bar{L}$ must equal the aggregate demand for unskilled labour, which in turn equals the sum over all sectors of their output multiplied by their unskilled labour requirement per unit output:

$$\bar{L} = \int_0^{\tilde{z}} [\gamma(z) + \theta(z)]\, q^A[c^N(z)]dz + \int_{\tilde{z}}^1 \gamma(z)\, q^A[c^K(z)]dz \tag{11}$$

The equilibrium level of output in autarky q^A is the outcome of profit-maximization by each firm in the face of the demand function (10). Routine calculations show that it equals:

$$q^A(c) = \frac{\hat{a} - c}{2\hat{b}} \tag{12}$$

where the marginal cost c equals $c^N(z)$ in sectors that do not invest in capacity and $c^K(z)$ in those that do. Note that the unskilled labour requirement in (11) drops discontinuously at $\tilde{z}$, the threshold sector where firms switch to investing in capacity, allowing them to save on $\theta(z)$ workers per unit output.

Equilibrium in the market for skilled workers is determined in a similar manner:

$$s\bar{L} = \int_{\tilde{z}}^{1} \delta q^A[c^K(z)]dz \tag{13}$$

The endowment of skilled workers is s times the endowment of unskilled workers, while the demand for skilled workers comes only from sectors that invest in capacity, in each of which it equals δ times its output q^A.

2.5 National Income

To complete the model we need to specify how profits are disbursed. It is convenient to assume that they are redistributed costlessly in equal shares to each of the $\bar{L}$ households. National income therefore equals the sum of factor payments and profits, so national income per household, denoted by I, is:

$$I = w + rs + \Pi/\bar{L} \tag{14}$$

where Π is the sum of profits of all firms in the economy.

3 Autarky Equilibrium

The full model consists of the two labour-market equilibrium conditions, (11) and (13), with the level of output in each sector given by (12); the equation for the threshold sector or extensive margin $\tilde{z}$, (4); and the definitions of income and the marginal utility of income, (14) and (9). However, we have one degree of freedom in solving for nominal variables: as in Neary (2003a), all real variables are homogeneous of degree zero in the nominal variables w, r and λ^{-1}. Hence we can choose an arbitrary numéraire without affecting the model's properties, and it is convenient to choose the marginal utility of income itself as numéraire, setting λ equal to one.

The model can be further simplified by using (4) to eliminate the skilled wage r. This reduces the model to two equations in w and $\tilde{z}$, which can be illustrated in a single diagram as in Fig. 1.[13] The properties of these equations are derived formally in the Appendix, Section 8.2. Here we give an intuitive account.

Consider first the equilibrium condition in the market for skilled labour. This is given by equation (13) with monopoly output given by (12) and marginal cost $c^K(z)$ by (3). The demand for skilled labour is decreasing in the unskilled wage w for two distinct reasons. On the one hand, a rise in w raises costs directly, since skilled and unskilled labour are technical complements in production in each sector that invests in capacity.[14] On the other hand, a rise in w also raises costs indirectly, since from (4) it raises the skilled wage r needed to maintain the initial value of the threshold sector $\tilde{z}$. The demand for skilled labour is also decreasing in $\tilde{z}$ itself for similar reasons. On the one hand, an increase in $\tilde{z}$ reduces the demand for skilled labour at the extensive margin, as the marginal sector ceases to invest in capacity. On the other hand, an increase in $\tilde{z}$ raises the equilibrium skilled wage r at a given unskilled wage w, so inducing all capacity-using sectors (those for which $z > \tilde{z}$) to invest in less capacity at the intensive margin. The locus

[13]It might seem that it would be simpler to eliminate $\tilde{z}$ rather than r. However, the slopes of the loci in the figures are not so clear-cut in that case. Where this approach becomes very useful is in the boundary case where all sectors invest in capacity so $\tilde{z}$ is zero. The model then reduces to two excess factor demand equations which exhibit gross substitutability: $L = L^D(w,r)$ and $S = S^D(w,r)$. The comparative statics properties of this system are easily derived, and (provided $\tilde{z}$ remains equal to zero) they are very similar to those of the more complex case considered in the text.

[14]The technology could be described as "putty-clay". (See Solow (1962) and Bliss (1968).) There is a discrete choice between two techniques ex ante, while after capacity is installed the skilled-to-unskilled labour ratio equals $\delta/\gamma(z)$. Even the latter is not fixed in the engineering sense, since firms could in principle produce above or below capacity. However, in equilibrium it is never profit-maximising to do so.

is thus downward-sloping, as shown in Fig. 1, with points above corresponding to states of excess supply of skilled labour.

Consider next the equilibrium condition in the market for unskilled labour, equation (11). A rise in the unskilled wage induces all sectors to reduce their labour demand at the intensive margin, both directly and indirectly (by raising the skilled wage). So, not surprisingly, unskilled labour demand is decreasing in the unskilled wage. However, the effect of an increase in $\tilde{z}$ on unskilled labour demand is ambiguous. Let $L^A(w, r, \widetilde{z})$ denote the total demand for unskilled labour, given by the left-hand side of (11). Totally differentiating this with respect to the extensive margin $\widetilde{z}$ gives:

$$\frac{dL^A}{d\widetilde{z}} = \frac{\partial L^A}{\partial \widetilde{z}} + \frac{\partial L^A}{\partial r}\frac{dr}{d\widetilde{z}} = \theta(\tilde{z})q^A[c^N(\widetilde{z})\}] + \frac{\partial q^A}{\partial c} w\theta'(\widetilde{z})\int_{\tilde{z}}^{1}\gamma(z)\,dz \gtrless 0 \tag{15}$$

The first term, the direct or extensive-margin effect, is positive: as $\widetilde{z}$ increases, the marginal sector ceases to invest in capacity, increasing its demand for unskilled labour by $\theta(\tilde{z})$ times its output q^A. However, the second term, the indirect or intensive-margin effect, is negative: the increase in $\tilde{z}$ requires an increase in the skilled wage r from (4), which in turn raises c^K, the cost of production for firms that have invested in capital, and so reduces the demand for unskilled labour at the intensive margin in all the capacity-using sectors. (Note that $\frac{\partial q^A}{\partial c} = -\frac{1}{2b} < 0$ from (12).) When $\tilde{z}$ is close to one (strictly, infinitesimally close), the second effect vanishes and so the first, intensive-margin, effect dominates and the locus must be upward-sloping. We can characterize this as the case where skilled and unskilled labour are *general-equilibrium complements*, since their prices move in the same direction along the locus: the skilled wage r rises because of the increase in $\tilde{z}$; while, as fewer sectors invest in capacity, the demand for unskilled labour increases, so its wage w also rises.[15] Hence the locus is upward-sloping in the neighborhood of $\tilde{z} = 1$. However, for lower values of $\tilde{z}$, the second, intensive-margin, effect may (though it need not) dominate. If that happens, then unskilled labour is a *general-equilibrium substitute* for skilled labour: as fewer sectors invest in capacity, the demand for unskilled labour falls in those sectors which continue to invest, causing the locus to be downward-sloping.

In general, we cannot resolve this ambiguity concerning the slope of the unskilled-labour-market equilibrium locus. Even in the special case of linear labour requirement functions, we cannot pin down the shape of the locus, though in extensive simulations it was always found to be U-shaped as illustrated in Fig. 1.[16] Nor is it possible to rule out multiple equilibria. However, while the global behaviour of the model is therefore ambiguous, we can pin down its local properties by invoking plausible stability conditions, which imply that the out-of-equilibrium dynamics must be as shown by the arrows.[17] Hence the local configuration in the neighborhood of a stable interior equilibrium must have the skilled-labour-market equilibrium locus S^A cut the unskilled-labour-market equilibrium locus L^A from above, as shown by point A_0. Whether the equilibrium point is on the downward-sloping or the upward-sloping portion of the unskilled-labour-market equilibrium locus will turn out to be important for comparative statics in Section 5.

A final consideration is that we have so far considered only interior equilibria. It is also possible that the two loci may not intersect at all for values of $\tilde{z}$ in the $[0, 1]$ interval. This corresponds to an economy in which either all sectors invest in capacity, so $\tilde{z}$ equals zero, or no sectors invest in capacity, so $\tilde{z}$ equals

[15] Note that this is only one possible definition of complementarity or substitutability between factors. As we have already seen, skilled and unskilled labour are *always* technical complements in partial equilibrium in those sectors which invest in capacity. We have also seen that the skilled-labour-market equilibrium locus always slopes downwards: as fewer sectors invest in capacity, the unskilled wage must fall if the skilled-labour market is to remain in equilibrium.

[16] Details of the linear case are given in a supplementary appendix to the paper, available on request and at http://www.economics.ox.ac.uk/Members/peter.neary/papers/maggimix.htm.

[17] At points above the unskilled labour-market equilibrium locus, there is excess supply of unskilled labour, which we assume tends to reduce the unskilled wage; conversely for points below. As for the skilled labour-market equilibrium locus, at points to the right of it there is excess supply of skilled workers, as we have seen. We assume, as is natural, that this puts downward pressure on the skilled wage, which, at a given unskilled wage, encourages more sectors to invest in capacity and so reduces the extensive margin $\tilde{z}$. The converse applies for points to the left of the skilled labour-market equilibrium locus.

one. The latter case cannot be an equilibrium, since the demand for skilled labour would fall to zero.[18] The former is the case where skilled labour is extremely abundant, and as noted in footnote 13 its properties are less interesting and are easily derived. In most of the remainder of the text we concentrate on the case of a stable interior equilibrium, as shown in Fig. 1.

4 Free Trade

4.1 Firm Behaviour in Duopoly

We turn next to consider the case of free trade between two identical economies, each with the same structure as the economy of previous sections.[19] This symmetric framework allows us to focus on a "North-North" world where trade takes place because of oligopolistic interaction and product differentiation rather than because of comparative advantage. We begin in this sub-section by considering the duopoly equilibrium in each sector, where a single home firm competes against a single foreign one. We assume that the firms engage in a two-stage game, first choosing their levels of capacity and then, having observed each other's choices of capacity, choosing their prices, and meeting consumer demands at those prices.[20]

There are two cases to consider, corresponding to whether the marginal cost of investing in capacity, $r\delta$, is greater or less than the marginal benefit, $w\theta(z)$. Consider first the case where the cost is greater, i.e., from (4), consider those sectors where $z < \tilde{z}$. There is clearly a candidate equilibrium which is symmetric, and in which neither firm invests in capacity, engaging instead in a one-shot Bertrand game. Furthermore, it is straightforward to show that this is indeed an equilibrium and that it is unique, since neither firm has an incentive to deviate from it by investing in capacity.[21] Hence, just as in the monopoly case already considered, firms do not invest in capacity in sectors with $z < \tilde{z}$. We call these "Pure Bertrand" sectors. Firms incur the unit cost $c^N(z)$ and charge the Bertrand equilibrium price, which we denote $p^B[c^N(z)]$: see the first entry in Table 1.

[18] As $\tilde{z}$ approaches one, the unskilled-labour-market equilibrium locus is upward-sloping, as we have seen. Hence the value of w on this locus at $\tilde{z} = 1$ must be positive. However, the skilled-labour-market equilibrium locus asymptotes to a value for w of minus infinity, as the sectors which demand skilled workers disappear. Hence if s is strictly positive there cannot be an equilibrium at $\tilde{z} = 1$.

[19] With minor modifications to the demand and factor-market-equilibrium conditions below, the model can be reinterpreted as applying to a single economy in autarky, with two active firms in each sector. This yields a closed-economy general-equilibrium extension of Kreps and Scheinkman.

[20] Following Maggi, we assume that firms never find it profitable to ration consumers. Strictly speaking, there are some feasible off-equilibrium prices which would imply losses for firms if they met all demand, so they would wish to ration consumers. (see Boccard and Wauthy (2000).) However, if the cost function had a continuous first derivative but was arbitrarily close to the step function assumed here (which has a finite jump where output equals capacity), the results would be the same and firms would never have recourse to rationing. The need to pay attention to rationing is therefore a knife-edge feature of the model, which justifies ignoring it in applications, especially to general equilibrium.

[21] In the symmetric case with no investment in capacity, each firm has marginal cost equal to c^N, so we can write their price and output as $p\left(c^N, c^N\right)$ and $q\left(c^N, c^N\right)$ respectively, yielding profits of $\Pi^{NN} = \left[p\left(c^N, c^N\right) - c^N\right] q\left(c^N, c^N\right)$. Suppose instead that the first firm deviates from this by investing in a level of capacity k which is less than or equal to the output it plans to sell. As in Maggi (1996), the second-stage profit-maximising price for the first firm is still the price which would obtain in a one-shot Bertrand game where its costs equalled c^N. Hence its profits if it deviates equal $\Pi^{KN} = \left[p\left(c^N, c^N\right) - c^K\right] k + \left[p\left(c^N, c^N\right) - c^N\right]\left[q\left(c^N, c^N\right) - k\right]$. Rearranging terms, we see that $\Pi^{KN} = \Pi^{NN} - \left(c^K - c^N\right) k$. Hence investment in capacity is not profitable for $c^K > c^N$, i.e., for $z < \tilde{z}$.

Sector	Price	Price-Cost Margin	Lerner Index
"Pure" Bertrand: $0 \leq z \leq \tilde{z}$	$p^B[c^N(z)]$	$p^B[c^N(z)] - c^N(z)$	$1 - \frac{(2-e)c^N}{(1-e)\hat{a}+c^N}$
Quasi-Bertrand: $\tilde{z} \leq z \leq z^C$	$p^B[c^N(z)]$	$p^B[c^N(z)] - c^K(z)$	$1 - \frac{(2-e)c^K}{(1-e)\hat{a}+c^N}$
Cournot: $z^C \leq z \leq 1$	$p^C[c^K(z)]$	$p^C[c^K(z)] - c^K(z)$	$1 - \frac{ec^K}{\hat{a}+(1+e)c^K}$

Table 1: Prices, Price-Cost Margins, and the Lerner Index Across Sectors

Turning next to the case where the marginal cost of investing in capacity is less than the marginal benefit, $r\delta < w\theta(z)$, so $z > \tilde{z}$, we can draw on the results of Maggi (1996). Note first that, just as in the monopoly case of Section 2, firms will never choose to hold excess capacity in equilibrium; and, provided it is profitable to invest in capacity (i.e., provided $z > \tilde{z}$), they will never produce less than their installed capacity. Hence the equilibrium level of investment is $k(z) = q(z)$ when $z > \tilde{z}$. How will firms set prices when $z > \tilde{z}$? Investment in capacity lowers the cost of producing the marginal unit of output. In addition, because capacity choices are observable before decisions on prices are taken, investing in capacity serves as a commitment device, committing the firm to incurring a penalty if production exceeds capacity. Hence investment in capacity sustains a higher price than the one-stage Bertrand equilibrium price. How much higher depends, as Maggi shows, on the value of $\theta(z)$, yielding two-sub-cases, which we call "quasi-Bertrand" and "Cournot" respectively. Firms which invest in capacity but have relatively low values of $\theta(z)$ choose a price equal to the equilibrium price which would be set in a one-stage Bertrand game with unit costs equal to $c^N(z)$, which in our general-equilibrium setting equals $w\{\gamma(z) + \theta(z)\}$. We call these "quasi-Bertrand" sectors, since this unit cost is higher than the true unit cost the firms actually incur, which equals $c^K(z)$ or $w\gamma(z) + r\delta$. (Firms in these sectors pay the unit cost of investing in capacity $r\delta$ but do not incur the surcharge of $\theta(z)$ for producing above it).[22] Thus the commitment to higher prices is relatively stronger the greater the cost penalty $\theta(z)$. However, the price cannot be indefinitely higher than the Bertrand price corresponding to the costs actually incurred $c^K(z)$. The highest price which investment can sustain is the price that would obtain in a one-stage Cournot equilibrium with unit costs equal to $c^K(z)$. Hence, firms in sectors with sufficiently high values of $\theta(z)$ can credibly commit to charging this price.

Summarizing these arguments, there is a threshold sector, denoted by z^C, such that sectors with $z \leq z^C$ exhibit "quasi-Bertrand" behaviour and sectors with $z \geq z^C$ exhibit "Cournot" behaviour, yielding the equilibrium prices shown in the second column of Table 1. Using the linear inverse demand functions in (10) these prices can be shown to equal:

$$p^B(c) = \frac{(1-e)\hat{a} + c}{2-e} \qquad \text{and} \qquad p^C(c) = \frac{\hat{a} + (1+e)c}{2+e} \tag{16}$$

for an arbitrary marginal cost c. The appropriate cost, c^N or c^K, is given in equation (3). As for the threshold sector z^C, it is determined implicitly by the condition that the Bertrand and Cournot equilibrium prices coincide:

$$p^B[c^N(z^C)\}] = p^C[c^K(z^C)] \tag{17}$$

[22] This result is analogous to the outcome of a one-stage Bertrand game with homogeneous products and heterogeneous costs. In our model both firms incur a marginal cost of $w\gamma(z) + r\delta$ but they charge prices which reflect the marginal cost they would incur if they deviated from the low-output equilibrium, $w\{\gamma(z) + \theta(z)\}$. Similarly, in the one-stage Bertrand game, all firms produce zero output except the lowest-cost firm. It charges a price equal, not to its own marginal cost, but to the marginal cost of the second-lowest-cost firm, since that is the price which would prevail if the lowest-cost firm deviated and produced less than equilibrium output.

It is intuitively obvious that the threshold z^C, defined by (17), at which sectors that invest in capacity switch to behaving "as if" a one-stage Cournot game was being played, must exceed the threshold $\widetilde{z}$, defined by (4), at which it becomes profitable to invest in capacity. For completeness we state this formally:

Lemma 1 *The threshold sector z^C between "quasi-Bertrand" and Cournot sectors, defined by (17), must exceed $\widetilde{z}$.*

(The proofs of this and subsequent results are in the Appendix.)

Consider next the comparative statics properties of the threshold sector z^C. They can be found by totally differentiating equation (17), and using the definitions of c^N and c^K from equation (3). The properties we seek turn out to hinge on the sign of the expression $H(z) \equiv \theta'(z) + [e^2/(2+e)]\gamma'(z)$, evaluated at z^C:

Lemma 2 *The threshold Cournot sector z^C is decreasing in the return to unskilled workers w and increasing in the return to skilled workers r, if and only if $H\left(z^C\right)$ is positive.*

A plausible sufficient condition to ensure that $H\left(z^C\right)$ is positive is that unskilled labour productivity in the absence of investment in capacity is lower in more skill-intensive sectors: recalling the discussion in Section 2.1, this is equivalent to $\theta\left(z\right)+\gamma\left(z\right)$ increasing in z, or $\theta'\left(z\right)+\gamma'\left(z\right) > 0$. This sufficient condition is implied by the assumption of log-supermodularity of the worker productivity function made by Costinot and Vogel (2010): more skilled workers have a comparative advantage in more skill-intensive tasks or sectors. More generally, recall that, from (2), $\theta'(z)$ is non-negative; moreover, the coefficient of $\gamma'(z)$ in $H\left(z\right)$ lies between zero (when $e = 0$) and one third (when $e = 1$). Hence the condition $H\left(z^C\right) > 0$ would fail only if $\gamma'\left(z\right)$ is negative, so $\gamma\left(z\right)$, the marginal cost when producing at or below capacity, falls in z, and by considerably more than $\theta\left(z\right)$, the cost premium for producing above capacity, increases in z. This in turn would imply that unskilled labour productivity in the absence of investment in capacity increased rapidly as we move across sectors from less to more skill-intensive. It seems plausible to rule out this case, so henceforward we assume that the condition in Lemma 2 holds at $z = z^C$.

An immediate corollary of this result follows from the fact that, recalling (4), the return to skilled workers r is increasing in both w and $\widetilde{z}$. Hence:

Corollary 1 *When r is determined endogenously in general equilibrium, the threshold Cournot sector z^C is decreasing in w and increasing in the extensive margin $\widetilde{z}$, if and only if $H\left(z^C\right)$ is positive.*

Thus Lemma 1 ensures that z^C always exceeds $\widetilde{z}$, while from Lemma 2 and its Corollary the condition that $H\left(z^C\right)$ is positive also ensures that both move in the same direction in response to exogenous shocks.

Fig. 2 summarizes the implications of this discussion, illustrating how equilibrium prices vary across sectors for given factor prices and threshold sectors. Here and subsequently (except where otherwise specified) we assume that the equilibrium is an interior one, so both $\widetilde{z}$ and z^C lie between zero and one.[23] In the "pure Bertrand" sectors with z below $\widetilde{z}$, firms do not invest in capacity, and the equilibrium price is that in a standard one-stage game with marginal costs equal to $c^N\left(z\right) = w\left\{\gamma\left(z\right)+\theta\left(z\right)\right\}$. The expression for the equilibrium price is the same in the "quasi-Bertrand" sectors with z between $\widetilde{z}$ and z^C, but now this price is above the pure Bertrand level, since the full marginal cost in this range is $c^K\left(z\right) = w\gamma\left(z\right) + \delta r$, which is less than $c^N\left(z\right)$. Finally, the "Cournot" sectors with z above z^C have the highest sustainable price, the Cournot price corresponding to the marginal cost $c^K\left(z\right)$.

Fig. 2 also illustrates the price-cost margins in each sector. Explicit expressions for these and for the corresponding Lerner indices of market power (defined as $\Lambda \equiv \left(p-c\right)/p$) are given in the third and fourth columns of Table 1. In the "pure Bertrand" sectors, costs rise with z as $\theta\left(z\right)$ is increasing in z, and part of

[23]To avoid distracting non-linearities, Figs. 2 and 3 use the special linear functional forms for the technology distributions specified in Section 2.1, with the added simplification that γ_1 is zero, so $\gamma\left(z\right)$ is independent of z.

this rise is passed on to consumers, causing margins to fall slightly with z. However, beyond the threshold sector $\widetilde{z}$, continuing rises in $\theta(z)$ allow firms to sustain higher prices and margins increase steadily until the Cournot threshold z^C. Beyond z^C, further changes in price and margins occur only if $\gamma(z)$ changes (which, to simplify the figure, it does not in this case). Crucially, in these Cournot sectors, the Lerner index is greater than it would be without investment in capacity, even though costs are lower as a result:

$$\Lambda_C - \Lambda_B = \frac{\left(2 - 2e + e^2\right)\hat{a}c^N + \left(2 - e^2\right)c^N c^K + e(1-e)\left(c^N - c^K\right)\hat{a}}{\left[\hat{a} + (1+e)c^K\right]\left[(1-e)\hat{a} + c^N\right]} \tag{18}$$

Thus all sectors with $c^N \geq c^K$, i.e., with $z \geq \tilde{z}$, are less competitive under Cournot behaviour than they would be under Bertrand behaviour. The same also holds for the comparison between the "quasi-Bertrand" and "pure-Bertrand" sectors. Summarizing:

Lemma 3 *Competition is reduced, in the sense that the Lerner Index of market power is higher, as a result of firms being able to sustain higher prices, in all sectors above the $\tilde{z}$ threshold.*

The fact that Cournot is less competitive than Bertrand, other things equal, is familiar from Vives (1985). However, this is usually interpreted as a discrete comparison between two alternative models. Here, it arises as a result of an endogenous behavioral response in the same model. Moreover, there is a gradual transition from pure Bertrand to Cournot behaviour between the two thresholds $\tilde{z}$ and z^C, as Fig. 2 illustrates. All of this justifies our viewing a rise in the value of $\tilde{z}$ as an increase in the degree of competition in the economy: such a change in the extensive margin implies that fewer sectors exhibit quasi-Bertrand or Cournot behaviour, with higher price-cost margins than otherwise.

4.2 Intersectoral Differences in Factor Demands

We are now ready to consider the full general equilibrium of the integrated world economy with duopoly in each sector. Because of symmetry between countries, we need consider equilibrium in one country only. The full employment conditions are similar to those in the autarky case, equations (11) and (13), with two added complications. First, factor demands differ between the "quasi-Bertrand" sectors (with $\widetilde{z} < z < z^C$) and the "Cournot" sectors (with $z > z^C$); and, second, factor demands from all sectors are higher than in autarky because the goods market has doubled in size. It is true that firms now face competition, but this is more than offset by the increase in market size. Routine calculations show that outputs in Bertrand and Cournot competition equal:

$$q^B(c) = \frac{\hat{a} - c}{\hat{b}(1+e)(2-e)} \qquad \text{and} \qquad q^C(c) = \frac{\hat{a} - c}{\hat{b}(2+e)} \tag{19}$$

Because there are now two firms in each sector rather than one, these would be smaller than autarky output as given by (12) if the market size were unchanged. But the opening up of the foreign market means that the demand parameter $\hat{b}$, an inverse measure of market size, now equals $b/2\lambda\bar{L}$ instead of $b/\lambda\bar{L}$ in the autarky case. It is easily checked that this market size effect dominates, so $q^B(c) \geq q^C(c) > q^A(c)$ (with the first equality strict except when e is zero).

Given these equilibrium outputs, their implications for the derived demand for skilled labour are summarized in the equilibrium condition:

$$s\bar{L} = \int_{\tilde{z}}^{z^C} \delta q^B[c^N(z)]dz + \int_{z^C}^{1} \delta q^C[c^K(z)]dz \tag{20}$$

Unlike the autarky case (13), the demand for skilled labour comes from both the "quasi-Bertrand" sectors (with $z \in \left[\tilde{z}, z^C\right]$) and the "Cournot" ones (with $z \in \left[z^C, 1\right]$). Similarly, the equilibrium condition in the market for unskilled labour is:

$$\bar{L} = \int_0^{\tilde{z}} \left[\gamma(z) + \theta(z)\right] q^B \left[c^N(z)\right] dz + \int_{\tilde{z}}^{z^C} \gamma(z)\, q^B[c^N(z)]dz + \int_{z^C}^{1} \gamma(z)\, q^C[c^K(z)]dz \tag{21}$$

Note that the demand for unskilled labour per unit output falls discretely from $\gamma(z) + \theta(z)$ to $\gamma(z)$ at $z = \widetilde{z}$ as in the autarky case given by (11); while the level of output is continuous in z, both at $z = \widetilde{z}$ and at $z = z^C$ where it switches from the Bertrand equilibrium output $q^B(c)$ to the Cournot output $q^C(c)$.

These aggregate factor demands are most easily understood by considering how they vary across sectors, as illustrated in Fig. 3, where $s(z)$ and $l(z)$ denote the skilled and unskilled labour demand in sector z respectively. Sectors with z below $\tilde{z}$ do not invest in capacity and so demand unskilled labour only. Their demand for unskilled labour may either rise or fall with z: Fig. 3 illustrates the case where it falls with z.[24] At $z = \widetilde{z}$, there is a discrete drop in the demand for unskilled labour and a corresponding jump in demand for skilled labour, as sectors begin to invest in capacity: output is continuous in z, so investment in capacity in effect substitutes skilled for unskilled labour. As z increases further, demand for both factors falls, not because actual costs incurred rise, but because the penalty for producing beyond capacity rises and so higher prices can be sustained. Finally, beyond z^C, factor demands do not change further as $\gamma(z)$ is assumed to be independent of z in the figure.

4.3 Free-Trade Equilibrium

Despite the added complexities of the duopoly case, the analysis of the monopoly case continues to apply in qualitative terms. In particular, the equilibrium conditions can still be reduced to two equations in the unskilled wage w and the extensive margin $\widetilde{z}$, and the qualitative properties of Fig. 1 are unchanged.[25] The skilled-labour-market equilibrium locus continues to be unambiguously downward-sloping, as a higher extensive margin leads to excess supply of skilled labour, requiring a fall in the unskilled wage to restore equilibrium. In addition, the unskilled-labour-market equilibrium locus continues to be ambiguous in slope except that it must be upward-sloping in the neighborhood of $\widetilde{z} = 1$: a higher extensive margin must lead to excess demand for unskilled labour when the extensive-margin effect dominates, but may lead to excess supply if the intensive-margin effect is important. (Equation (33) in the Appendix shows that the effects under duopoly are formally identical to those in the monopoly case as given by equation (15) above.)

5 Comparative Statics

We can now consider the effects of shocks to an initial equilibrium. We concentrate on symmetric shocks to both countries, to preserve our "North-North" focus. The first shock we consider is a change in factor

[24] The responsiveness of $l(z)$ to an increase in z in pure Bertrand sectors equals $\eta'(z)q^B\{c(z)\}[1-\varepsilon(z)]$. Here $\eta(z) \equiv \theta(z) + \gamma(z)$ and so $\eta'(z)$ may be either positive or negative in general, though it is positive under the special assumptions made in Fig. 3; $c(z)$ equals $w\eta(z)$ in this range; and $\varepsilon(z) \equiv -[c(z)/q^B\{c(z)\}][\partial q^B\{c(z)\}/\partial c(z)]$ is the elasticity of output with respect to marginal cost, which can be greater or less than one. Hence the case illustrated in Fig. 3 corresponds to a relatively high cost elasticity of output.

[25] Technically, this arises because, as a marginal sector switches from quasi-Bertrand to Cournot behaviour, its output, and hence its factor demands, do not change. Hence the labour-market equilibrium conditions, (20) and (21), are independent of the new variable z^C, and so the Jacobian of the coefficient matrix is block-triangular: the equilibrium values of $\tilde{z}$, w and r are determined by (4), (20) and (21), just as they were determined by (4), (11) and (13) in autarky, while equation (17) alone determines the equilibrium value of z^C.

endowments, both absolute and relative. Then we turn to consider skill-biased technological progress, also in both absolute and relative forms.

Consider first an increase in the overall size of each economy as measured by the labour force $\bar{L}$, which implies a uniform increase in the endowment of both skilled and unskilled labour. Inspection of the labour-market equilibrium conditions, (11) and (13), and the expression for output, (12), shows that this type of growth is completely neutral. Demands for all goods, and hence outputs by all firms, rise in line with growth, and so no change in the initial factor prices and threshold sectors is required. This occurs despite the fact that demands are not homothetic.[26] It arises because, with investment in capacity chosen endogenously, there are no exogenous fixed costs in the economy: all costs are proportional to output. It is true that capacity costs are incurred before output is produced, so it is appropriate to call them fixed costs, but their level is endogenous rather than exogenous. By contrast, in traditional models of monopolistic competition with exogenous fixed costs, such as Krugman (1979), growth per se leads to an increase in productivity and firm size (and/or firm numbers if entry is possible). For medium- and long-run analysis it seems more plausible to assume that fixed costs arise from prior investments rather than from fundamental properties of the technology. For completeness, we summarize this result as follows:

Proposition 1 *An increase in the number of households $\bar{L}$, which implies an equal proportionate increase in the endowments of skilled and unskilled labour, leads to an equal proportionate increase in the outputs of all sectors, and no change in factor prices or in the threshold sectors $\tilde{z}$ and z^C.*

By contrast, a change in relative factor endowments is not neutral. To see this, consider the effects of an increase in s, the representative household's endowment of skilled labour, and thus the economy-wide ratio of skilled to unskilled labour. Inspecting the equilibrium loci, (11) and (13), and recalling that $r\delta = w\theta(\widetilde{z})$, this shock leaves the unskilled-labour-market equilibrium locus unaffected while it shifts downwards the skilled-labour-market equilibrium locus. As Fig. 4 shows, the effect is to lower the extensive margin $\widetilde{z}$. As a result, the skill premium r/w definitely falls, although the unskilled wage itself may rise or fall. Fig. 4 illustrates the case where the unskilled wage rises because unskilled labour is a general-equilibrium substitute for skilled labour in the relevant range: the increased endowment of skilled labour drives down its reward, encouraging more unskilled labour usage in all capacity-using sectors, with the result that the unskilled wage rises. By contrast, when unskilled labour is a general-equilibrium complement for skilled labour, so the initial equilibrium is along the upward-sloping portion of the unskilled-labour-market equilibrium locus, the unskilled wage falls.

How do these responses to a greater endowment of skilled labour affect the degree of competition in the economy? Since $\widetilde{z}$ falls, the number of "pure Bertrand" sectors definitely falls. The effect on the threshold Cournot sector z^C is less clear-cut. Using Corollary 1, we can decompose the change in z^C as follows:

$$\frac{dz^C}{ds} = \underset{-}{\frac{\partial z^C}{\partial w}} \underset{+/-}{\frac{dw}{ds}} + \underset{+}{\frac{\partial z^C}{\partial \widetilde{z}}} \underset{-}{\frac{d\widetilde{z}}{ds}} \tag{22}$$

where the signs of the terms on the right-hand side are as indicated. The second pair of terms is unambiguously negative: the rise in s reduces the threshold sector $\widetilde{z}$ as we have seen, which tends to pull down z^C. However, the change in the unskilled wage is ambiguous as we have also seen: if the wage falls, the case where unskilled labour is a general-equilibrium complement for skilled labour, this tends to raise z^C. Even in this case however, we can conclude that the economy has become less competitive: since *both* factor prices fall relative to the numéraire, aggregate profits must rise: firm owners gain both directly from the increase in the endowment of skilled labour and indirectly from the resulting softening in demand for unskilled labour.[27]

[26] As discussed in Neary (2003a), even when $e = 1$, continuum-quadratic preferences as in (5) and (6) are not homothetic, though they are a member of the Gorman polar form or quasi-homothetic family of preferences. The implied Engel curves are straight lines, but do not pass through the origin.

[27] We are grateful to Jonathan Eaton for pointing out this implication of our results.

Similar effects follow when the relative endowment of skilled labour rises not because of an absolute increase in its supply but because of skill upgrading of some of the existing labour force. This can be represented by compensating changes in the unskilled and skilled endowment parameters μ and s (with μ initially equal to one), such that the aggregate endowment $(\mu + s)\,\bar{L}$ remains constant. As in Fig. 4, an increase in the skilled endowment s shifts the skilled-labour-market equilibrium locus downwards; in addition, the fall in the unskilled endowment μ shifts the unskilled-labour-market equilibrium locus upwards. Once again, the extensive margin $\widetilde{z}$ and the skill premium r/w definitely fall, but the unskilled wage may rise or fall, with the latter outcome only possible when unskilled labour is a general-equilibrium complement for skilled labour. Summarizing these results:

Proposition 2 *An increase in the relative endowment of skilled labour, whether in absolute terms or through skill upgrading of some unskilled workers, reduces the skill premium and the extensive margin $\widetilde{z}$. The unskilled wage rises if and only if unskilled labour is a general-equilibrium substitute for skilled labour. In either case, the economy becomes less competitive in aggregate.*

The final shock we consider is skill-biased technological progress, corresponding in our model to an exogenous fall in the skilled-labour requirements parameter δ.[28] This affects the diagram in $\{w, \tilde{z}\}$ space in the same way as an increase in the relative endowment of skilled workers in Proposition 2: the unskilled-labour-market equilibrium locus is unaffected while the skilled-labour-market equilibrium locus shifts to the left. As a result, Fig. 4 still applies in qualitative terms. In particular, $\tilde{z}$ definitely falls: more sectors adopt skill-intensive techniques in response to an improvement in their productivity. Once again, therefore, the economy becomes less competitive, because more sectors invest in capacity which allows them to sustain higher prices. In addition, the unskilled wage may rise or fall as before, rising if and only if unskilled labour is a general-equilibrium substitute for skilled labour. By contrast, the implications for the skill premium are different from the case of an endowment increase in Proposition 2. Totally differentiating the equilibrium condition (4) gives:

$$d\ln r - d\ln w = E_{\theta z} d\ln \tilde{z} - d\ln \delta \tag{23}$$

where $E_{\theta z} \equiv \frac{z}{\theta}\frac{d\theta}{dz}$ is the elasticity of the $\theta(z)$ schedule across sectors, here evaluated at $\tilde{z}$. The second term on the right-hand side is the direct effect of pure skill-biased technological progress, which tends to raise the skill premium (since δ falls). However, this could be offset by the first term, since $\tilde{z}$ also falls. Intuitively, from (4) the skill premium r/w equals the marginal rate of technical substitution between skilled and unskilled labour in the threshold sector $\tilde{z}$: the ratio of the unskilled labour saved by investing in one extra unit of capacity $\theta(\tilde{z})$ to the skilled labour needed to construct that unit of capacity, δ. The direct effect of the fall in δ could be offset by the indirect effect of the expansion of sectors investing in capacity, if $\tilde{z}$ falls sufficiently and/or if the fall in $\tilde{z}$ reduces sufficiently the penalty for producing above capacity $\theta(z)$. Either of these effects can dominate, so the change in the skill premium is ambiguous. Thus our model highlights how general-equilibrium adjustments, working through changes in the extensive margin, can partially or fully offset the direct effects of technological progress on the skill premium. In summary:

Proposition 3 *Skill-biased technological progress in all sectors raises the skilled wage, has an ambiguous effect on the skill premium, and reduces the extensive margin $\widetilde{z}$, so the economy becomes less competitive in aggregate.*

[28] As Johnson (1997) notes, this type of technological progress, which he calls "intensive skill-biased", corresponds to skilled workers becoming more productive in jobs they already perform, for example as a result of the widespread adoption of personal computers. (See also Card and DiNardo (2002).) Our model also allows us to consider technological progress that is "extensive skill-biased", represented by the combination of a fall in δ with an increase in the unskilled-labour requirements parameters $\gamma(z)$. Again, following Johnson (1997), this corresponds to skilled workers becoming more efficient in jobs that were formerly done by unskilled workers, for example as a result of the adoption of robotics in manufacturing. The effects of the latter are broadly similar to the case considered in the text, with the additional complication that the unskilled-labour equilibrium locus also shifts.

6 Comparing Autarky and Free Trade

So far, we have looked only at shocks to either the autarky or free trade equilibria. In this section we turn to compare them. Note first the effects of moving from autarky to free trade in sectors which do not invest in capacity in autarky (i.e., sectors with $z < \tilde{z}^A$). On the one hand, those sectors' demand for unskilled labour at initial wages clearly increases as the market size expands. On the other hand, since these sectors do not use skilled labour, there is no change in their demand for skilled labour at initial wages. This asymmetric change in factor demands by itself tends to raise the unskilled wage as the economy moves from autarky to free trade. A higher unskilled wage in turn encourages more sectors to invest in capacity, so both the extensive margin and the skill premium fall. In a skill-scarce economy where most sectors do not invest in capacity, so $\tilde{z}^A$ is close to one, this effect dominates: so the primary impact of moving to free trade is to lower the skill premium. This result is straightforward, but for completeness we state it formally:

Proposition 4 *In a skill-scarce economy, where $\tilde{z}^A$ is close to one, a move from autarky to free trade leads to an increase in the unskilled wage, and a decrease in both the extensive margin and the skill premium.*

(The proof is immediate.)

Next, we show that the effect highlighted in Proposition 4 also dominates in the special case where variable costs are the same in all sectors, provided only that $\tilde{z}^A$ is strictly positive:

Proposition 5 *When $\gamma(z)$ is independent of z, and $\tilde{z}^A$ is strictly positive, a move from autarky to free trade leads to an increase in the unskilled wage, and a decrease in both the extensive margin and the skill premium.*

The proof (in the Appendix) is complex but can be explained intuitively with the help of Fig. 5. With increased competition, the demand for both factors rises in the move from monopoly to duopoly. Hence the unskilled-labour-market equilibrium locus shifts upwards and the skilled-labour-market equilibrium locus shifts rightwards as shown. To prove the proposition we need to show that the vertical shift in the L locus is greater than that in the S locus. Let w^S denote the new unskilled wage rate which is just sufficient to re-establish equilibrium on the market for skilled labour without any change in the extensive margin $\tilde{z}$. Hence point A^S, with an unskilled wage equal to w^S and a threshold sector equal to the monopoly level $\tilde{z}^A$, lies on the duopoly skilled-labour-market equilibrium locus, and we need to show that it lies below the duopoly unskilled-labour-market equilibrium locus. Because $\gamma(z)$ is independent of z, the increase in w to w^S exactly offsets the effect of extra competition in raising demand for unskilled labour from the capacity-using sectors. But the remaining sectors (those with $z < \tilde{z}$) are unskilled-labour-intensive, both on average and at the margin, precisely because they do not invest in capacity. Hence this increase in w is not sufficient to choke off their extra demand for unskilled labour, and the unskilled wage must rise by more, to the level denoted w^F in the figure, to clear both markets. As a result, the new equilibrium is at A^F, where the threshold sector $\tilde{z}$ and the skill premium are lower in free trade relative to autarky.

Consider next the case where variable costs are strictly decreasing in z. Now the factor intensity differences across sectors work in the opposite direction to Proposition 5: the increased market size tends to encourage disproportionately the expansion of sectors which invest in capacity in autarky, increasing the relative demand for skilled labour, which in turn tends to raise the skill premium. This effect is most likely to dominate in a skill-abundant economy, where relatively few sectors use only unskilled labour in autarky; and in an economy where firms face little competition, so their factor demands expand to take full advantage of the larger market. It will definitely dominate, and so the skill premium will definitely increase, if both these properties hold: $\tilde{z}^A$ is zero, so no sectors use only unskilled labour in autarky, and e equals zero, so firms do not compete head-to-head. Summarizing:

Proposition 6 *When $\gamma(z)$ is strictly decreasing in z, $\tilde{z}^A$ is zero, and e equals zero, then a move from autarky to free trade increases both the extensive margin and the skill premium.*

Formally, the proof proceeds in a similar way to that of Proposition 5, except that now there is excess *supply* of unskilled labour at the autarky threshold sector ($\tilde{z}^A = 0$) and at the wage w^S just sufficient to choke off excess demand for skilled labour.

The results of Propositions 5 and 6 are summarized in Fig. 6. Here we specialize to the case where the distributions of technology parameters are linear, so $\gamma(z) = \gamma_0 - \gamma_1 z$ and $\theta(z) = \theta_0 + \theta_1 z$. The vertical axis plots γ_1, which is a measure of intersectoral differences in factor intensity (specifically, in the unskilled labour requirement per unit output). The horizontal axis plots e, which as already mentioned can be viewed as a measure of the intensity of competition within sectors. We have seen from Proposition 5 that, when all sectors have the same unskilled labour requirements (so γ_1 is zero), free trade leads capacity–using sectors to raise their demands for both factors in equal proportions. Provided there are some sectors in autarky which do not use capacity, their increased relative demand for unskilled labour therefore dominates the move from autarky to free trade and induces a fall in the skill premium. Hence Proposition 5 tells us that, at points along the horizontal axis in Fig. 6, free trade leads to a lower skill premium. As for Proposition 6, it considers the case where e is zero, so the move from autarky to free trade does not expose firms to extra competition but only has a market size effect, which encourages a large increase in output by all firms. When all sectors use skilled labour in autarky and γ_1 is strictly positive, this effect encourages a larger relative increase in the demand for skilled labour. Hence, Proposition 6 tells us that at points along the vertical axis free trade leads to a higher skill premium.

The locus in the interior of Fig. 6, based on simulations for the linear case, shows combinations of γ_1 and e which yield no change in the skill premium and the extensive margin between autarky and free trade.[29] Thus a rise in the skill premium and the extensive margin is encouraged by greater differences in factor intensity between sectors, and by less intense competition within sectors.

7 Conclusion

This paper has presented a new model which integrates some key features of industrial organization and general-equilibrium trade theory, and highlights a new mechanism whereby relative wages and the nature of competition within sectors are affected by exogenous shocks. The model extends to general equilibrium the work of Maggi (1996), building on Kreps and Scheinkman (1983), which predicts that firms will exhibit Bertrand or Cournot behaviour depending on the costs of investing in capacity, where capacity serves as a commitment device to sustain higher prices. Maggi looked at normative questions only. In particular, he showed that the Kreps-Scheinkman approach resolves the apparent conflict between Brander and Spencer (1985) and Eaton and Grossman (1986), who proved respectively that the optimal export subsidy is positive in Cournot competition and negative in Bertrand competition.[30] Here we have focused instead on positive questions, including the effects of exogenous shocks such as changes in relative factor endowments and trade liberalization on the distribution of income and on the margin between more and less competitive sectors.

Of course, trade liberalization leads directly to more competition when the number of firms in each sector rises. However, just how much more competition is induced depends on whether firms are able to sustain prices above the Bertrand level. Our model shows that this in turn depends both on technology and on factor prices, with the latter determined endogenously in general equilibrium. When sectors differ in their requirements of unskilled labour, and when goods are more differentiated within sectors so inter-firm competition is less intense, trade between similar economies raises the relative return to skilled labour, making it more difficult to sustain higher prices through investment in capacity and so leading to greater competition throughout the economy. By contrast, when sectors have relatively similar unskilled-labour

[29] The parameter values underlying the simulation are: s=0.99; b=10; γ_0=1; θ_0=0; θ_1=1; a=100; L=45. A *Mathematica* program giving the calculations is available on our web pages.

[30] An obvious extension of the present paper would be to consider optimal trade and industrial policy. This would qualify Maggi's results by adding general-equilibrium effects similar to those considered by Dixit and Grossman (1986).

requirements, and when competition between firms is relatively intense, opening up to trade lowers the skill premium thereby reducing the cost of investing in capacity and sustaining higher prices.

The model also exhibits other novel features. It shows that the effects of exogenous shocks to factor endowments and technology differ greatly depending on the relative importance of changes at the intensive or extensive margin in their effects on the demand for unskilled labour. And, although preferences are non-homothetic and fixed costs play an important role, the fact that the fixed costs are endogenous implies that the economy exhibits constant returns to scale in the aggregate, in striking contrast to standard trade models with exogenous fixed costs. More work is needed to explore the robustness of these and other properties of the model to alternative specifications of the workings of factor markets and the ways in which technology and factor prices interact to affect the nature of competition between firms.

8 Appendix

8.1 Derivation of the Marginal Utility of Income

An individual's marginal utility of income with continuum quadratic preferences and homogeneous products in each sector is derived in Neary (2003a). With differentiated products, the steps are similar. First invert the individual inverse demand functions (8) to get the direct demand functions:

$$x_i(z) = \alpha - \lambda\beta[p_i(z) - ep_j(z)] \qquad i,j = 1,2; \quad i \neq j \tag{24}$$

where α and β are related to the utility parameters a, b and e as follows

$$\alpha \equiv \frac{a}{b(1+e)} \qquad \text{and} \qquad \beta \equiv \frac{1}{b(1-e^2)} \tag{25}$$

Now multiply the direct demand functions for goods i and j in sector z by $p_i(z)$ and $p_j(z)$ respectively, add to get the individual's expenditure on both goods in that sector, and integrate over all sectors to get her total expenditure. Substituting for I and solving gives the explicit expression for λ in (9), where the moments of the distribution of prices are defined as follows:

$$\mu_1^p \equiv \int_0^1 [p_i(z) + p_j(z)]\, dz \qquad \mu_2^p \equiv \int_0^1 \left[p_i(z)^2 + p_j(z)^2\right] dz \qquad \nu^p \equiv 2\int_0^1 p_i(z)p_j(z)dz \tag{26}$$

When prices are the same in all sectors, ν^p reduces to μ_2^p. Note, however, that we cannot take the limit of (9) as e approaches 1, since the inverse demand functions cannot be inverted in this case. The value of λ when e equals 1 can instead be calculated directly by integrating over the inverse demand functions times the corresponding prices as in Neary (2003a).

8.2 Properties of the Equilibrium Loci

Consider first the monopoly or autarky equilibrium of Sections 2 and 3. Write the equilibrium condition for the skilled-labour-market, equation (13), as $s\bar{L} = S^A(w, r, \widetilde{z})$, with r determined by (4). The derivative of the demand function with respect to the unskilled wage is:

$$\frac{dS^A}{dw} = \frac{\partial S^A}{\partial w} + \frac{\partial S^A}{\partial r}\frac{dr}{dw} = \delta\frac{\partial q^A}{\partial c}\int_{\widetilde{z}}^1 \{\gamma(z) + \theta(\widetilde{z})\}dz < 0 \tag{27}$$

which is negative since $\frac{\partial q^A}{\partial c} = -\frac{1}{2\hat{b}}$ from (12). The derivative with respect to the extensive margin is also negative:

$$\frac{dS^A}{d\widetilde{z}} = \frac{\partial S^A}{\partial \widetilde{z}} + \frac{\partial S^A}{\partial r}\frac{dr}{d\widetilde{z}} = -\delta q^A[w\{\gamma(\widetilde{z}) + \theta(\widetilde{z})\}] + \delta\frac{\partial q^A}{\partial c}\int_{\widetilde{z}}^1 w\theta'(\widetilde{z})\, dz < 0 \tag{28}$$

Similarly, the equilibrium condition for the unskilled-labour-market, equation (11), can be written as $\bar{L} = L^A(w, r, \widetilde{z})$, and the derivative of this demand function with respect to the unskilled wage is once again negative:

$$\frac{dL^A}{dw} = \frac{\partial L^A}{\partial w} + \frac{\partial L^A}{\partial r}\frac{dr}{dw} = \frac{\partial q^A}{\partial c}\left[\int_0^{\widetilde{z}} \{\gamma(z) + \theta(z)\}^2 dz + \int_{\widetilde{z}}^1 \gamma(z)\{\gamma(z) + \theta(\widetilde{z})\}dz\right] < 0 \tag{29}$$

However, the derivative of the demand for unskilled labour with respect to the extensive margin $\widetilde{z}$ is ambiguous in sign, as discussed in the text.

Consider next the duopoly or free-trade case of Sections 4 and 5. As before, write the equilibrium condition for the skilled-labour market, equation (21), as $s\bar{L} = S^F(w, r, \widetilde{z})$, with r determined by (4). The derivatives of the demand function are as follows:

$$\frac{dS^F}{dw} = \frac{\partial S^F}{\partial w} + \frac{\partial S^F}{\partial r}\frac{dr}{dw} = \delta\frac{\partial q^B}{\partial c}\int_{\tilde{z}}^{z^C}\{\gamma(z) + \theta(z)\}dz + \delta\frac{\partial q^C}{\partial c}\int_{z^C}^{1}\{\gamma(z) + \theta(\widetilde{z})\}dz < 0 \tag{30}$$

$$\frac{dS^F}{d\widetilde{z}} = \frac{\partial S^F}{\partial\widetilde{z}} + \frac{\partial S^F}{\partial r}\frac{dr}{d\widetilde{z}} = -\delta q^B[c^N(\widetilde{z})\}] + \delta\frac{\partial q^C}{\partial c}\int_{z^C}^{1} w\theta'(\widetilde{z})\,dz < 0 \tag{31}$$

Similarly, the equilibrium condition for the unskilled-labour market, equation (21), can be written as $\bar{L} = L^F(w, r, \widetilde{z})$, and the derivatives of the demand function are as follows:

$$\frac{dL^F}{dw} = \frac{\partial L^F}{\partial w} + \frac{\partial L^F}{\partial r}\frac{dr}{dw}$$

$$= \frac{\partial q^B}{\partial c}\left[\int_0^{\tilde{z}}\{\gamma(z) + \theta(z)\}^2 dz + \int_{\tilde{z}}^{z^C}\gamma(z)\{\gamma(z) + \theta(z)\}dz\right] + \frac{\partial q^C}{\partial c}\int_{z^C}^{1}\gamma(z)\{\gamma(z) + \theta(\widetilde{z})\}dz < 0 \tag{32}$$

$$\frac{dL^F}{d\widetilde{z}} = \frac{\partial L^F}{\partial\widetilde{z}} + \frac{\partial L^F}{\partial r}\frac{dr}{d\widetilde{z}} = \theta(\tilde{z})q^B[c^N(\widetilde{z})] + \frac{\partial q^C}{\partial c}w\theta'(\widetilde{z})\int_{z^C}^{1}\gamma(z)\,dz \gtrless 0 \tag{33}$$

Crucially, the latter derivative is ambiguous in sign, for similar reasons to the corresponding derivative in the monopoly case, (15), as discussed in the text.

8.3 Proof of Lemma 1

We prove the Lemma by contradiction. Suppose that z^C is less than or equal to $\tilde{z}$: $z^C \leq \tilde{z}$. It then follows that:

$$\theta(z^C) \leq \theta(\tilde{z}) \qquad \text{[since } \theta \text{ is increasing in } z\text{]} \tag{34}$$

$$\Rightarrow w\{\gamma\left(z^C\right) + \theta(z^C)\} \leq w\{\gamma\left(z^C\right) + \theta(\tilde{z})\} \tag{35}$$

$$\Rightarrow c^N\left(z^C\right) \leq c^K\left(z^C\right) \qquad \text{[from (3) and (4)]} \tag{36}$$

$$\Rightarrow p^C[c^N\left(z^C\right)] \leq p^C[c^K\left(z^C\right)] \qquad \text{[since } p^C \text{ is increasing in } c \text{ from (16)]} \tag{37}$$

$$\Rightarrow p^B[c^N\left(z^C\right)] < p^C[c^K\left(z^C\right)] \tag{38}$$

The last inequality follows from the fact that, by direct calculation from (16), the Cournot equilibrium price strictly exceeds the Bertrand equilibrium price for all c, provided e is strictly positive:

$$p^C(c) - p^B(c) = \frac{e^2(\hat{a} - c)}{4 - e^2} \tag{39}$$

Since the inequality in (38) is strict, this contradicts the definition of z^C given by (17). Hence it is not possible to have $z^C \leq \tilde{z}$, which proves the Lemma.

8.4 Proof of Lemma 2

To prove the lemma, define the following function:

$$\Delta(z,w,r) \equiv p^C[c^K(z;w,r)] - p^B[c^N(z;w)] \tag{40}$$

where we have made explicit the dependence of the cost terms on factor prices. The function Δ equals the difference between the Cournot and Bertrand prices evaluated at an arbitrary z. From equation (17), which defines z^C, we know that $\Delta(z^C,w,r)=0$. Direct calculation shows that the partial derivatives of Δ are:

$$\Delta_z(z,w,r) = \frac{dp^C}{dc}w\gamma'(z) - \frac{dp^B}{dc}w[\gamma'(z)+\theta'(z)] = -\frac{w}{2-e}H(z) \tag{41}$$

$$\Delta_w(z,w,r) = \frac{dp^C}{dc}\gamma(z) - \frac{dp^B}{dc}[\gamma(z)+\theta(z)] = -\frac{e^2\gamma(z)+(2+e)\theta(z)}{4-e^2} < 0 \tag{42}$$

$$\Delta_r(z,w,r) = \frac{dp^C}{dc}\delta = \frac{1+e}{2+e}\delta > 0 \tag{43}$$

Evaluating these terms at $z=z^C$ implies that z^C is decreasing in w and increasing in r if and only if $H(z^C)$ is positive, which proves the Lemma.

To prove the corollary, we define a new function Δ^G whose arguments are $(z,w,\tilde{z})$ rather than (z,w,r), i.e., with $r\delta$ replaced by $w\theta(\tilde{z})$:

$$\Delta^G(z,w,\tilde{z}) = p^C[c^K(z;w,\tilde{z})] - p^B[c^N(z;w)] \tag{44}$$

The derivative of this with respect to z is the same as before, $\Delta^G_z = \Delta_z$, which is negative if and only if $H(z)$ is positive. As for the other two derivatives, they equal:

$$\Delta^G_w(z,w,\tilde{z}) = -\frac{e^2}{(2+e)(2-e)}[\gamma(z)+\theta(z)] - \frac{1+e}{2+e}[\theta(z)-\theta(\tilde{z})] \tag{45}$$

$$\Delta^G_{\tilde{z}}(z,w,\tilde{z}) = \frac{dp^C}{dc}\frac{\partial c^K}{\partial \tilde{z}} = \frac{1+e}{2+e}w\theta'(\tilde{z}) > 0 \tag{46}$$

The former is negative at $z=z^C>\tilde{z}$ (recalling Lemma 1). Hence, we have proved the corollary: in general equilibrium, z^C is decreasing in w at given $\tilde{z}$ and increasing in $\tilde{z}$ at given w, if and only if $H(z^C)$ is positive.

8.5 Proof of Proposition 5

Denote the equilibrium wage and extensive margin in the autarky equilibrium by w^A and $\tilde{z}^A$ respectively. In the autarky equilibrium where we assume that $\gamma(z)$ is independent of z, so $\gamma(z)=\gamma_0$ for all z, the skilled-labour-market equilibrium condition (13) reduces to:

$$s\bar{L} = \int_{\tilde{z}^A}^1 \delta q^A[w^A\{\gamma_0+\theta(\tilde{z}^A)\}]dz = S^A(w^A,\tilde{z}^A) \tag{47}$$

Now, consider the move to free trade. Hold the extensive margin fixed at the autarky equilibrium level $\tilde{z}^A$, and assume that the unskilled wage needed to restore equilibrium on the skilled labour market is given by w^S. (See Fig. 5.) Hence the skilled-labour-market equilibrium condition (20) reduces to:

$$s\bar{L} = \int_{\tilde{z}^A}^{z^C} \delta q^B[w^S\{\gamma_0+\theta(z)\}]dz + \int_{z^C}^1 \delta q^C[w^S\{\gamma_0+\theta(\tilde{z}^A)\}]dz = S^F(w^S,\tilde{z}^A) \tag{48}$$

Since the increase in market size raises the demand for skilled labour in every sector, we have that $w^S > w^A$.

Consider next the market for unskilled workers. In the autarky case, the equilibrium condition for this market is given from (11) by the following:

$$\bar{L} = \int_0^{\tilde{z}^A} \{\gamma_0 + \theta(z)\} q^A [w^A \{\gamma_0 + \theta(z)\}] dz + \gamma_0 \int_{\tilde{z}^A}^1 q^A [w^A \{\gamma_0 + \theta(\tilde{z}^A)\}] dz \tag{49}$$

Using the equilibrium condition in the market for skilled workers from equation (47), the second integral can be replaced by $s\gamma_0 \bar{L}/\delta$ to give:

$$\left(1 - \frac{s\gamma_0}{\delta}\right) \bar{L} = \int_0^{\tilde{z}^A} \{\gamma_0 + \theta(z)\} q^A [w^A \{\gamma_0 + \theta(z)\}] dz = L^{A1}\left(w^A, \tilde{z}^A\right) \tag{50}$$

where $L^{A1}(.)$ denotes the autarky demand for unskilled workers from those sectors which do *not* invest in capacity. (Note that $\delta > s\gamma_0$ is necessary for an interior equilibrium with $\tilde{z}^A > 0$.) Similarly, in free trade, the demand for unskilled workers from the non-capacity-using sectors only, evaluated at w^S and $\tilde{z}^A$, is:

$$\int_0^{\tilde{z}^A} \{\gamma_0 + \theta(z)\} q^B [w^S \{\gamma_0 + \theta(z)\}] dz = L^{F1}\left(w^S, \tilde{z}^A\right) \tag{51}$$

where $L^{F1}(.)$ denotes the free trade demand for unskilled workers from those sectors which do not invest in capacity. To prove the proposition, we need to show that $L^{F1}\left(w^S, \tilde{z}^A\right) - L^{A1}\left(w^A, \tilde{z}^A\right)$ is positive, so there is excess demand for unskilled labour at w^S and $\tilde{z}^A$. When this is the case, the move from autarky to free trade will lead to an unskilled wage greater than w^S and a threshold sector $\tilde{z}$ lower than $\tilde{z}^A$, as in Fig. 5.

Using the equations above, we have:

$$\begin{aligned} & L^{F1}\left(w^S, \tilde{z}^A\right) - L^{A1}\left(w^A, \tilde{z}^A\right) \\ = & \int_0^{\tilde{z}^A} \{\gamma_0 + \theta(z)\} \left\langle q^B \left[w^S \{\gamma_0 + \theta(z)\}\right] - q^A [w^A \{\gamma_0 + \theta(z)\}] \right\rangle dz \end{aligned} \tag{52}$$

A sufficient condition for the last expression to be positive is that for all $z \in \left[0, \tilde{z}^A\right]$:

$$q^B [w^S \{\gamma_0 + \theta(z)\}] > q^A [w^A \{\gamma_0 + \theta(z)\}] \tag{53}$$

Substituting from the expressions for output in (19) and (12), this is equivalent to:

$$\Omega(z) \equiv \frac{\hat{a} - w^A \{\gamma_0 + \theta(z)\}}{\hat{a} - w^S \{\gamma_0 + \theta(z)\}} < \frac{4}{\eta} \tag{54}$$

where $\eta \equiv (2 - e)(1 + e)$.

The expression $\Omega(z)$ is increasing in z:

$$\begin{aligned} \frac{\partial \Omega(z)}{\partial z} &= \frac{-w^A \theta'(z) \left[\hat{a} - w^S \{\gamma_0 + \theta(z)\}\right] + w^S \theta'(z) \left[\hat{a} - w^A \{\gamma_0 + \theta(z)\}\right]}{\left[\hat{a} - w^S \{\gamma_0 + \theta(z)\}\right]^2} \\ &= \theta'(z) \frac{\hat{a}\left(w^S - w^A\right)}{\left[\hat{a} - w^S \{\gamma_0 + \theta(z)\}\right]^2} > 0 \end{aligned} \tag{55}$$

since $\theta'(z) > 0$ and $w^S > w^A$.

Define a new function which gives the demand for skilled labour in the hypothetical situation where the equilibrium in all capacity-using sectors is as if firms behave in a Bertrand manner facing the true production cost $w(\gamma_0 + r\delta) = w\{\gamma_0 + \theta(\tilde{z})\}$:

$$S^{F'}(w, \tilde{z}) \equiv \int_{\tilde{z}}^{1} q^B[w\{\gamma_0 + \theta(\tilde{z})\}]dz$$

Now define a new unskilled wage w' as the solution to $s\bar{L} = S^{F'}(w', \tilde{z}^A)$. $S^{F'}(w, \tilde{z})$ overestimates the demand for skilled workers relative to $S^F(w, \tilde{z})$ for all values of w and $\tilde{z}$, since it assumes a lower production cost in those sectors for which $\tilde{z} < z < z^C$ and a Bertrand rather than a Cournot outcome in those sectors for which $z > z^C$. Hence it must be the case that $w' > w_F^S$.

We have:

$$S^A(w^A, \tilde{z}^A) = S^{F'}(w', \tilde{z}^A) \tag{56}$$

since both are equal to $s\bar{L}$ by construction. Substituting once again from the expressions for output in (19) and (12), this implies:

$$\frac{\hat{a} - w^A\{\gamma_0 + \theta(\tilde{z}^A)\}}{\hat{a} - w'\{\gamma_0 + \theta(\tilde{z}^A)\}} = \frac{4}{\eta} \tag{57}$$

Since $w' > w^S$, we have

$$\Omega(\tilde{z}^A) = \frac{\hat{a} - w^A\{\gamma_0 + \theta(\tilde{z}^A)\}}{\hat{a} - w^S\{\gamma_0 + \theta(\tilde{z}^A)\}} < \frac{4}{\eta}$$

This, together with (55), means that (54) holds for all $z \in [0, \tilde{z}^A]$, which proves the proposition.

8.6 Proof of Proposition 6

The proof of Proposition 6 proceeds in the same way as that of Proposition 5, with two key differences. First, we wish to show that there is excess supply of (not excess demand for) unskilled labour at w^S and $\tilde{z}^A = 0$. Second, the additional assumption that $e = 0$ implies from (19) and (12) that $q^B(c) = q^C(c) = 2q^A(c)$ (recalling that $\hat{b}$ in free trade is twice the autarky level); and that $z^C = \tilde{z}$. With these assumptions equation (48) which defines w^S becomes:

$$s\bar{L} = 2\int_{\tilde{z}^A}^{1} \delta q^A[w^S\{\gamma(z) + \theta(\tilde{z}^A)\}]dz = S^F(w^S, \tilde{z}^A) \tag{58}$$

Equating this to the autarky skilled-labour-market equilibrium locus, equation (13), yields $\int_{\tilde{z}^A}^{1} Q(z)\,dz = 0$, where:

$$Q(z) \equiv 2\delta q^A[w^S\{\gamma(z) + \theta(\tilde{z}^A)\}] - \delta q^A[w^A\{\gamma(z) + \theta(\tilde{z}^A)\}] \tag{59}$$

It is easily checked that Q' is positive:

$$Q' = \frac{\delta\lambda\bar{L}}{2b}(w^A - w^S)\gamma' > 0 \tag{60}$$

Next, consider the unskilled labour market. The equilibrium locus in autarky is given by (11). In free trade, evaluated at w^S and $\tilde{z}^A = 0$, the demand for unskilled labour is:

$$L^F(w^S, \tilde{z}^A) = 2\int_{\tilde{z}^A}^{1} \gamma(z)\, q^A[w^S\{\gamma(z) + \theta(\tilde{z}^A)\}]dz \tag{61}$$

This holds when $\tilde{z}^A = 0$ but not when $\tilde{z}^A > 0$, since in that case sectors with $z < \tilde{z}^A$ also demand unskilled workers. Hence the excess demand for unskilled labour at w^S and $\tilde{z}^A = 0$ equals:

$$L^F \left(w^S, \tilde{z}^A\right) - \bar{L} = \int_{\tilde{z}^A}^{1} \gamma\left(z\right) Q\left(z\right) dz \tag{62}$$

Since $\gamma'\left(z\right) < 0$ and $Q' > 0$, we can invoke the Chebyshev Integral Inequality and conclude that the right-hand-side integral is negative, which proves the proposition.[31]

[31] We thank Banu Demir for pointing out that the Chebyshev Integral Inequality considerably simplifies this proof.

9 Supplementary Appendix

We want to explore further the shapes of the two labour-market equilibrium loci, and to see what, if any, additional restrictions can be imposed on the monopoly equilibrium when we assume that the factor requirements are linear in z: $\gamma(z) = \gamma_0 - \gamma_1 z$ and $\theta(z) = \theta_0 + \theta_1 z$. We assume that all four parameters, γ_0, γ_1, θ_0 and θ_1, are non-negative. In addition, since we require $\gamma(z) > 0$ for all z, we assume that $\gamma_0 > \gamma_1$.

9.1 The Skilled-Labour-Market Equilibrium Locus

The properties of the skilled-labour-market equilibrium locus (13) have already been derived in general, but for completeness we derive an explicit expression for its slope. Even with general functional forms, (13) is linear in the wage rate, and so we can solve it for w^S, the wage which clears the skilled-labour market, as a function of the threshold sector $\tilde{z}$:

$$w^S(\tilde{z}) = \frac{A(\tilde{z})}{B(\tilde{z})} \equiv \frac{(1-\tilde{z})\hat{a} - \frac{2\hat{b}}{\delta} s\bar{L}}{(1-\tilde{z})\theta(\tilde{z}) + \int_{\tilde{z}}^{1}\gamma(z)\,dz} \tag{63}$$

The denominator $B(\tilde{z})$ is always positive for $\tilde{z} < 1$, and so the numerator, though negative when $\tilde{z} = 1$, must be positive when $\tilde{z} = 0$ for an equilibrium with a positive wage to exist. Differentiating w^S, the slope of this locus equals:

$$\frac{dw^S}{d\tilde{z}} = \frac{1}{B(\tilde{z})}\left[A'(\tilde{z}) - w^S B'(\tilde{z})\right] \tag{64}$$

where:

$$A'(\tilde{z}) = -\hat{a} < 0 \qquad B'(\tilde{z}) = (1-\tilde{z})\theta'(\tilde{z}) - \{\gamma(\tilde{z}) + \theta(\tilde{z})\} \gtrless 0 \tag{65}$$

Substituting for these expressions confirms that w^S is monotonically decreasing in $\tilde{z}$:

$$\frac{dw^S}{d\tilde{z}} = -\frac{1}{B(\tilde{z})}\left[\hat{a} - w^S\{\gamma(\tilde{z}) + \theta(\tilde{z})\} + (1-\tilde{z})w^S\theta'(\tilde{z})\right] < 0 \tag{66}$$

9.2 The Unskilled-Labour-Market Equilibrium Locus

Consider next the unskilled-labour-market equilibrium locus (11). Once again, this can be solved for w^L, the wage which clears the unskilled-labour market, as a function of the threshold sector $\tilde{z}$:

$$w^L(\tilde{z}) = \frac{C(\tilde{z})}{E(\tilde{z})} \qquad C(\tilde{z}) \equiv \left[\int_0^1 \gamma(z)\,dz + \int_0^{\tilde{z}} \theta(z)\,dz\right]\hat{a} - 2\tilde{b}\bar{L} \tag{67}$$

$$E(\tilde{z}) \equiv \int_0^1 \gamma(z)^2\,dz + \int_0^{\tilde{z}} \theta(z)\{2\gamma(z) + \theta(z)\}\,dz + \theta(\tilde{z})\int_{\tilde{z}}^1 \gamma(z)\,dz > 0$$

Differentiating this:

$$\frac{dw^L}{d\tilde{z}} = \frac{1}{E(\tilde{z})}\left[C'(\tilde{z}) - w^L E'(\tilde{z})\right] \tag{68}$$

$$C'(\tilde{z}) = \theta(\tilde{z})\hat{a} > 0 \qquad E'(\tilde{z}) = \theta(\tilde{z})\{\gamma(\tilde{z}) + \theta(\tilde{z})\} + \theta'(\tilde{z})\int_{\tilde{z}}^1 \gamma(z)\,dz > 0$$

Hence we see that the derivative is ambiguous in slope, as noted in the text:

$$\frac{dw^L}{d\tilde{z}} = \frac{1}{E(\tilde{z})}\left[\theta(\tilde{z})\left\langle \hat{a} - w^L\left\{\gamma(\tilde{z}) + \theta(\tilde{z})\right\}\right\rangle - w^L\theta'(\tilde{z})\int_{\tilde{z}}^{1}\gamma(z)\,dz\right] \tag{69}$$

9.3 The Second Derivative of the Unskilled-Labour-Market Equilibrium Locus

If it could be proved that the unskilled-labour-market equilibrium locus always has a negative second derivative when its first derivative is zero, then this would prove that it is always U-shaped. Direct calculation shows that:

$$\frac{d^2w^L}{d\tilde{z}^2} = \frac{1}{E(\tilde{z})}\left[C''(\tilde{z}) - w^L E''(\tilde{z}) - 2E'(\tilde{z})\frac{dw^L}{d\tilde{z}}\right] \tag{70}$$

$$C''(\tilde{z}) = \theta'(\tilde{z})\,\hat{a} > 0 \qquad E''(\tilde{z}) = \theta(\tilde{z})\left\{\gamma'(\tilde{z}) + 2\theta'(\tilde{z})\right\} + \theta''(\tilde{z})\int_{\tilde{z}}^{1}\gamma(z)\,dz \gtrless 0$$

At a point where the locus changes sign, we have $\frac{dw^L}{d\tilde{z}} = 0$, so $\frac{d^2w^L}{d\tilde{z}^2} = \frac{1}{E(\tilde{z})}\left[C''(\tilde{z}) - w(\tilde{z})E''(\tilde{z})\right]$. Evaluating the second derivative in the linear case yields:

$$\left.\frac{d^2w^L}{d\tilde{z}^2}\right|_{\frac{dw^L}{d\tilde{z}}=0} = \frac{1}{E(\tilde{z})}\left[\theta_1\hat{a} - w^L(\theta_0 + \theta_1\tilde{z})(2\theta_1 - \gamma_1)\right] \tag{71}$$

$$= \frac{\theta_1\left[\hat{a} - w^L\left\{\gamma(\tilde{z}) + \theta(\tilde{z})\right\}\right] - w^L\left[\theta_1(\theta_0 + \theta_1\tilde{z}) - \theta_1\gamma_0 - \theta_0\gamma_1\right]}{E(\tilde{z})}$$

The first term in square brackets in the numerator of this expression is definitely positive, since it is proportional to output in the threshold sector $\tilde{z}$, but the second may be negative. Hence the sign of the whole expression is ambiguous.

9.4 Direct Comparison of the Loci Slopes

Next, we compare the slopes of the two loci at a common point. We would like to show that, at any equilibrium, where $w^S = w^L = w$, it must be the case that $\frac{dw^L}{d\tilde{z}} > \frac{dw^S}{d\tilde{z}}$, implying that (for continuous functions) the equilibrium is unique and stable. Direct calculation yields:

$$\frac{dw^L}{d\tilde{z}} - \frac{dw^S}{d\tilde{z}} = \frac{1}{B(\tilde{z})E(\tilde{z})}\left[B(\tilde{z})\left\{C'(\tilde{z}) - wE'(\tilde{z})\right\} - E(\tilde{z})\left\{A'(\tilde{z}) - wB'(\tilde{z})\right\}\right] \tag{72}$$

$$= \frac{1}{B(\tilde{z})E(\tilde{z})}\left[\left\{B(\tilde{z})\theta(\tilde{z}) + E(\tilde{z})\right\}\left\langle\hat{a} - w\left\{\gamma(\tilde{z}) + \theta(\tilde{z})\right\}\right\rangle + w\theta'(\tilde{z})\left\{(1-\tilde{z})E(\tilde{z}) - B(\tilde{z})\int_{\tilde{z}}^{1}\gamma(z)\,dz\right\}\right]$$

The first term in square brackets, multiplying $\langle\hat{a} - w\{\gamma(\tilde{z}) + \theta(\tilde{z})\}\rangle$, represents extensive-margin effects and is unambiguously positive. However, the second term could be negative because of the intensive margin effect $-B(\tilde{z})\int_{\tilde{z}}^{1}\gamma(z)\,dz$. Writing out this term in full:

$$(1-\tilde{z})E(\tilde{z}) - B(\tilde{z})\int_{\tilde{z}}^{1}\gamma(z)\,dz = (1-\tilde{z})\left[\int_0^1\gamma(z)^2\,dz + \int_0^{\tilde{z}}\theta(z)\left\{2\gamma(z) + \theta(z)\right\}dz\right] - \left[\int_{\tilde{z}}^{1}\gamma(z)\,dz\right]^2 \tag{73}$$

In the linear case, we can calculate explicitly the terms in $\gamma(z)$:

$$(1-\tilde{z})\int_0^1 \gamma(z)^2\,dz - \left[\int_{\tilde{z}}^1 \gamma(z)\,dz\right]^2 = (1-\tilde{z})\int_0^1 (\gamma_0-\gamma_1 z)^2\,dz - \left[\int_{\tilde{z}}^1 (\gamma_0-\gamma_1 z)\,dz\right]^2 \tag{74}$$
$$= (1-\tilde{z})\left[\tilde{z}\gamma_0^2 - (1+\tilde{z})\gamma_0\gamma_1 + \frac{1}{4}(3+\tilde{z})\gamma_1^2\right]$$

This is still ambiguous in sign: it can be negative for low values of $\tilde{z}$ and high values of γ_1/γ_0 (even with the restriction that $\gamma_0 > \gamma_1$).

9.5 Conclusion

In practice, an extensive search failed to find a set of primitive parameter values which implies multiple equilibria. Nevertheless, as this Supplementary Appendix shows, we cannot rule them out definitively, even in the linear case, though they are likely to occur for only a relatively small subset of the parameter space. We have considered only the monopoly case here, but it is clear from the equations in the text that similar considerations apply to the duopoly case.

References

[1] Ben-Zvi, S. and E. Helpman (1992): "Oligopoly in segmented markets," in G. Grossman (ed.): *Imperfect Competition and International Trade*, Cambridge, Mass.: MIT Press, 31-53.

[2] Berman, E., J. Bound and Z. Griliches (1994): "Changes in the demand for skilled labor within US manufacturing: Evidence from the annual survey of manufactures," *Quarterly Journal of Economics*, 109, 367- 97.

[3] Bernard, A.B., S. Redding, P.K. Schott and H. Simpson (2008): "Relative wage variation and industry location in the United Kingdom," *Oxford Bulletin of Economics and Statistics*, 70, 431-459.

[4] Bliss, C.J. (1968): "On putty-clay," *Review of Economic Studies*, 35, 105-132.

[5] Boccard, N. and X. Wauthy (2000): "Bertrand competition and Cournot outcomes: Further results," *Economics Letters*, 68, 279–285; and "A correction," 84, 163–166.

[6] Brander, J.A. (1981) "Intra-industry trade in identical commodities," *Journal of International Economics*, 11, 1-14.

[7] Brander, J.A. and B.J. Spencer (1985): "Export subsidies and international market share rivalry," *Journal of International Economics*, 18, 83-100.

[8] Card, David and John E. DiNardo (2002): "Skill-Biased technological change and rising wage inequality: Some problems and puzzles," *Journal of Labor Economics*, 20, 733-783.

[9] Costinot, A. and J. Vogel (2010): "Matching and inequality in the world economy," *Journal of Political Economy*, 118, 747-786.

[10] Davidson, C. and R. Deneckere (1986): "Long-run competition in capacity, short-run competition in price, and the Cournot model," *Rand Journal of Economics*, 17, 404-415.

[11] Dixit, A.K. (1981): "The role of investment in entry deterrence," *Economic Journal*, 90, 95–106.

[12] Dixit, A.K. and G.M. Grossman (1986): "Targeted export promotion with several oligopolistic industries," *Journal of International Economics*, 21, 233-49.

[13] Eaton, J. and G.M. Grossman (1986): "Optimal trade and industrial policy under oligopoly," *Quarterly Journal of Economics*, 100, 383-406.

[14] Feenstra, R.C. (2003): *Advanced International Trade: Theory and Evidence*, Princeton, N.J.: Princeton University Press.

[15] Flam, H. and E. Helpman (1987): "Industrial policy under monopolistic competition," *Journal of International Economics*, 22, 79-102.

[16] Forslid, R. and G.I.P. Ottaviano (2003): "An analytically solvable core-periphery model," *Journal of Economic Geography*, 3, 229-240.

[17] Friedman, J.W. (1988): "On the strategic importance of prices versus quantities," *Rand Journal of Economics*, 19, 607-622.

[18] Fung, K. C. (1992): "Economic integration as competitive discipline," *International Economic Review*, 33, 837-847.

[19] Hanson, G. and A. Harrison (1999): "Trade liberalization and wage inequality in Mexico," *Industrial and Labor Relations Review*, 52, 271-288.

[20] Harrigan, J. and A. Reshef (2010): "Skill biased heterogeneous firms: Trade liberalization and the skill premium redux," mimeo., University of Virginia.

[21] Johnson, George E. (1997): "Changes in earnings inequality: The role of demand shifts," *Journal of Economic Perspectives*, 11, 41-54.

[22] Kreps, D.M. and J.A. Scheinkman (1983): "Quantity precommitment and Bertrand competition yield Cournot outcomes," *Bell Journal of Economics*, 14, 326-337.

[23] Krugman, P.R. (1979): "Increasing returns, monopolistic competition and international trade," *Journal of International Economics*, 9, 469-479.

[24] Lawrence, C. and P.T. Spiller (1983): "Product diversity, economies of scale, and international trade," *Quarterly Journal of Economics*, 98, 63-83.

[25] Madden, P. (1998): "Elastic demand, sunk costs and the Kreps-Scheinkman extension of the Cournot model," *Economic Theory*, 12, 199-212.

[26] Maggi, G. (1996): "Strategic trade policies with endogenous mode of competition," *American Economic Review*, 86, 237-258.

[27] Melitz, M.J. (2003): "The impact of trade on intra-industry reallocations and aggregate industry productivity," *Econometrica*, 71:6, 1695-1725.

[28] Melitz, M.J. and G.I.P. Ottaviano (2008): "Market size, trade, and productivity," *Review of Economic Studies*, 75:1, 295-316.

[29] Mussa, M. (1978): "Dynamic adjustment in the Heckscher-Ohlin-Samuelson model," *Journal of Political Economy*, 86, 775-791.

[30] Neary, J.P. (2003a): "Globalization and market structure," *Journal of the European Economic Association*," 1, 245-271.

[31] Neary, J.P. (2003b): "The road less travelled: Oligopoly and competition policy in general equilibrium," in R. Arnott, B. Greenwald, R. Kanbur and B. Nalebuff (eds.): *Economics for an Imperfect World: Essays in Honor of Joseph E. Stiglitz*, Cambridge, Mass.: MIT Press, 485-500.

[32] Neary, J.P. (2007): "Cross-border mergers as instruments of comparative advantage," *Review of Economic Studies*, 74, 1229-1257.

[33] Rotemberg, J.J. and G. Saloner (1989): "Tariffs vs quotas with implicit collusion," *Canadian Journal of Economics*, 22, 237-244.

[34] Solow, R.M. (1962): "Substitution and fixed proportions in the theory of capital," *Review of Economic Studies*, 29, 207-218.

[35] Venables, A.J. (1990): "International capacity choice and national market games," *Journal of International Economics*, 29, 23-42.

[36] Vives, X. (1985): "On the efficiency of Bertrand and Cournot equilibria with product differentiation," *Journal of Economic Theory*, 36, 166–175.

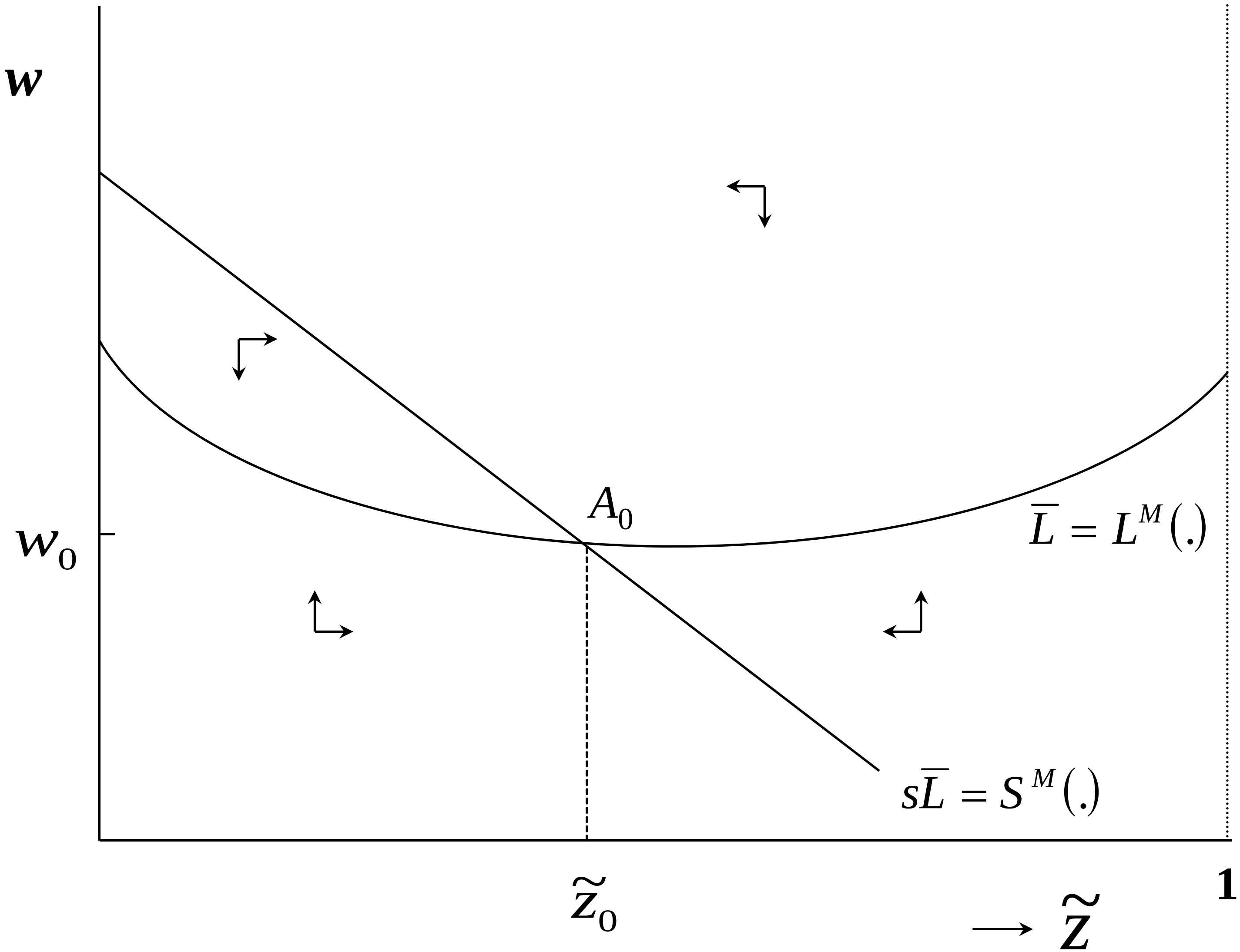

Fig. 1: Simultaneous Determination of the Unskilled Wage and the Extensive Margin

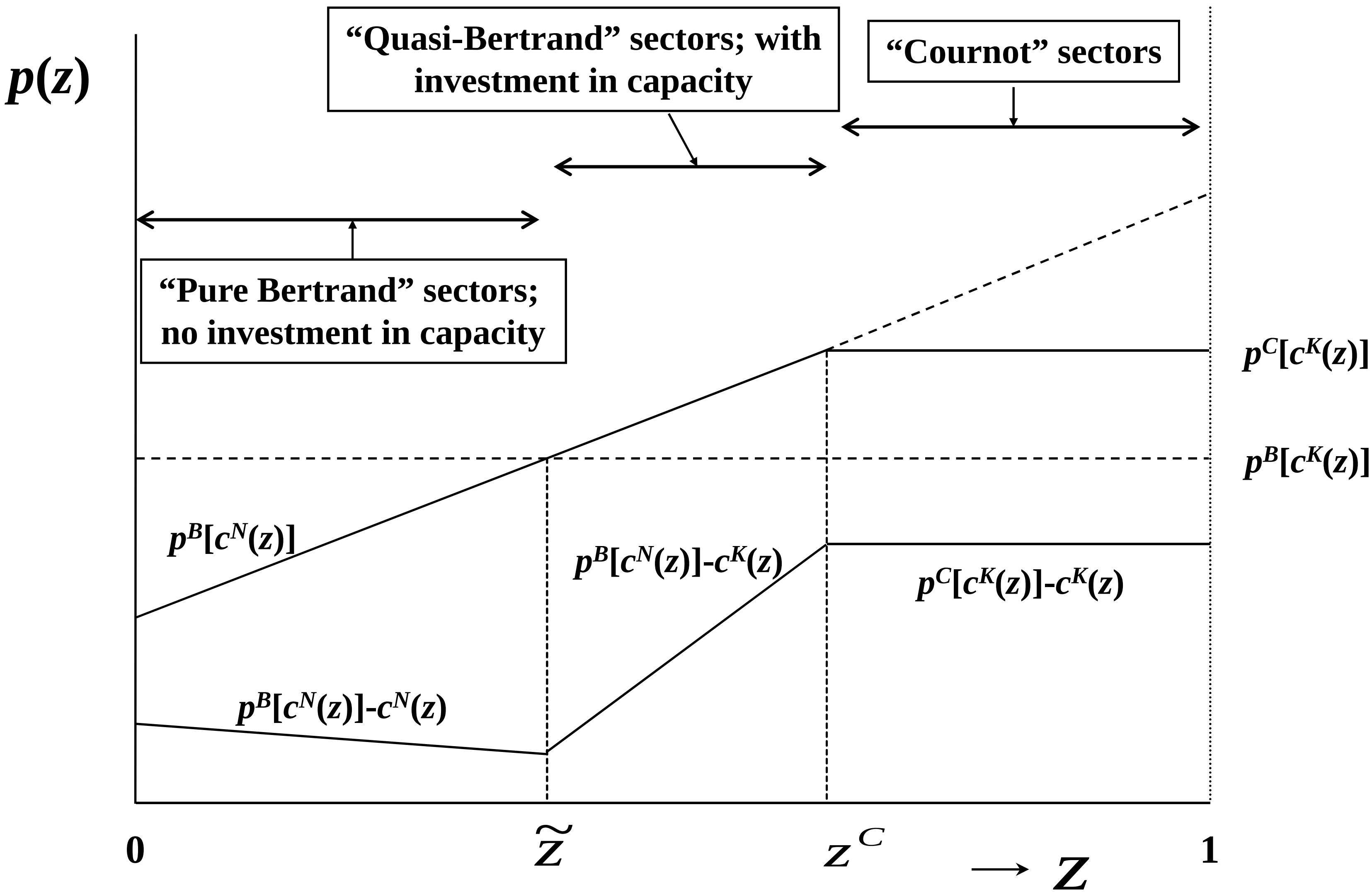

Fig. 2: Distribution of Prices and Price-Cost Margins across Sectors at Given Factor Prices; $\gamma_1 = 0$, $\theta_1 > 0$.

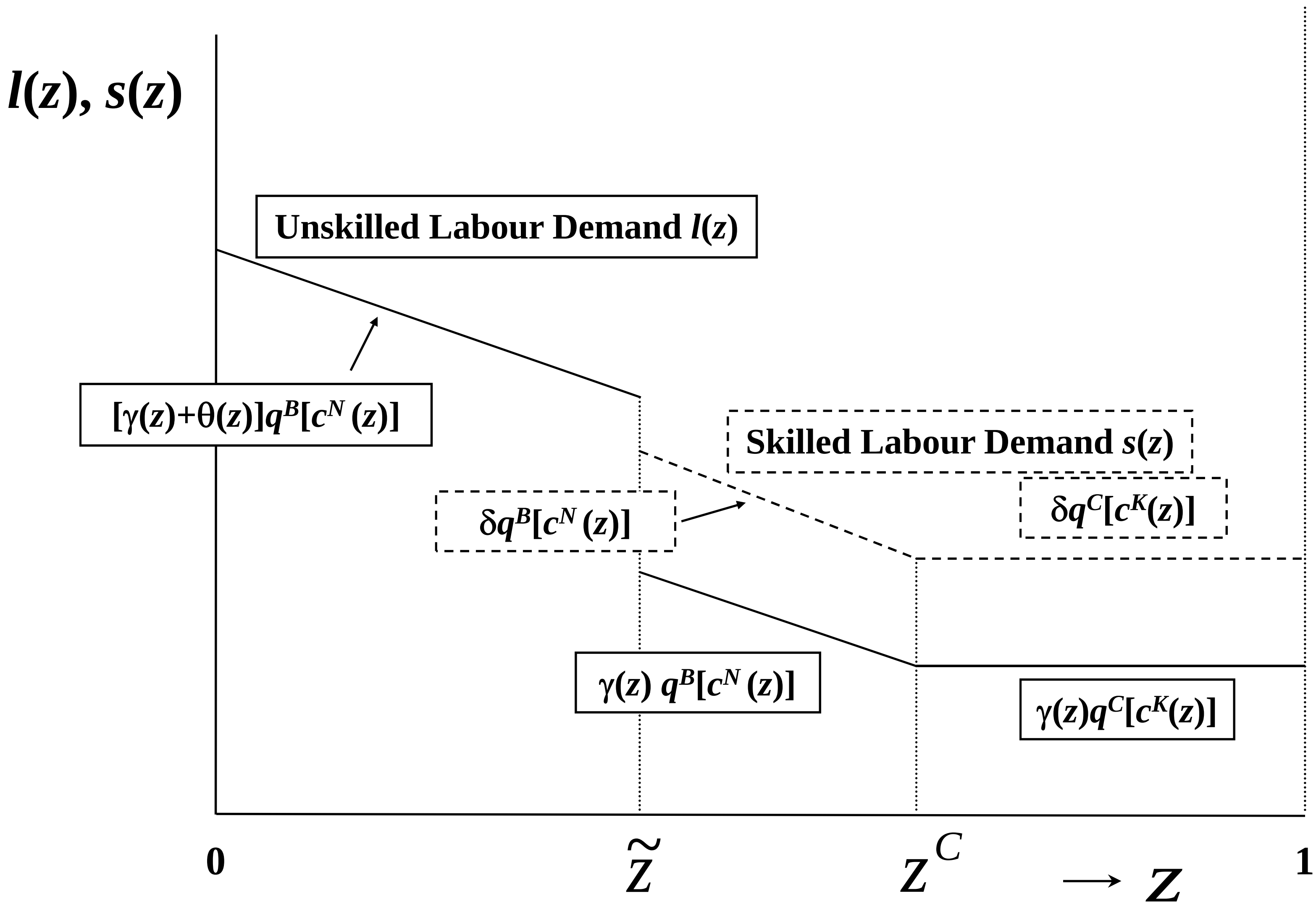

Fig. 3: Demand for Skilled and Unskilled Labour across Sectors at Given Factor Prices; $\gamma_1 = 0$, $\theta_1 > 0$.

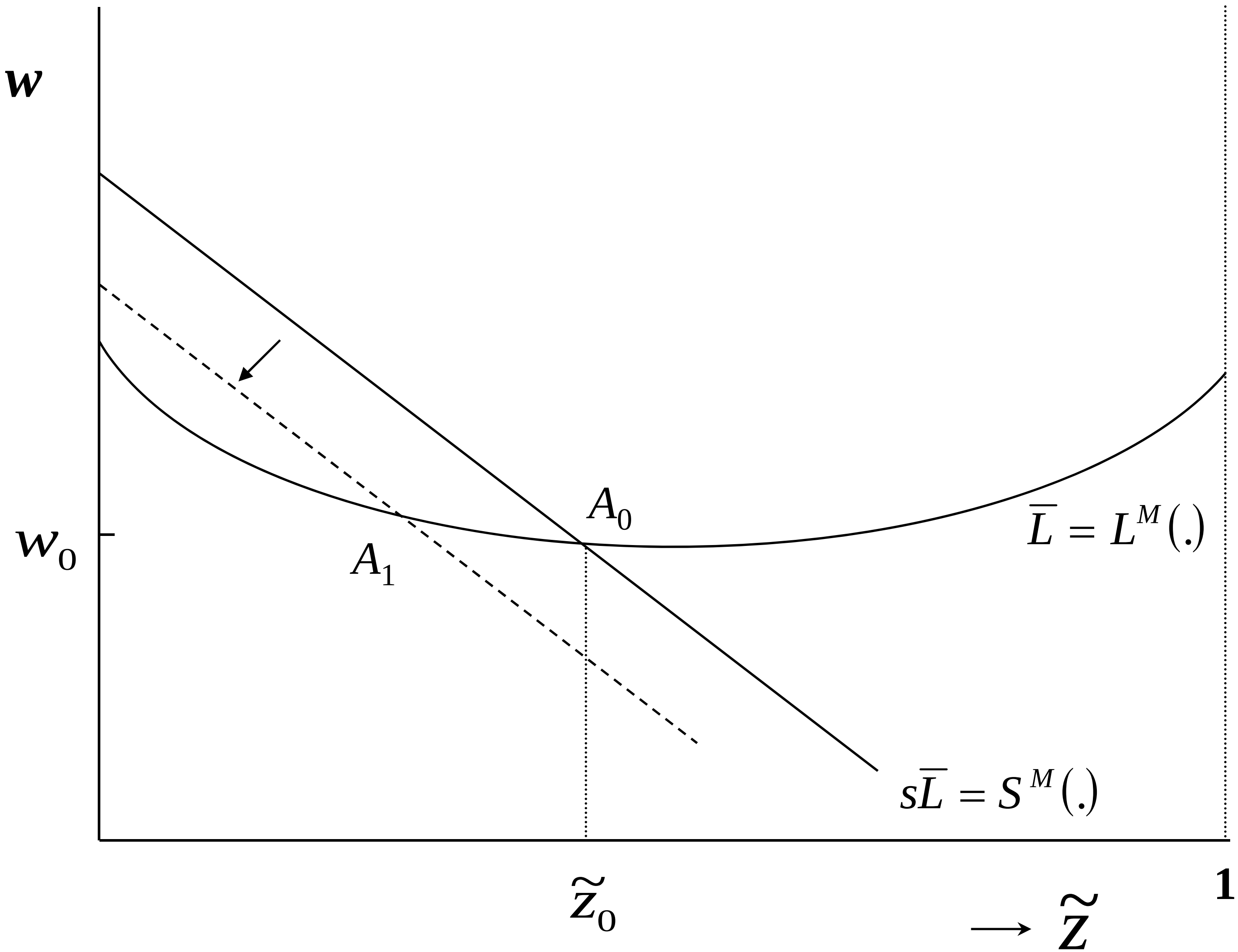

Fig. 4: Effects of an Increase in the Endowment of Skilled Labour

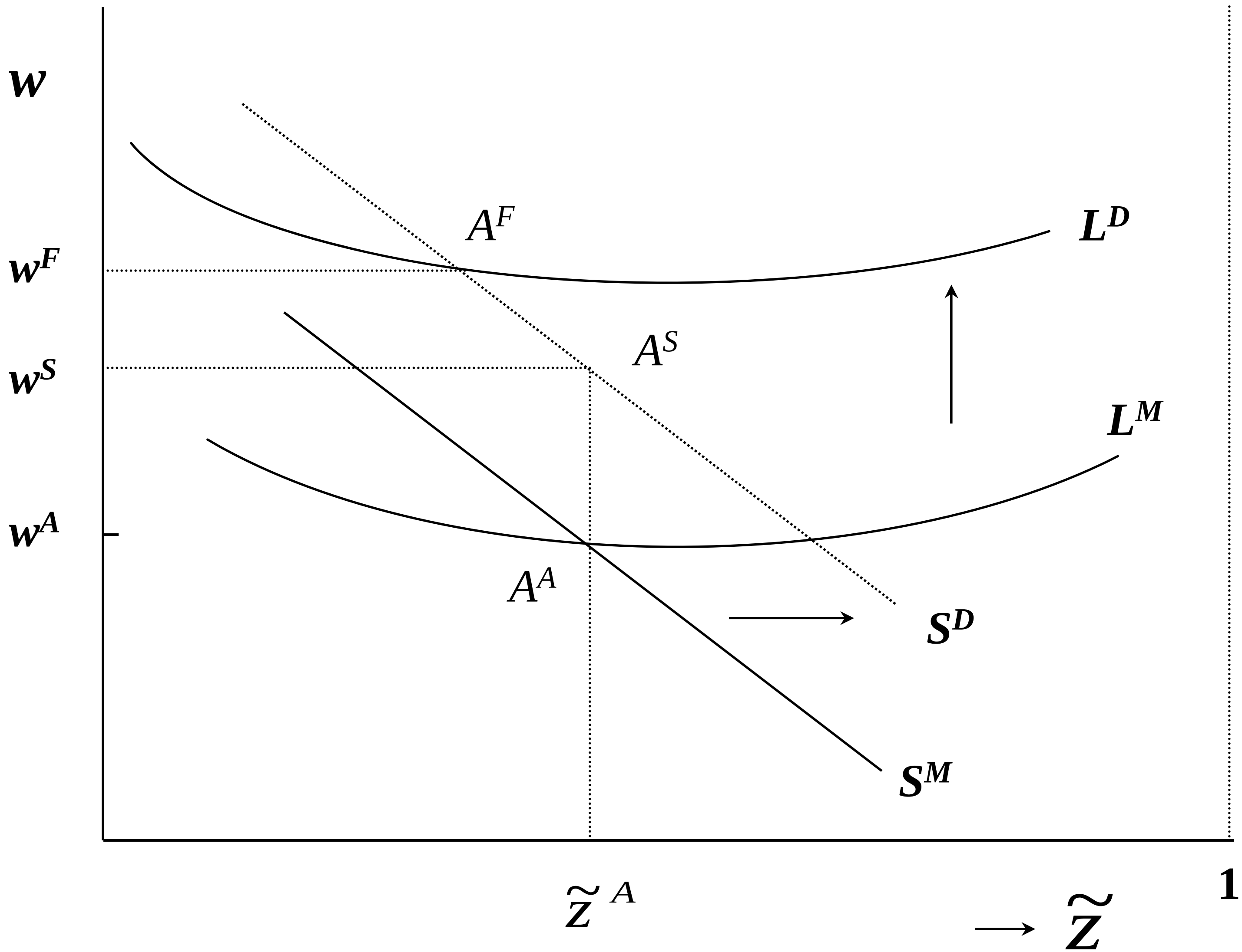

Fig. 5: Autarky and Free Trade Equilibria with Uniform Variable Costs

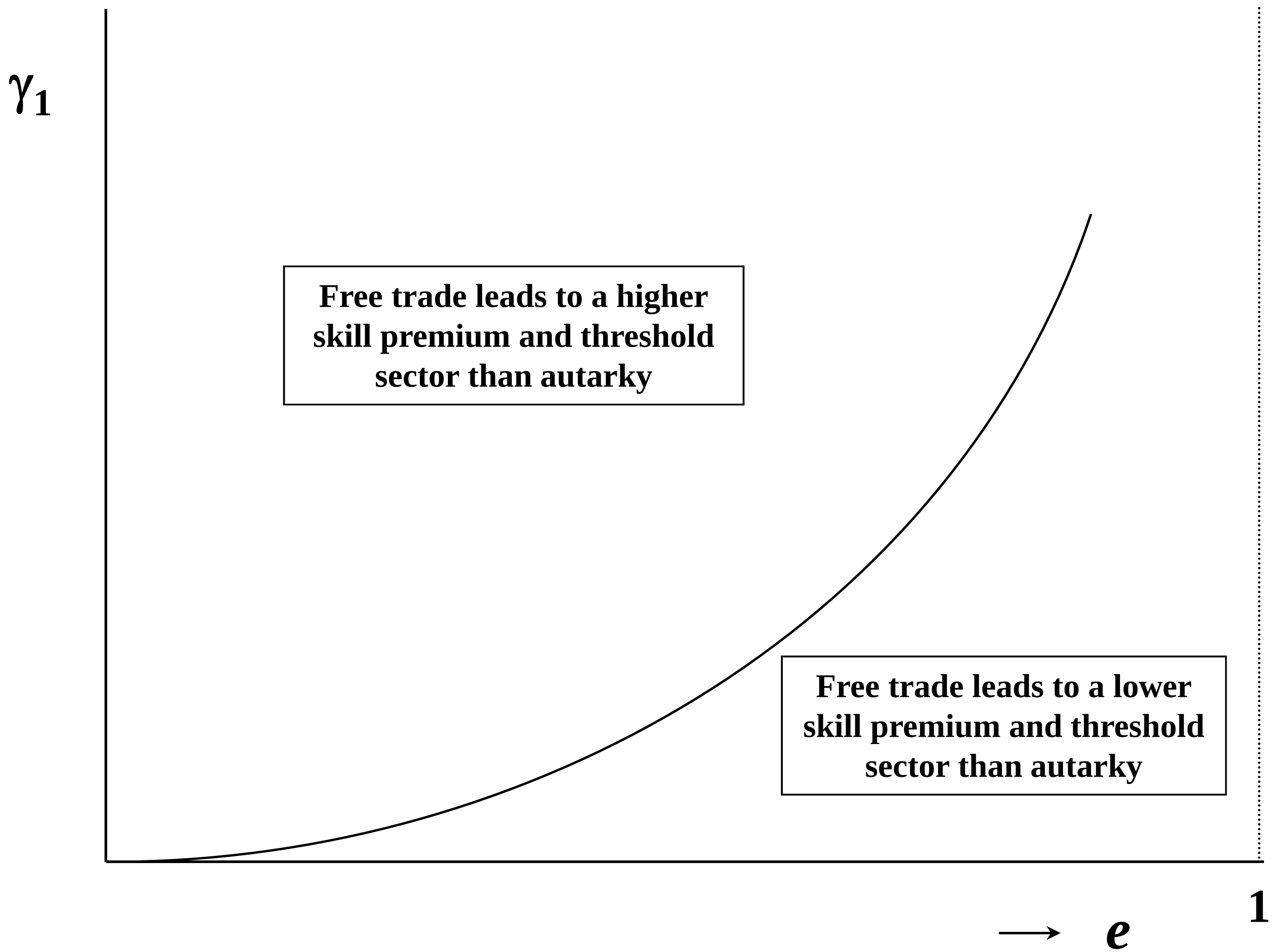

Fig. 6: Autarky versus Free Trade

γ_1: Intersectoral differences in factor intensity

e: Intrasectoral intensity of competition