Journal of Monetary Economics 58 (2011) 387–399

Contents lists available at ScienceDirect

Journal of Monetary Economics

journal homepage: www.elsevier.com/locate/jme

Resources, innovation and growth in the global economy

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ARTICLE INFO

Article history:
Received 16 July 2010
Received in revised form
14 July 2011
Accepted 18 July 2011
Available online 27 July 2011

ABSTRACT

The relative performance of open economies is analyzed in an endogenous growth model with asymmetric trade. A resource-rich country trades resource-based intermediates for final goods produced by a resource-poor economy. The effects of an increase in the resource endowment depend on the elasticity of substitution between resources and labor in intermediates' production. Under substitution (complementarity), the resource boom generates higher (lower) income, lower (higher) employment in the primary sector and faster (slower) growth in the resource-rich economy. In the resource-poor economy, the shock induces a higher (lower) relative wage and positive (negative) growth effects that are exclusively due to trade.

1. Introduction

The distribution of primary resources across countries is an important determinant of trade patterns. Economies endowed with natural resources that can be processed into essential factors of production export such resource-based commodities and import manufacturing goods from resource-poor countries. This asymmetric trade structure creates interesting interdependencies: while resource-poor economies specialize in manufacturing by force of nature, they gain from trading non-primary goods demanded by resource-rich countries specialized in primary production.

What does this asymmetric trade structure imply for economic growth once we account for such interdependencies? There is solid historical and case-study evidence for arguing that developing an economy's primary sector and boosting resource-based exports is a good way of sparking growth—an example is the experience of the US at the turn of the 19th century and of Chile in the 1990s (Wright and Czeulsta, 2007). But there is also evidence for arguing the opposite, namely, that dependence on primary exports hurts growth: Latin America posted a particularly poor growth performance in the post-war era, leading observers to conclude that a "resource curse" affected the area (Maloney, 2007). Statistical evidence is also subject to extensive debate. The argument that commodity specialization hurts growth because of adverse terms-of-trade dynamics—in particular, the Prebisch–Singer hypothesis according to which real commodity prices display a declining trend in the long run—did not receive empirical support (Cuddington et al., 2007). Similarly, the Sachs–Warner result of a negative cross-country correlation between growth and resource abundance has not survived subsequent scrutiny (Brunnschweiler and Bulte, 2008; Lederman and Maloney, 2007).

Although typical in reality, asymmetric trade structures do not play a prominent role in the theoretical literature on international trade and economic growth. The benchmark framework of two-country models (e.g., Grossman and Helpman, 1991) concentrates on the role of endogenous innovation in generating convergence across trading economies that exhibit productivity differences, and neglects the role of natural resources in driving trade specialization. To fill this

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doi:10.1016/j.jmoneco.2011.07.001

gap, we extend the closed-economy Schumpeterian model of Peretto (in press) and develop a two-country model of innovation-based growth featuring both inter-industry and intra-industry trade: the resource-rich economy, called Home, exports resource-based intermediates and differentiated final manufacturing goods, and imports only differentiated final goods from the resource-poor economy, called Foreign. The model yields a transparent characterization of the effects of *resource booms*—increases in Home's natural resource endowment—on expenditure levels, innovation rates, productivity growth, the allocation of labor across sectors, and welfare in both economies.

The production structure comprises two sectors, primary production (or resource processing) and manufacturing. The primary sector is located in Home and produces a resource-based intermediate using labor and the raw natural resource: the two inputs can be either complements or substitutes. The manufacturing sector is global, with firms active both in Home and Foreign, and uses labor and the processed natural resource to produce differentiated consumption goods. The manufacturing sector is technologically dynamic: entrepreneurs undertake R&D to design new products and set up firms to serve the global market. Because both sectors use labor, its reallocation from manufacturing to primary production in Home drives the world economy's adjustment to an increase in resource abundance.

This production structure captures two aspects that, according to the literature on growth and commodity specialization, are quite relevant empirically. First, the vertical structure with an upstream competitive resource-processing sector and a downstream manufacturing sector with imperfect competition is a core feature of virtually all the empirical papers on the Prebisch–Singer hypothesis (see Bloch and Sapsford, 2000; Cuddington et al., 2007). Second, the two-country framework makes the world price of the resource-based input endogenous. While not common, indeed rare, in the literature on resources and growth, this feature matches the ample evidence that, among the macroeconomic determinants of commodity price movements, supply-side events occurring in the exporting countries are not only prominent but essential to fit the dynamics (see, e.g., Borensztein et al., 1994; Reinhart and Borensztein, 1994).

The global effects of a resource boom in Home hinge on three main issues: the nature of the transmission mechanism across countries, the sign of the changes in income and growth, and the permanent reallocation of labor across sectors. Concerning the transmission mechanism, a rise in Home's resource endowment induces a change in the demand for Foreign goods, which triggers a change in the Foreign wage that offsets one-for-one the change in demand and thus leaves Foreign's TFP growth unaffected. In Home, labor moves across the primary and manufacturing sectors, with permanent effects on the number of firms and transitional effects on TFP growth. The variations in Home's productivity affect Foreign's import price index and thereby Foreign income dynamics.

The changes in income and growth depend on whether labor and the raw resource are complements or substitutes in the production of intermediates. If they are substitutes, a resource boom raises Home's resource income and its overall expenditure on manufacturing goods; labor moves into manufacturing, there is a permanent increase in the number of firms and the process of entry raises Home's TFP growth during the transition. In Foreign, both the wage and the value of production increase and the increase in Home's TFP growth is transmitted to Foreign incomes via trade. If labor and the raw resource are complements, instead, the same mechanism works in the opposite direction: the resource boom lowers resource income and Home's demand for Foreign goods. The Foreign wage falls, Home's number of firms declines and the transitional growth effects are negative for both countries.

The intuition for these results is that the elasticity of substitution in the intermediate sector determines the reaction of Home's resource income to an increase in the resource endowment. Substitutability implies elastic demand for the raw resource: an increase in supply induces a mild reduction in the resource price so that the net effect on resource income is positive. Complementarity, instead, implies inelastic demand: the resource boom causes a drastic fall of the resource price so that resource income falls. From an empirical standpoint, these results suggest that the effects of natural resources on income and growth should depend on the type of natural resource. The argument is relevant since the degree of substitutability greatly varies across types of natural resources: Jin and Jorgenson (2010) find complementarity for several products of mining/harvesting activities (metal mining, petroleum and gas, coal mining, primary metals, nonmetallic mining, tobacco products) and substitutability for others (lumber and wood, stone and clay, non-tobacco agricultural products), and generally reject the existence of Cobb–Douglas specifications for the price functions associated to material inputs.[1]

The plan of the paper is as follows. Section 2 describes the model assumptions. Section 3 characterizes the world competitive equilibrium. Section 4 derives the main results. Section 5 discusses the connections with previous literature, and Section 6 concludes.

2. The model

There are two countries and two factors of production: Home, denoted H, has labor and a non-tradeable natural resource; Foreign, denoted F, has only labor. Home uses labor and the natural resource to produce a homogeneous intermediate input that the final sectors of both countries combine with labor to produce differentiated manufacturing goods. Labor is homogeneous and moves freely across sectors within each country but does not move across countries.

[1] See, in particular, Fig. 6, p. 212 in Jin and Jorgenson (2010). It is worth stressing that their main estimating equation (4) on p. 206 links the sign of price effects determined by the demand elasticity to the elasticity of substitution between inputs—the same concept used in our analysis.

Each economy develops innovations that expand the variety of manufacturing goods it supplies. This section specifies our assumptions concerning the behavior of households (Section 2.1), manufacturing firms (Section 2.2), the primary sector (Section 2.3), and states the condition for balanced trade (Section 2.4).

2.1. Households

Country $J=H,F$ is populated by a representative household with a constant mass L^J of identical members who supply inelastically one unit of labor each. The household's preferences over differentiated consumption goods are

$$u^H = \left[\left(\int_0^{N^H} (X_i^{Hh}/L^H)^{(\varepsilon-1)/\varepsilon}\, di\right)^{\varepsilon/(\varepsilon-1)}\right]^{\xi}\left[\left(\int_0^{N^F} (X_i^{Fh}/L^H)^{(\varepsilon-1)/\varepsilon}\, di\right)^{\varepsilon/(\varepsilon-1)}\right]^{1-\xi},$$

$$u^F = \left[\left(\int_0^{N^F} (X_i^{Ff}/L^F)^{(\varepsilon-1)/\varepsilon}\, di\right)^{\varepsilon/(\varepsilon-1)}\right]^{\xi}\left[\left(\int_0^{N^F} (X_i^{Hf}/L^F)^{(\varepsilon-1)/\varepsilon}\, di\right)^{\varepsilon/(\varepsilon-1)}\right]^{1-\xi}, \tag{1}$$

where u^J is the instantaneous utility of the household in country J, N^J is the mass of goods produced in country J, X_i^{Jh} and X_i^{Jf} are the physical quantities of the i-th variety of consumption good produced in country J that are respectively consumed by Home and Foreign residents. Parameter $\varepsilon > 1$ is the elasticity of substitution across goods and $\xi \in [1/2,1)$ is domestic bias, i.e., the weight that each consumer assigns to utility from consuming goods produced in her country of residence. We rule out $\xi = 1$ because it yields no trade.

Assuming integrated world markets for all consumption goods, the law of one price holds and P_i^J, the price of good i produced in country J, applies in both Home and Foreign. Denoting by E^J aggregate consumption expenditure in country J, the intratemporal expenditure constraints read:

$$E^H = \int_0^{N^H} P_i^H X_i^{Hh}\, di + \int_0^{N^F} P_i^F X_i^{Fh}\, di,$$

$$E^F = \int_0^{N^H} P_i^H X_i^{Hf}\, di + \int_0^{N^F} P_i^F X_i^{Ff}\, di. \tag{2}$$

At time $t=0$ the representative household of country J maximizes

$$U^J(0) = \int_0^{\infty} e^{-\rho t} \log u^J(t)\, dt \tag{3}$$

subject to (1), (2) and to the dynamic wealth constraint

$$\dot{A}^J = r^J A^J + W^J L^J + \Pi_M^J + p^J \Omega^J - E^J, \tag{4}$$

where $\rho > 0$ is the discount rate, A^J is assets, r^J is the rate of return on assets and W^J is the wage rate. Constraint (4) also includes dividend income from resource-processing firms, Π_M^J, and resource income $p^J \Omega^J$, where Ω^J is the endowment and p^J the price of the resource. These two terms are zero in Foreign since it has no endowment of the natural resource. Consequently, the superscript on p and Ω is henceforth omitted.

2.2. Manufacturing: production and horizontal innovation

In country J, the i-th producer of manufacturing goods operates with the technology

$$X_i^J = (Z_i^J)^{\theta} \cdot [(M_i^J)^{\sigma}(L_{X_i}^J - \phi)^{1-\sigma}], \tag{5}$$

where X_i^J is output, $L_{X_i}^J$ is labor input, $\phi > 0$ is a fixed labor cost, M_i^J is the resource-based input, Z_i^J is the stock of firm-specific knowledge and $\theta \in (0,1)$ is the elasticity of the firm's total factor productivity with respect to knowledge. The fixed labor cost limits product proliferation in the long run. For simplicity, we assume that the knowledge of each firm grows at the exogenous rate $\dot{Z}_i^J/Z_i^J = z \geq 0$. The model yields the same qualitative results on the interaction between resource abundance and economic growth if knowledge growth, instead, results from costly in-house R&D activity: see Peretto and Valente (2010).[2]

[2] Peretto and Valente (2010) develop a more general model where firms undertake costly in-house R&D activity and choose the path of the rate of vertical innovation $\dot{Z}_i^J/Z_i^J$ that maximizes the value of their knowledge stock. The main difference is that, in the present simplified environment, steady-state growth is exogenous whereas in Peretto and Valente (2010), it is endogenous but still independent of the resource endowment because the interaction of vertical and horizontal R&D sterilizes the scale effect. As discussed extensively in the literature (e.g., Aghion and Howitt, 1998; Laincz and Peretto, 2006; Madsen, 2008, 2010), this property has important implications for theory, empirics and policy. In the present context, the absence of scale effects is furthermore plausible because scenarios in which long-term growth is proportional to the size of natural resource endowments are empirically irrealistic.

The value of a manufacturing firm that starts its activity at instant t in country J is given by the net present value

$$V_i^J(t) = \int_t^\infty \Pi_{X_i}^J(v) e^{-\int_t^v [r^J(s)-\delta]\,ds}\,dv, \tag{6}$$

where $\Pi_{X_i}^J$ is instantaneous profit, r^J is the interest rate and $\delta > 0$ is the death rate of firms. Firms behave monopolistically: each producer maximizes (6) by choosing at any instant the cost-minimizing combination of M_i^J and $L_{X_i}^J$, and then choosing the profit-maximizing volume of production X_i^J taking as given the global demand schedule for its product.

Outside entrepreneurs perform R&D to develop new products and then set up firms to serve the market. This process of horizontal innovations increases the mass of firms over time and the growth rate of N^J depends on how much labor is employed in start-up operations. For each entrant, denoted i without loss of generality, the labor requirement translates into a sunk cost that is proportional to the value of the production good: denoting by $L_{N_i}^J$ the units of labor employed in start-up activity, the entry cost equals $W^J L_{N_i}^J = \beta P_i^J X_i^J$, where $P_i^J X_i^J$ is the value of production of the new good when it enters the market, and $\beta > 0$ is a parameter representing technological opportunity. This assumption captures the notion that entry requires more effort the larger the anticipated volume of production.[3] Because entry at instant t creates value $V_i^J(t)$, free entry requires

$$V_i^J(t) = \beta P_i^J(t) X_i^J(t) = W^J(t) L_{N_i}^J(t), \tag{7}$$

which says that the value of the new firm must equal the entry cost for each entrant.

2.3. Resource processing in Home

The total output of the intermediate sector, M, is split between the quantities sold to domestic and to foreign manufacturing firms: denoting by M^J the quantity of resource-based intermediate purchased by final producers in country J, market clearing requires

$$M = M^H + M^F = \int_0^{N^H} M_i^H\,di + \int_0^{N^F} M_i^F\,di, \tag{8}$$

where M_i^J is the amount of intermediate used by the i-th manufacturing firm. The Home resource-processing firms are competitive and operate under constant returns to scale. The production function of the whole sector takes the CES form

$$M = [\varsigma L_M^{(\tau-1)/\tau} + (1-\varsigma) R^{(\tau-1)/\tau}]^{\tau/(\tau-1)}, \tag{9}$$

where L_M is labor, R is the raw natural resource, $\varsigma \in (0,1)$ is a weighting parameter and $\tau \geq 0$ is the elasticity of substitution between inputs. Specifically, labor and the natural resource are complements when $\tau < 1$, substitutes when $\tau > 1$. As $\tau \to 1$, the technology reduces to the Cobb–Douglas form ($L_M^\varsigma R^{1-\varsigma}$). The profit flow generated by this activity is $\Pi_M = P_M M - W^H L_M - pR$, where P_M is the price of the resource-based good. Since the sector is competitive, $\Pi_M = 0$.

The link between resource use, R, and the resource endowment, Ω, can take various forms. To keep the analysis simple, we assign full property rights over the endowment to the household and assume full utilization at each point in time of the non-depletable resource stock. The results do not change if R is a constant fraction of Ω.

2.4. Balanced trade

Since Home is the sole supplier of resource-based intermediates it runs a deficit in manufacturing trade, that is, the value of its manufacturing imports exceeds the value of its manufacturing exports. Ruling out trade in assets, balanced trade at any time t requires

$$\int_0^{N^F} P_M M_i^F\,di + \int_0^{N^H} P_i^H X_i^{Hf}\,di = \int_0^{N^F} P_i^F X_i^{Fh}\,di, \tag{10}$$

where the left-hand side is the value of total exports from Home to Foreign, i.e., the value of resource-based exports plus the value of manufacturing exports, and the right-hand side is the value of manufacturing exports from Foreign to Home.

3. Agents' behavior and world general equilibrium

This section describes the behavior of households (Section 3.1), manufacturing firms (Section 3.2), resource-processing firms (Section 3.3), and derives the conditions that characterize the world general equilibrium (Section 3.4). All the equations appearing in the remainder of the paper are derived in the Appendix to this article, which also contains the proofs of the various propositions.[4]

[3] See Etro (2004) and, in particular, Peretto and Connolly (2007) for a more detailed discussion of the microfoundations of our assumption. In symmetric equilibrium (see below) our formulation yields an entry cost equal to $\beta Y^J/N^J$. Barro and Sala-i-Martin (2004, Chapter 6) use this assumption to eliminate the scale effect and argue that it is empirically appropriate: the available evidence suggests that rates of innovation are functions of R&D intensity, not of the absolute flow of resources devoted to R&D.

[4] The Appendix to this article is available online on the authors' and the journal's websites.

3.1. Households

The household follows a three-stage budgeting procedure. It first chooses the optimal path of expenditure, obtaining

$$\dot{E}^J/E^J = r^J - \rho. \tag{11}$$

At each point in time, it then allocates the planned expenditure across Home and Foreign goods according to

$$Y^H = \xi E^H + (1-\xi)E^F \quad \text{and} \quad Y^F = \xi E^F + (1-\xi)E^H. \tag{12}$$

Consequently, the value of manufacturing production in each country is a weighted sum of domestic and foreign expenditures. Aggregating the demand for each consumption good across consumers, we obtain

$$X_i^J = \left[Y^J \Big/ \int_0^{N^J} (P_i^J)^{1-\varepsilon}\, di \right] \cdot (P_i^J)^{-\varepsilon}, \tag{13}$$

which is the global demand schedule for the i-th variety.

3.2. Manufacturing firms

Given the global demand (13), where the term in brackets contains only aggregate variables and is taken as given by the firm, each monopolist sets its price at a constant markup $\varepsilon/(\varepsilon-1)$ over the marginal cost. The resulting equilibrium is symmetric: each firm i employs the same amounts of inputs, $L_{X_i}^J = L_X^J/N^J$ and $M_i^J = M^J/N^J$, to produce the same quantity $X_i^J = X^J$. The aggregate factor demands thus read

$$M^J = \sigma \frac{\varepsilon-1}{\varepsilon} \cdot \frac{Y^J}{P_M} \quad \text{and} \quad L_X^J = N^J \phi + (1-\sigma)\frac{\varepsilon-1}{\varepsilon} \cdot \frac{Y^J}{W^J}. \tag{14}$$

The free entry condition (7) yields the rate of return to entry

$$r_N^J(t) = \frac{\dot{Y}^J(t)}{Y^J(t)} - \frac{\dot{N}^J(t)}{N^J(t)} + \frac{1}{\beta}\left[\frac{1}{\varepsilon} - \phi \cdot \frac{N^J(t)W^J(t)}{Y^J(t)}\right] - \delta. \tag{15}$$

The financial market in each country clears when the return to investment in horizontal innovation, r_N^J, equals the return to assets demanded by savers shown in (11).

3.3. Home resource-processing firms

The Home resource-processing firms produce up to the point where the price equals the marginal cost, $P_M = C_M(W^H, p)$, where $C_M(.,.)$ is the unit cost function associated to (9). The conditional input demands read

$$pR = S_M^R(W^H, p) \cdot P_M M \quad \text{and} \quad W^H L_M^H = (1 - S_M^R(W^H, p)) \cdot P_M M. \tag{16}$$

The term $S_M^R(W^H, p)$ that enters these expressions is a key element of the model. It is the share of the natural resource in the total cost of processing, $P_M C_M(W^H, p)$ or, equivalently, the elasticity of the unit cost of processing with respect to the resource price. Formally,

$$S_M^R(W^H, p) \equiv \frac{\partial C_M(W^H, p)}{\partial p} \frac{p}{C_M(W^H, p)} = \frac{(1-\varsigma)^\tau p^{1-\tau}}{(\varsigma)^\tau (W^H)^{1-\tau} + (1-\varsigma)^\tau p^{1-\tau}}, \tag{17}$$

which is increasing in p if the natural resource and labor are complements ($\tau < 1$), decreasing in p if they are substitutes ($\tau > 1$), and independent of p in the Cobb–Douglas case ($\tau = 1$).

3.4. World general equilibrium

In this world economy there are $N^H + N^F + 1$ global goods markets and four local markets. In each differentiated good market, each monopolist sets the price P_i^J given the global demand curve. In the market for the resource-based intermediate good the price P_M is set competitively at the point where the aggregate supply of Home producers meets global demand. Home's internal market for the raw resource clears when local demand meets local supply, i.e., when $R = \Omega$. The Home and Foreign labor markets clear, respectively, when $L^H = L_X^H + L_N^H + L_M^H$ and $L^F = L_X^F + L_N^F$, determining the local wages. Finally, having ruled out trade in assets, in each country savings meet the demand for investment funds to determine the local interest rate.

An important property is that the expenditure allocation across Home and Foreign goods in (12) and the balanced trade condition (10) comprise a system of three equations determining the ratios of expenditure-to-production both within and across countries. Using subscripts '$*$' to denote equilibrium values, we have

Proposition 1. *At any time t, expenditure and production in Home and Foreign satisfy*:

$$\left(\frac{E^F}{E^H}\right)_* = \frac{1-\sigma\dfrac{\varepsilon-1}{\varepsilon}}{1+\dfrac{\xi}{1-\xi}\sigma\dfrac{\varepsilon-1}{\varepsilon}} \quad \text{and} \quad \left(\frac{Y^F}{Y^H}\right)_* = \frac{1}{1+\dfrac{2\xi-1}{1-\xi}\sigma\dfrac{\varepsilon-1}{\varepsilon}} \equiv \mu, \tag{18}$$

$$\left(\frac{E^H}{Y^H}\right)_* = \frac{1+\dfrac{\xi}{1-\xi}\sigma\dfrac{\varepsilon-1}{\varepsilon}}{1+\dfrac{2\xi-1}{1-\xi}\sigma\dfrac{\varepsilon-1}{\varepsilon}} \quad \text{and} \quad \left(\frac{E^F}{Y^F}\right)_* = 1-\frac{\varepsilon-1}{\varepsilon}\sigma. \tag{19}$$

The constant expenditures ratio $(E^F/E^H)_*$ *yields interest-rate equalization,* $r^H = r^F$.

The intuition for Proposition 1 is as follows. On the one hand, the Cobb–Douglas technology (5) implies that the value of production of *both* the resource-intensive input and the raw resource are proportional to the *sum* of the values of manufacturing production in the two economies. On the other hand, the Cobb–Douglas preferences (1) yield constant expenditure shares across Home- and Foreign-made goods in both countries. Since balanced trade requires that the value of Foreign's manufacturing trade deficit must equal the value of its resource-based imports, all markets are interdependent and all nominal variables—i.e., manufacturing sectors' revenues Y^J and household expenditures E^J—are proportional to each other. The result of interest-rate equalization, $r^H = r^F$, follows from the Keynes–Ramsey rule (11) and confirms that our assumption of separated financial markets is indeed a simplification bearing no substantial effect on the results.

4. Resource booms in world equilibrium

This section characterizes the dynamic response of the world economy to a resource-endowment shock. Section 4.1 studies the effects of a resource boom on the value of manufacturing production in Home and Foreign, the resource price and the Foreign wage. Section 4.2 derives in closed form the equilibrium rates of horizontal innovation and the associated time path of the mass of firms in each country. Section 4.3 describes the reallocation of labor across sectors induced by the resource boom in the Home labor market, and Section 4.4 shows how these dynamics affect welfare.

4.1. Production, wages and the resource price

Home labor is the numeraire, implying $W^H \equiv 1$. The equilibrium relations (12), (14), (16) and (18)–(19) reduce to a system of four equations in the resource price p, the values of manufacturing production Y^H and Y^F, and the foreign wage W^F:

$$Y^F = \mu Y^H, \tag{20}$$

$$W^F = \frac{(E^F/Y^F)_* - \beta\rho}{L^F} Y^F, \tag{21}$$

$$Y^H = \frac{L^H + p\Omega}{(E^H/Y^H)_* - \beta\rho}, \tag{22}$$

$$p\Omega = S_M^R(1,p)\sigma\frac{\varepsilon-1}{\varepsilon}(1+\mu)Y^H, \tag{23}$$

where the expenditure-to-production ratios are given in (19). The first two equations define the equilibrium in Foreign. Eq. (20) shows that the value of Foreign's manufacturing production, Y_*^F, is proportional to Home's due to balanced trade. From (21), a change in Y_*^F yields a proportional change in W_*^F in the same direction: the reason is that Y_*^F drives the demand for labor of Foreign manufacturers who face a fixed labor supply.

Eqs. (22) and (23) determine the relationship between resource scarcity and Home's production and income levels. From (22), an increase in Home resource income, $p\Omega$, tends to increase the value of Home manufacturing production via an increase in Home household expenditure. Eq. (23) describes how Home resource income depends on the value of manufacturing production via the demand for the raw natural resource of Home resource-processing firms. The shape of this relation is governed by the cost share $S_M^R(1,p)$: given Y^H, resource income is increasing in p under complementarity and decreasing in p under substitutability. Combining (22) with (23) we obtain

$$p\Omega = \frac{L^H \cdot S_M^R(1,p)}{\kappa - S_M^R(1,p)}, \quad \kappa \equiv \frac{(E^H/Y^H)_* - \rho\beta}{\sigma\dfrac{\varepsilon-1}{\varepsilon}(1+\mu)} > S_M^R(1,p) \;\; \forall p. \tag{24}$$

Expression (24) shows that when the resource endowment Ω rises, the equilibrium resource price p_* always falls but the effect on equilibrium resource income, $p_*\Omega$, depends on the elasticity of substitution. Specifically, resource income falls when $\tau<1$, rises when $\tau>1$, and it is unaffected by the resource boom when $\tau=1$.[5] The salient property of this equilibrium is as follows.

Proposition 2. *At any time t, the resource price p_* is constant. The equilibrium values of expenditure and production, E_*^H, Y_*^H, E_*^F, Y_*^F, and the Foreign wage W_*^F are all constant and linear functions of Home's resource income Ωp_*. The effect of an increase in Ω on the resource price p_* is always negative. The effect on resource income in Home is*

$$\frac{d(\Omega p_*)}{d\Omega}=\underbrace{\frac{\kappa\Omega}{\kappa-S_M^R(1,p_*)}}_{+}\cdot\underbrace{\left(\frac{dS_M^R(1,p_*)}{dp_*}\frac{p_*}{S_M^R(1,p_*)}\right)}_{1-\varepsilon_M^R(1,p_*)}\cdot\underbrace{\frac{dp_*}{d\Omega}}_{-},\tag{25}$$

where $\varepsilon_M^R(1,p)$ is the price elasticity of demand for the raw resource and for all p:

$$\varepsilon_M^R(1,p)<1 \;\; if \;\; \tau<1, \quad \varepsilon_M^R(1,p)=1 \;\; if \;\; \tau=1, \quad \varepsilon_M^R(1,p)>1 \;\; if \;\; \tau>1.\tag{26}$$

The effects on the value of manufacturing production in Home and Foreign and the wage in Foreign are all proportional to the effect on resource income in Home:

$$\frac{dY_*^H}{d\Omega}=\frac{\frac{d(\Omega p_*)}{d\Omega}}{\left(\frac{E^H}{Y^H}\right)_*-\beta\rho},\quad \frac{dY_*^F}{d\Omega}=\frac{\mu\frac{d(\Omega p_*)}{d\Omega}}{\left(\frac{E^H}{Y^H}\right)_*-\beta\rho},\quad \frac{dW_*^F}{d\Omega}=\frac{\left(\left(\frac{E^F}{Y^F}\right)_*-\beta\rho\right)\mu\frac{d(\Omega p_*)}{d\Omega}}{\left(\left(\frac{E^H}{Y^H}\right)_*-\beta\rho\right)L^F}.\tag{27}$$

Proposition 2 highlights the connection between the slope of the cost share function $S_M^R(1,p_*)$ and the price elasticity of the associated factor demand: the intuition for our results is that the income effect of an increase in the resource endowment, $d(\Omega p_*)/d\Omega$, depends on the price elasticity of the demand for the raw resource, $\varepsilon_M^R(1,p)$, which determines the net effect between the fall in the price p_* and the increase in the quantity Ω. This elasticity in turn depends on the input elasticity of substitution in resource processing. If $\tau>1$ the demand for the natural resource is elastic and a rise of the resource supply yields a mild reduction of the equilibrium price. In this case, resource income rises and drives up expenditures and the value of manufacturing production. If $\tau<1$, instead, resource demand is inelastic and the rise of the resource in supply yields a drastic reduction of the resource price. Accordingly resource income falls and drives down expenditure and production.

4.2. Horizontal innovation and resource booms

Proposition 1 and the Keynes–Ramsey rule (11) yield $r^H=r^F=\rho$. Substituting this result in (15), we obtain the growth rate of the mass of firms

$$\frac{\dot N^J(t)}{N^J(t)}=\nu\cdot\left[1-\frac{\varepsilon\phi}{1-\beta\varepsilon(\rho+\delta)}\cdot\frac{W_*^J}{Y_*^J}\cdot N^J(t)\right],\quad \nu\equiv\frac{1-\beta\varepsilon(\rho+\delta)}{\beta\varepsilon}>0.\tag{28}$$

This is a logistic equation with explicit solution

$$N^J(t)=\frac{N_*^J}{1+e^{-\nu t}[(N_*^J/N_0^J)-1]},\tag{29}$$

where $N_0^J\equiv N^J(0)$ is the initial mass of firms, and

$$N_*^J\equiv\lim_{t\to\infty}N^J(t)=\frac{1-\beta\varepsilon(\rho+\delta)}{\varepsilon\phi}\cdot\frac{Y_*^J}{W_*^J}\tag{30}$$

is the steady-state (or asymptotic) mass of firms. The interpretation is that, at any point in time, the equilibrium of factors market, the consumption/saving decision of households and balanced trade determine the size of the market for manufacturing goods Y_*^J and the wage W_*^J in each country. The ratio Y_*^J/W_*^J, in turn, determines the asymptotic mass of firms (30) and thereby the whole *logistic* time path of $N^J(t)$ in each economy. The reason why the mass of firms exhibits logistic instead of exponential growth is the existence of fixed operating costs: setting $\phi=0$, the model collapses to the Grossman and Helpman (1991, Chapter 3) model with expanding varieties, where the mass of goods grows exponentially at rate ν. The intuition is that, in the present framework, the *finite* endowments of labor and natural resource limit the proliferation of product variety: if unchecked by the crowding effect generated by the fixed operating cost, the mass of firms would grow unboundedly.[6]

[5] Graphically, the solution is the intersection of two functions of p: the left-hand side, $p\Omega$, and the right-hand side of (24). Under complementarity ($\tau<1$), the right-hand side is an increasing concave function starting at the origin, converging asymptotically to a finite upper bound, and intersecting the $p\Omega$ locus from above. Under substitutability ($\tau>1$), instead, the right-hand side is a decreasing convex function approaching zero asymptotically, intersecting the $p\Omega$ locus from above. As Ω rises, the $p\Omega$ locus rotates upward and the equilibrium changes as a movement along the right-hand side: after an increase in Ω, the equilibrium price p_* always falls whereas equilibrium resource income, $p_*\Omega$, falls if $\tau<1$ and rises if $\tau>1$.

[6] Peretto and Connolly (2007) provide a detailed discussion of how logistic dynamics arise in a broad class of models and how they relate to the literature.

Assume now that Ω increases at time t_0 and, for simplicity, that Home is in steady state at t_0. First, suppose that $\tau > 1$. From Proposition 2, there is an immediate and permanent increase in Home's value of manufacturing production, Y_*^H, which, by (30), yields an increase in the steady-state mass of firms, N_*^H. Because the mass of firms is the state variable, this increase occurs over time: according to (28) the rate of net entry $\dot{N}^H/N^H$ jumps up and then gradually declines, taking the economy smoothly from $N^H(t_0)$ to the new steady state, N_*^H. Foreign adjusts to the resource boom with a rise of both its value of production and its wage, which leaves the innovation rate unchanged: from (21), the ratio Y_*^F/W_*^F is constant and independent of Home's resource endowment; as the ratio Y_*^F/W_*^F does not change, Eq. (28) implies that resource booms do not influence $\dot{N}^F/N^F$. The direction of these effects is reversed when $\tau < 1$. Under complementarity, the resource boom induces a drop in Y_*^H, the mass of Home firms declines during the transition ($\dot{N}^H/N^H < 0$) and converges the lower steady state N_*^H whereas, in Foreign, the value of manufacturing production falls and yields a one-for-one reduction of the wage. We summarize these results as follows.

Proposition 3. *If $\tau > 1$ ($\tau < 1$), an increase in Ω raises (lowers) the steady-state mass of firms in Home and consequently triggers a transition with a temporarily higher (lower) innovation rate. Foreign fully absorbs the shock through a rise (fall) of the value of its manufacturing production matched one-for-one by a rise (fall) of its wage and no change of its innovation rate.*

The logistic entry process provides the main channel through which the resource endowment affects productivity and sectoral employment over time. In the next subsection, we exploit Eq. (29) to determine the dynamics of employment across sectors.

4.3. Reallocation of labor in Home

In Home, the resource boom induces a reallocation of labor across the upstream and downstream sectors and, within manufacturing, across production and innovation. Using (14), (16) and the labor market clearing condition, we obtain

$$L_N^H(t) = \frac{1-\beta\varepsilon\rho}{\varepsilon} \cdot Y_*^H - \phi \cdot N^H(t), \tag{31}$$

$$L_X^H(t) = \phi N^H(t) + (1-\sigma)\frac{\varepsilon-1}{\varepsilon} \cdot Y_*^H, \tag{32}$$

$$L_M^H(t) = L^H - [(1-\sigma)(\varepsilon-1) + (1-\beta\varepsilon\rho)]\frac{1}{\varepsilon} \cdot Y_*^H. \tag{33}$$

Now assume that Ω increases at time t_0 and consider the case $\tau > 1$. The mass of firms at the time of the shock, $N^H(t_0)$, is pre-determined and does not jump. From Proposition 3, the resource boom yields an immediate increase in Y_*^H which induces a higher value of N_*^H. The resulting effects on Home's allocation of labor are as follows.

According to (31), employment in start-up activities, $L_N^H(t)$, jumps up at t_0 as the larger size of the market attracts labor into entry operations. Importantly, after the initial jump up, employment in entry gradually declines and converges from above to a higher steady-state level (from (30), we have $\lim_{t\to\infty} L_N^H(t) = \frac{\beta\delta}{\varepsilon} \cdot Y_*^H$). From (32), employment in manufacturing production, $L_X^H(t)$, jumps up at t_0 and keeps rising as the entry process attracts even more labor into production. Intuitively, $L_X^H(t)$ converges to a higher steady-state level for two reasons: (a) each firm wishes to produce more because the market is larger, and (b) the larger market supports more firms. Eq. (33) shows that employment in resource processing is decreasing in the value of Home's manufacturing production but is independent of the mass of firms. Specifically, $L_M^H(t)$ adjusts instantaneously to the increase in Y_*^H with no further dynamics. Fig. 1 summarizes these results. The effects of the resource boom in the case $\tau < 1$ yield mirror-image paths.

It is worth stressing that when the transition entails net entry, the crowding-in of manufacturing generated by the resource boom implies that the reallocation of labor is from innovation to production: as new firms squeeze profits away from incumbents, the incentive to enter weakens. Moreover, the two forces driving this transition—the immediate increase in market size and the process of net entry it induces—offset each other in the long run so that employment per firm, $L_X^H(t)/N^H(t)$, is independent of the endowments L^H and Ω.[7]

The reallocation of labor between resource processing and manufacturing provides further insight on the mechanism driving our results. Proposition 2 emphasized the relation between the elasticity of input substitution and the price response to the endowment shock. Fig. 1 highlights a more fundamental aspect: the change in relative prices induces/accommodates the reallocation of labor dictated by technology. Under substitutability, the primary sector exploits the additional resource endowment and expands while *shedding* labor. Under complementarity, in contrast, the resource boom prompts the primary sector to *attract* labor from the rest of the economy.

[7] This exact offset, which is the key to the elimination of the scale effect in this class of models, is the reason why the growth acceleration due to the resource boom is only temporary even if the rate of vertical innovations is endogenous, as in Peretto and Valente (2010).

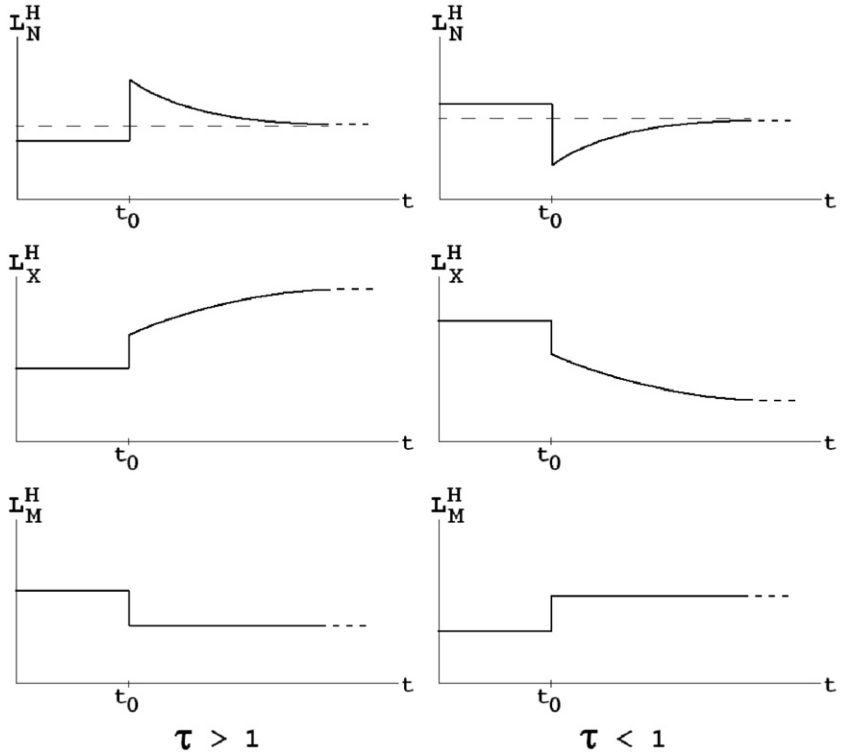

Fig. 1. Transitional dynamics of employment levels in Home sectors after the resource boom when $\tau > 1$ (left graphs) and $\tau < 1$ (right graphs).

4.4. Total factor productivity and growth

With $W^H \equiv 1$, the relevant measures of real income in the two countries are the utility functions (1), that can be re-interpreted as production functions for a final homogenous good assembled from the differentiated manufacturing goods. The model yields closed-form solutions for flow utility and welfare. Since firms set a constant markup $\varepsilon/(\varepsilon-1)$ over marginal cost in both countries, the global demand (13) for consumption goods yields

$$X^J = \frac{Y^J}{C_X(W^J, C_M(W^J, p))} \cdot \frac{(Z^J)^\theta}{N^J} = \frac{Y^J}{C_X^J} \cdot \frac{(Z^J)^\theta}{N^J}, \tag{34}$$

where $C_X^J \equiv C_X(W^J, C_M(W^J, p))$. Substituting (34) in (1) we obtain

$$\log u^J = \log \underbrace{[(Y^J/C_X^J)^\xi (Y^K/C_X^K)^{1-\xi}]}_{\Upsilon^J \text{ (``Static term'')}} + \log \underbrace{[(T^J)^\xi (T^K)^{1-\xi}]}_{\Gamma^J \text{ (``TFP term'')}} - \log \frac{\varepsilon}{\varepsilon-1} L^J, \tag{35}$$

where $T^J \equiv (Z_i^J)^\theta (N^J)^{1/(\varepsilon-1)}$ is the country-specific index of TFP, and $K \neq J$ is the other country's index. Expression (35) decomposes utility in two terms. The static term Υ^J captures how real consumption depends on income and on C_X^J, i.e., the part of the manufacturing unit cost that depends on input prices. The second term, Γ^J, captures how real consumption evolves with the two countries' TFP indices. Each country's TFP, in turn, is a combination of its product variety and its average firm-specific knowledge stock.

The static term Υ^J is constant over time because, by Proposition 1, all nominal variables and prices jump to stationary equilibrium values. Using (20), we can rewrite it as

$$\log \Upsilon^J = \log Y_*^J - \log \underbrace{[(C_X^J)_*^\xi (C_X^K)_*^{1-\xi}]}_{\text{CPI given TFP in } J} + \psi^J, \quad \psi^J = \begin{cases} (1-\xi)\mu & \text{for } J = H, \\ (1-\xi)/\mu & \text{for } J = F. \end{cases} \tag{36}$$

Recalling that E_*^J is proportional to Y_*^J, Eq. (36) shows that Υ^J depends on the ratio between domestic expenditure and a CPI index reflecting the relative expensiveness of domestic and imported manufacturing goods.

The term Γ^J, instead, is time-varying and depends on the two countries' TFP levels: due to trade, real income growth in *each* economy is a weighted average of the productivity growth rates of *both* economies. As the mass of firms in each country follows a logistic process, there is a closed-form solution for the dynamics of Γ^J and, consequently, welfare. Using

(29), and normalizing $\log T_0^J \equiv 0$ without loss of generality, the dynamics of TFP obey

$$\log T^J(t) = \theta z \cdot t + \frac{\Delta^J}{\varepsilon - 1} \cdot (1 - e^{-\nu \cdot t}), \quad \Delta^J \equiv (N_*^J / N_0^J) - 1, \tag{37}$$

where θz is the asymptotic growth rate of firms' productivity and Δ^J is a country-specific value that captures the distance between the initial mass of firms and the asymptotic equilibrium level.

4.5. Welfare

The closed-form solution for the path of TFP in Eq. (37) allows us to calculate welfare in closed form. Substituting (36) and (37) in (35), we obtain

$$\log u^J(t) = \log \Upsilon^J + \theta z \cdot t + \frac{\xi \Delta^K + (1-\xi)\Delta^K}{\varepsilon - 1}(1 - e^{-\nu \cdot t}) - \log \frac{\varepsilon L^J}{\varepsilon - 1}, \quad K \neq J, \tag{38}$$

which, upon substitution in (3), yields the explicit solution for welfare:

Proposition 4. *Present-value welfare in country $J = H,F$ is given by*

$$\rho U_0^J = \log \Upsilon^J + \frac{\theta z}{\rho} + \Phi \cdot [\xi \Delta^J + (1-\xi)\Delta^K] - \log \frac{\varepsilon L^J}{\varepsilon - 1}, \quad K \neq J, \tag{39}$$

where $\Phi \equiv \nu/(\varepsilon - 1)(\rho + \nu)$ is the welfare multiplier of a temporary deviation of the rate of innovation from its steady-state value due to the permanent change in the two economies steady-state mass of firms.

Expression (39) says that, in both countries, the overall effect of an increase in Ω is given by the sum of a *level effect* that operates through the static term Υ^J (via changes in expenditures and prices) and a *transitional growth effect* that operates through the term $\xi \Delta^J + (1-\xi)\Delta^K$ (via changes in the asymptotic mass of firms). Notice, however, that the transitional growth effect is exclusively determined by variations in Δ^H: when the shock hits, Foreign adjusts instantaneously through changes in Y_*^F and W_*^F that leave N_*^F unaffected. Consequently, $\partial \Delta^F / \partial \Omega = 0$ and we can calculate

$$\rho \frac{\partial U_0^H}{\partial \Omega} = \frac{\partial \log \Upsilon^H}{\partial \Omega} + \Phi \xi \frac{\partial \log \Delta^H}{\partial \Omega} \quad \text{and} \quad \rho \frac{\partial U_0^F}{\partial \Omega} = \frac{\partial \log \Upsilon^F}{\partial \Omega} + \Phi(1-\xi) \frac{\partial \log \Delta^H}{\partial \Omega}. \tag{40}$$

The direction of the transitional growth effects is easy to characterize: by Proposition 3, the steady-state mass of firms in Home, N_*^H, moves in the same direction as the value of Home production, Y_*^H, implying

$$\frac{\partial \log \Delta^H}{\partial \Omega} < 0 \ \text{if} \ \tau < 1, \quad \frac{\partial \log \Delta^H}{\partial \Omega} = 0 \ \text{if} \ \tau = 1, \quad \frac{\partial \log \Delta^H}{\partial \Omega} > 0 \ \text{if} \ \tau > 1. \tag{41}$$

The level effects $\partial \Upsilon^J / \partial \Omega$, instead, have generally ambiguous sign because an increase in Ω modifies both expenditure levels and the Foreign wage W_*^F in the same direction. For example, under substitutability ($\tau > 1$), the expenditure effects are strictly positive because greater resource abundance increases both Y_*^H and Y_*^F. The resource boom also reduces the Home unit cost, $C_X^H(1, C_M^H(1, p_*))$, through the fall of the resource price p_*. However, because W_*^F rises, the change of the Foreign unit cost, $C_X^F(W_*^F, C_M^H(1, p_*))$, is ambiguous. If the rise of the Foreign wage is strong enough, Foreign goods become more expensive—despite the fact that the fall in the resource price should make them cheaper—and we can have $\partial \Upsilon^J / \partial \Omega < 0$. If, instead, the fall of the resource price dominates the Foreign wage increase, greater resource abundance produces $\partial \Upsilon^J / \partial \Omega > 0$. In the case of complementarity, $\tau < 1$, we obtain opposite results. We summarize this discussion as follows.

Proposition 5 (*Welfare effects*). *If $\tau > 1$, a resource boom generates* (i) *a positive transitional growth effect and* (ii) *an ambiguous level effect in both countries*; *if the increase in W_*^F is relatively weak* (*strong*), *the overall welfare effect is positive* (*negative*). *If $\tau < 1$, a resource boom generates* (i) *a negative transitional growth effect and* (ii) *an ambiguous level effect in both countries*; *if the fall in W_*^F is relatively weak* (*strong*), *the overall welfare effect is negative* (*positive*).

5. Discussion: the role of trade and our model's relation to the literature

This section discusses the role of international trade in our results (Section 5.1) and the model's relation to the previous literature (Section 5.2).

5.1. The role of international trade

To appreciate the paper's contribution more fully, especially in relation to Peretto (in press), it is useful to explore in more detail the role of international trade. If we focus on Home, the resource-rich economy, the solution of the two-country model collapses to that of the one-country model when $\xi = 1$. In this no-trade equilibrium, Eqs. (22) and (23) respectively yield $(E^H/Y^H)_* = 1$ and $(Y^F/Y^H)_* = \mu = 0$. This implies that trade has two effects on Home's equilibrium. First, it introduces a wedge between the value of manufacturing consumption and the value of manufacturing production (with trade, we have $E^H/Y^H_* > 1$). Second, it introduces the foreign component to the total demand for the resource-intensive input (with trade, we have $\mu > 0$). We call these, respectively, the *specialization* effect and the *global demand* effect.

The two effects work in opposite directions in determining the resource price and the value of Home's manufacturing production.[8] Consider a shift from the no-trade equilibrium ($\xi = 1$) to the trade equilibrium ($\xi < 1$). As Home becomes an exporter of the resource-intensive good, it needs to run a deficit in manufacturing trade, a force that reduces its manufacturing production (Y^H falls for given p) and the demand for the resource-intensive input by its own manufacturers (p falls for given Y^H). However, Foreign's consumers add to the demand for Home's manufacturing goods (Y^H rises for given p) while Foreign's manufacturers add to the demand for the resource-intensive good—two forces that, directly and indirectly, put upward pressure on p given Y^H. Hence, three scenarios may arise: relative to the closed-economy setting, the two-country equilibrium exhibits (i) lower Y^H and p if the specialization effect dominates, (ii) higher Y^H and p if the global demand effect dominates, or (iii) lower Y^H and higher p.

International trade affects the Foreign economy in two respects. First, the welfare effects of the resource boom are fully "imported": greater resource abundance in Home does not influence TFP growth in Foreign but, because of trade, income dynamics and welfare in Foreign do change with the resource boom. Second, trade implies an ambiguous level effect that does not apply in the one-country model: if we exclude trade, the Foreign wage disappears from the term Υ^H in Eq. (36) and the overall welfare effect of the resource boom is surely positive (negative) if labor and resource-based inputs are substitutes (complements).[9]

To shed further light on this mechanism, we introduce trade frictions. Let α_h and α_f denote, respectively, an ad-valorem tariff imposed by Home and Foreign on imported consumption goods, and α_m denote an ad-valorem tariff imposed by Foreign on imported resource-based intermediates. Both governments rebate tariff revenues to the residents via lump-sum transfers. Without going through the details of the analysis (see the Appendix), the effects of tariffs are as follows.

As Home's tariff on manufacturing imports, α_h, rises, Home's manufacturing trade deficit falls and restoring equilibrium requires a fall of the value of Home's resource-based exports. This fall is accomplished through a fall of the global demand for the resource-based input that triggers a fall of the resource price and, consequently, a fall of Home's resource income. The negative income effect reduces the value of manufacturing production and the incentive to innovate, triggering a *Home TFP growth slowdown*. Importantly, the tariff α_h does not affect the dynamics of Foreign TFP because Foreign absorbs the shock via a fall in the wage W^F that cancels out with the fall in Y^F. The tariff α_h, therefore, hurts Home's growth directly and Foreign's income growth indirectly.

The tariff imposed by Foreign on manufacturing imports, α_f, raises Home's manufacturing trade deficit and thus requires a rise of the value of its resource-based exports. This reinforces the specialization and global demand effects discussed above: the overall effects on Y^H and p are ambiguous. In Foreign, instead, the effects are clear cut: the wage-to-production ratio, W^F/Y^F, increases so that the tariff α_f generates *net exit* from the manufacturing sector and therefore a *Foreign TFP growth slowdown*.

The tariff on intermediates imports, α_m, implies that Foreign is less "willing" to import the resource-based intermediate: p tends to drop while Home runs a smaller deficit in manufacturing trade, which tends to raise Y^H. Again, the qualitative effect in Home is ambiguous as the specialization and global demand effects, which this tariff weakens, work in opposite directions. On the other hand, the tariff on resource-based imports triggers a temporary *growth deceleration of Foreign TFP*—because the change in the wage W^F more than compensates the change in Y^F—which indirectly affects Home's real income growth via trade.

The reason why all three tariffs trigger a slowdown of TFP that hurts both countries is that they interfere with comparative advantage: α_h makes it harder for Foreign to pay for resource-based imports; α_f forces Home to specialize in primary production in excess of what comparative advantage dictates; α_m makes Foreign "unwilling" to import the good in which it has comparative disadvantage.

5.2. Relation to the literature

The results discussed above are novel in that they highlight the dynamic implications of tariff policies through its effects on endogenous innovation in a world of resource-rich and resource-poor countries. The strand of literature most closely related to our work studies the Dutch Disease (Corden, 1984; Van Wijnbergen, 1984; Krugman, 1987) with models that typically posit a small open economy and interpret the resource curse as an aggregate productivity slowdown generated by a sectoral boom, that is, an increase in resource *income* due to exogenous shocks that raises the size or the productivity of the economy's resource-intensive sector. The conventional view is that such booms harm economic growth because the reallocation of labor and capital toward the resource-intensive sector crowds-out the strategic, knowledge-creating sector.

[8] In the (p,Y^H) space, Eq. (22) is an increasing straight line whereas Eq. (23) is an increasing curve that cuts (22) from below. The intersection is the equilibrium (p_*,Y^H_*). If we exclude trade by setting $\xi = 1$, the expenditure locus (22) shifts upward and rotates counterclockwise, while the income locus (23) rotates clockwise, pivoting around the origin. The net effect on (p_*,Y^H_*) is thus generally ambiguous.

[9] Indeed, in the closed-economy model of Peretto (in press), a resource boom under substitutability ($\tau > 1$) yields a welfare increase due to (i) an upward jump in utility at time 0 followed by (ii) a temporary growth acceleration that eventually dies out.

Our analysis differs from Dutch Disease models in three important ways. First, Dutch Disease models do not distinguish between physical resource endowments and resource income but characterize resource booms as income shocks (windfalls). Second, Dutch Disease models ignore the vertical structure of production that, in the present model, generates the crucial transmission channel between endowment shocks and aggregate productivity. Third, Dutch Disease models view resource-rich countries as small open economies and thus neglect the role of the price effects that determine the extent to which resource-rich economies are able to exploit the natural endowment to obtain additional income.[10] These differences in assumptions are reflected in our results. In Dutch Disease models, greater resource abundance is associated with (i) higher resource income, (ii) higher employment in the resource-intensive sector, (iii) less knowledge creation and slower growth. In the present model, the link between resource income, employment and growth effects is clearly different: under substitutability (complementarity) the resource boom generates (i) higher (lower) resource income, (ii) lower (higher) employment in the resource-processing sector and (iii) higher (lower) innovation rates. Consequently, a growth slowdown occurs only if the resource boom *reduces* resource incomes.

6. Conclusion

The uneven distribution of natural resource endowments generates asymmetric trade structures and important interdependencies among countries. The two-country model developed in this paper provides a straightforward formalization of these phenomena: a resource-rich economy (Home) exports resource-based intermediates and final manufacturing goods while importing differentiated final goods from a resource-poor economy (Foreign). In this environment, the effects of a *resource boom*—i.e., an increase in Home's natural resource endowment—depend on whether labor and the raw resource are complements or substitutes in the production of resource-based intermediates. Under substitutability, the resource boom raises Home's resource income and its overall expenditure on manufacturing goods, triggering a temporary acceleration of TFP growth. In Foreign, the wage rises due to Home's higher demand for its manufacturing goods but TFP growth remains the same. Nevertheless, consumption growth accelerates temporarily because the growth acceleration in Home causes the price index of Foreign's imports to fall temporarily faster. Under complementarity, the same mechanism works in the opposite direction, generating negative transitional growth effects for both countries. The intuition for these results is that the elasticity of substitution between labor and raw resources in the intermediate sector determines the elasticity of resource demand and, hence, the reaction of Home's resource income to an increase in the resource endowment.

These results raise three issues that deserve empirical scrutiny. First, once we account for the endogenous resource price, the response of employment in the primary sector to resource-endowment shocks drastically differs from the response to resource-income shocks (e.g., windfalls): to our knowledge, however, there is yet no empirical analysis that disentangles the quantity response from the price response. Second, because asymmetric trade matters for growth and countries are highly interdependent, the study of resource-rich economies should be extended to investigate how the economic performance of resource-*poor* countries responds to resource-endowment shocks. Third, the central role of the elasticity of substitution between resources and labor in our model suggests analyzing in detail the technologies of resource-based industries. It would be interesting to extend the empirical results of Jin and Jorgenson (2010) to the case of upstream versus downstream sectors and link the results of substitutability/complementarity with the observed income effects generated by shocks to the resource supply. Also, it would be interesting to replicate the estimates for countries other than the US, to control for technological differences that possibly characterize less developed economies.

Acknowledgments

We thank Rick van der Ploeg, Associate Editor Esteban Rossi-Hansberg, and an anonymous referee for helpful comments and suggestions. Simone Valente gratefully acknowledges financial support from the Swiss National Science Foundation (Grant no. IZK0Z1-125589).

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jmoneco.2011.07.001.

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[10] Interestingly, in his seminal paper Corden (1984, p. 367) regards the lack of price effects as a simplifying assumption: "extra exports of [the resource-intensive good] owing to technical progress in the [resource-intensive] sector or any other reason may lower the world price of [the resource-intensive good]. This is an obvious effect, and we can suppose that it has already been incorporated in the calculation of the size of the boom.". The subsequent literature, however, does not extend the basic framework to include price effects via endogenous terms-of-trade.

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