Natural Resource Wealth and Directed Technical Change

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Abstract

This paper analyses the effect of endogenous directed technical change in a resource-rich economy, embedding a version of Acemoglu's model of directed technical change in a three-by-three trade theory model. Technical progress depends on entrepreneurs who either produce or adopt technology, and who endogenously choose which sector to operate in. The static effect of a resource discovery is de-industrialization and a rise in non-resource factor incomes, as in standard trade theory. The dynamic effect is to exacerbate the de-industrialization over time, but unless the discovery is large enough it leads to lower growth in non-resource factor incomes, which in the long run are lower than in the absence of the resource discovery. Thus if natural resources are owned by the government and other factors are owned by the private sector, then real private sector income may grow more slowly in a resource-rich economy than a resource-poor economy.

1 Introduction

Countries with large natural resource sectors tend to exhibit features that mark them out from their resource-poor counterparts. Two phenomena in particular have been analysed in the literature. The first is Dutch Disease, which refers to the de-industrialization caused by a resource boom, for which the classic reference is Corden and Neary's (1982) trade-theoretic analysis. The second is the Resource Curse, or the association between having a large natural resource sector and a low rate of economic growth, a finding confirmed by Sachs and Warner (1995) and numerous subsequent studies. The two phenomena have been brought together in models that posit a higher rate of growth in manufacturing than in the rest of the economy, due to learning-by-doing, so that de-industrialization leads to a lower rate of aggregate growth (Neary and Wijnbergen, 1985; van Wijnbergen, 1984; Sachs and Warner, 1995). Technical change in these models remains exogenous, however, and the process of technological change in a resource-rich economy has not itself been analysed. This paper aims to fill that gap by presenting a model of a resource-rich economy in which the inter-sectoral allocation of technical progress is endogenized as the outcome of the optimizing actions of agents.

The model draws particularly on Corden and Neary (1982) and Acemoglu (2002). Corden and Neary present a range of static models of a three-sector open economy, with several alternative factor mobility assumptions, and use them to analyse the effect of a resource boom. Acemoglu (2002) presents a dynamic model of directed technical change in a two-sector closed economy.[1] Both models analyse the impact of changes in factor endowments on the structure of output and relative factor returns, but they cover quite different mechanisms. Corden and Neary use traditional competitive trade theory with no endogenous technical change, while the core of Acemoglu's model is endogenous growth theory. The model I present can be thought of as a dynamic version of Corden and Neary, or a three-sector open-economy version of Acemoglu. Endogenizing technical change *à la* Acemoglu requires the use of explicit production and demand functions, and the price of this is to lose the generality

[1] Acemoglu and Zilibotti (2001) and Acemoglu (2003a, b) analyse similar models in different contexts.

of Corden and Neary's approach. On the other hand, explicit functions have the advantage of illuminating the role of various parameters, notably the elasticity of substitution.

The benefit of combining the approaches is to show how the static and dynamic effects interact. In the absence of factor movement towards the resource sector (as is assumed in the model here), traditional trade theory predicts that a resource discovery will raise non-resource factor incomes (e.g. wages) and lead to de-industrialization, this being an explanation for Dutch Disease. I find that the dynamic effect of a resource discovery is to exacerbate de-industrialization as technical progress accelerates in the resource sector and stalls in the manufacturing sector but, unless the resource discovery is particularly large, it reduces the rate of growth of non-resource factor incomes. Thus the static and dynamic mechanisms both cause de-industrialization, but under certain circumstances they push non-resource factor incomes in opposite directions.

Unlike the papers that assume that learning-by-doing takes place only in manufacturing, I assume that investment in the resource sector looks rather like investment in other sectors. This follows Wright and Czelusta's (2004, p. 10) observation that "the abundance of American mineral resources should not be seen as merely a fortunate natural endowment. It is more appropriately understood as a form of collective learning, a return on large-scale investments in exploration, transportation, geological knowledge, and the technologies of mineral extraction, refining, and utilization". These investments, from the basic science of geology and chemistry up to the development of special materials or equipment used in the sector, are not obviously different from R&D investments in any other sector. Moreover, resource extraction, particularly the upstream energy sector, is one of the most technologically advanced sectors in the global economy. Explaining why this is so - modeling the process through which the resource sector receives so much technological investment - and examining its consequences is the main goal of this paper.

The model is also intended to illuminate the role of entrepreneurs in technical change. High-tech natural resource companies employ many highly able individuals.

In particular, a well-known phenomenon in resource-rich countries is that the most able and entrepreneurial individuals are attracted out of the rest of the economy and into the resource sector. Indeed, it is a common complaint of executives in national oil companies (NOCs) that their governments ask them to manage large public investments in unrelated areas, such as the building of schools and hospitals, because NOCs are often considered the only really competent arm of government.

The role of entrepreneurial individuals in development has been discussed by Baumol (1990) and by Murphy, Shleifer and Vishny (1991), all of whom consider the possibility of entrepreneurs being diverted into "rent-seeking" rather than productive activities. In the context of resource wealth, Gelb et al. (1988, p. 17) write that "a large rent component in national income, if not rapidly and widely dispersed across the population, is liable to divert scarce entrepreneurial talent away from commodity production into 'rent-seeking' activities." The present model does not share this somewhat jaded view of entrepreneurs in the resource sector. There is no rent seeking and all activity is productive, but the actions of entrepreneurs do affect the structure of output and relative factor incomes.

One could model these individuals simply as factors of production. Instead, I model them as drivers of growth - in particular, it is entrepreneurs who adopt or produce technology. In developing countries technology is typically adopted rather than invented, but in either case technological progress requires entrepreneurs. The model is thus also intended to capture the concerns that have been expressed over the implications of entrepreneurs being absorbed into a resource sector. In this regard Sachs and Warner (2001, p. 837), sharing the standard negative view of entrepreneurs in the resource sector, comment that "to the extent that entrepreneurial talent is in limited supply, this will crowd out growth-promoting entrepreneurship of all kinds." In the present model "growth-promoting entrepreneurship" is not crowded out of the economy as a whole, but is rather re-directed from the non-resource sector into the resource sector.

The view of entrepreneurs in the resource sector presented here, in contrast to the dim view taken by most of the literature, is more consistent with the fact that the resource sector in resource-rich developing economies not only employs talented people, but is often far more technically advanced than the rest of the economy. Thus, for instance, the national oil companies Saudi Aramco and Brazil's Petrobras are recognised internationally as technology leaders. The sophisticated managerial and technical jobs in these firms are dominated by highly able nationals, who have found the oil sector to be more rewarding than other sectors of the economy and who have brought the technological level of their companies up to world standards. If these people were merely factors of production then their companies would not be any closer to the technological frontier than other domestic companies in these middle-income countries.

Thus I model technical change as depending on the number of entrepreneurs. The formal model follows Romer (1990) in that increases in technical change are proportional to the existing stock of knowledge. The implication is that, as in Romer (1990, p. S84), "unbounded growth is more like an assumption than a result of the model," but the point is to facilitate the analysis of the impact of resource wealth on the direction, and not the aggregate rate, of technical change.

In analysing the impact on factor incomes of a resource discovery - or to put it another way, the difference between a resource-rich economy and a resource-poor economy - I consider the case where households, also described as the (domestic) private sector, own labour and capital, while some other agents, such as the government and international mining companies, own the natural resource. Household primary (or market) income is thus due to wages and the return to capital only, and the impact of a resource discovery on private sector income works only through its knock-on effect on returns to these factors. To the extent that the government redistributes resoure revenues to households, resource rents may add to secondary (post-fisc) household income, and to the extent that the government spends revenues on public services, they may add to household utility. However, there are two reasons to distinguish between household primary income and income or services provided by the government.

First, considerable evidence suggests that some share of government resource revenues are spent on goods and services that do not benefit the population, so a dollar per capita of resource rent to the government is probably worth less to households than a dollar per capita of primary income. For instance, Gelb et al. (1988) and Collier and Gunning (1999) cite numerous examples of white elephant projects in which public money from resource booms has been squandered.

The second reason is that people's attitudes towards primary income and receipts from government are different, and this difference can be politically salient. A reduction in primary real income, such as through inflation, often induces political opposition even if it is accompanied by fiscal compensation. This is very clear in countries that have had large fuel subsidies, and have then tried to reduce them in order to lower the fiscal burden. In 1989 Venezuela raised fuel prices, sparking mass riots that resulted in the deaths of several hundred people. Today gasoline prices in Venezuela remain under 5 US cents per litre. In 1998 Indonesia increased fuel prices, leading to voilent public protests and the eventual downfall of the government.[2] Many governments around the world have found that price changes, including subsidies and their withdrawal, have a different political impact from other fiscally-equivalent policies.

So the analysis of the model is motivated partly by the question of when a resource discovery is good for citizens and the private sector. Does it improve household real income regardless of who owns the resource, and what is done with the revenues? Or is it only good for households when they get to enjoy some of the revenue directly, or at least its expenditures? I find that under some circumstances a resource discovery reduces private sector income in the long-run, relative to not having the resource, and under these circumstances the questions of who owns the resource, and how they spend the revenues, would seem particularly important.

In section 2 I present the static model, which is a standard three-factor, three-sector competitive trade model, augmented by the inclusion of entrepreneurs who sell machines in a monopolistically competitive market. Section 3 considers the impact of a resource discovery in this model, confirming that standard comparative static

[2] These examples, along with a range of issues surrounding fuel subsidies, are discussed in Bacon and Kojima (2006).

results apply. Section 4 then endogenizes directed technical change and analyses the impact of a resource discovery over time, comparing the dynamic effects with the static effects of the previous section. Section 5 concludes.

2 The static model

I start with a static model with three factors and three intermediate sectors. The sectors are resource exports (e.g. oil or other minerals) E, import-competing domestic output (e.g. agriculture and manufacturing) M, and non-traded services S, with output Y_Z in sector Z. There are three factors of production, labour L, capital K, and a natural resource R. Labour and capital are used in sectors M and S, while the natural resource R is used in sector E. By assuming that the resource sector does not employ labour or capital I am treating it as an 'enclave' sector (Sachs and Warner, 1995, make the same assumption). The effect in the model is to eliminate what Corden and Neary denote the 'resource movement' effect, in which the booming sector draws factors of production (the 'resources') out of the rest of the economy. It simplifies the analysis by restricting the effect of the resource boom to its effect on the real exchange rate. But it is also quite plausible. The assumption that labour is not employed in the natural resource sector is certainly close to the truth, reflecting the fact that even very large natural resource sectors typically employ only a tiny share of the labour force. With capital K interpreted as domestic capital, it is also reasonable to assume that domestic capital owners cannot invest in the resource sector.[3] One could also interpret K as any other factor of production not used in significant proportions by the resource sector.

Each sector Z also uses technology in the form of machines $x_Z(i)$ that embody technical progress. These machines are produced from the final good and thus comprise a reproducible, rather than scarce, type of capital. In each sector Z the level of technology is A_Z, where the range of available machines $x_Z(i)$ in each sector

[3] On the other hand, if the government is investing in the sector then government bonds held by domestic agents could be intrepreted as investments in the resource sector. See Corden and Neary (1982), Section III for a model where one of the mobile factors is shared with the resource sector (they interpret this factor as labour).

is defined by $i \in [0, A_Z]$. Factor and goods markets are competitive and take the A_Z's as given, but later I will introduce a monopolistically-competitive market for technology where the A_Z's will be endogenized.

The production functions are

$$\begin{aligned} Y_E &= \frac{R^{\alpha+\beta}}{1-\alpha-\beta} \int_0^{A_E} x_E(i)^{1-\alpha-\beta} \, di && (1) \\ Y_M &= \frac{L_M^{\alpha} K_M^{\beta}}{1-\alpha-\beta} \int_0^{A_M} x_M(i)^{1-\alpha-\beta} \, di && (2) \\ Y_S &= \frac{L_S^{\beta} K_S^{\alpha}}{1-\alpha-\beta} \int_0^{A_S} x_S(i)^{1-\alpha-\beta} \, di && (3) \end{aligned}$$

while full employment implies that

$$\begin{aligned} L_M + L_S &= L \\ K_M + K_S &= K. \end{aligned}$$

Output of the final good Y is a CES function of the nontradable good S and an aggregated tradable good T. The natural resource export is traded for imports, which have the same exogenous price p_T as domestic tradables. Units of the export are chosen so that the price of exports is also p_T.[4] Thus (I drop the time index for convenience)

$$Y = \left[\gamma Y_S^{\frac{\varepsilon-1}{\varepsilon}} + (1-\gamma) T^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (4)$$

where ε is the elasticity of substitution between tradables and non-tradables, and

$$T = Y_M + \tau Y_E. \quad (5)$$

I set the price of the final good as the numeraire, so[5]

$$\left[\gamma^{\varepsilon} p_S^{1-\varepsilon} + (1-\gamma)^{\varepsilon} p_T^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} = 1 \quad (6)$$

[4] I do not consider changes in the terms of trade, but a change in the relative price of the export is equivalent to an exogenous change in Hicks-neutral technical progress A_E, and could be modeled as such.

[5] This follows from the fact that prices are consistent with minimizing the cost of achieving a given C. Denoting the numeraire price p_C, the FOCs for the minimization are e.g. $p_C \frac{\partial C}{\partial Y_S} = p_S$. Thus $1 = p_C = p_S \div \frac{\partial C}{\partial Y_S} = p_T \div \frac{\partial C}{\partial T}$.

Product markets are competitive so demand for Y_S and Y_M implies that their relative price is

$$\frac{p_S}{p_T} = \frac{\gamma}{(1-\gamma)} \left(\frac{T}{Y_S} \right)^{1/\varepsilon}, \tag{7}$$

which is also the real exchange rate.

Factor returns are competitively determined and labour and capital are mobile between sectors M and S. With a wage of w, return to capital r, and a return ('rent') to the natural resource of v, factor returns are determined by the factor demand equations

$$w = p_T \frac{\alpha}{1-\alpha-\beta} L_M^{\alpha-1} K_M^{\beta} \int_0^{A_M} x_M(i)^{1-\alpha-\beta} \, di = p_S \frac{\beta}{1-\alpha-\beta} L_S^{\beta-1} K_S^{\alpha} \int_0^{A_S} x_S(i)^{1-\alpha-\beta} \, di \tag{8}$$

$$r = p_T \frac{\beta}{1-\alpha-\beta} L_M^{\alpha} K_M^{\beta-1} \int_0^{A_M} x_M(i)^{1-\alpha-\beta} \, di = p_S \frac{\alpha}{1-\alpha-\beta} L_S^{\beta} K_S^{\alpha-1} \int_0^{A_S} x_S(i)^{1-\alpha-\beta} \, di \tag{9}$$

$$v = p_T \frac{\alpha+\beta}{1-\alpha-\beta} R^{\alpha+\beta-1} \int_0^{A_E} x_E(i)^{1-\alpha-\beta} \, di. \tag{10}$$

Note that r is the return to non-reproducible capital, rather than the intertemporal return to investment.

Final goods producers buy machines in order to maximize profits, given factor returns and the price χ_Z of each machine in sector Z. The FOCs for this profit maximization produce machine demands

$$\begin{aligned}
x_E(i) &= \left(\frac{p_T}{\chi(i)_E} \right)^{\frac{1}{\alpha+\beta}} R \\
x_M(i) &= \left(\frac{p_T}{\chi(i)_M} L_M^{\alpha} K_M^{\beta} \right)^{\frac{1}{\alpha+\beta}} \\
x_S(i) &= \left(\frac{p_S}{\chi(i)_S} L_S^{\beta} K_S^{\alpha} \right)^{\frac{1}{\alpha+\beta}}.
\end{aligned}$$

The price $\chi(i)$ of machines is chosen by the entrepreneur. Assume it costs ψ to build a machine in any sector. Each entrepreneur sells machines at the monopoly price by maximizing profit subject to demand:

$$\max_{x_Z} x_Z (\chi_Z - \psi). \tag{11}$$

This implies

$$\chi_E = \chi_M = \chi_S = \frac{\psi}{(1-\alpha-\beta)}.$$

I follow Acemoglu (2002) in assuming that $\psi = 1-\alpha-\beta$. This loses some generality, but is harmless as long as we are not interested in what happens if ψ changes. Then the price of machines is equal to one in all sectors and for all i, with $\chi_E = \chi_M = \chi_S = 1$ in terms of the final good. Hence machine demand is

$$x_E = p_T^{\frac{1}{\alpha+\beta}} R \tag{12}$$

$$x_M = \left(p_T L_M^{\alpha} K_M^{\beta}\right)^{\frac{1}{\alpha+\beta}} \tag{13}$$

$$x_S = \left(p_S L_S^{\beta} K_S^{\alpha}\right)^{\frac{1}{\alpha+\beta}}. \tag{14}$$

I assume that machines fully depreciate each period. Substituting (12)-(14) into (1)-(3), the supply of output is

$$Y_E = \frac{A_E}{1-\alpha-\beta} p_T^{\frac{1-\alpha-\beta}{\alpha+\beta}} R \tag{15}$$

$$Y_M = \frac{A_M}{1-\alpha-\beta}\left(p_T^{1-\alpha-\beta} L_M^{\alpha} K_M^{\beta}\right)^{\frac{1}{\alpha+\beta}} \tag{16}$$

$$Y_S = \frac{A_S}{1-\alpha-\beta}\left(p_S^{1-\alpha-\beta} L_S^{\beta} K_S^{\alpha}\right)^{\frac{1}{\alpha+\beta}}. \tag{17}$$

Substituting (12)-(14) into (8)-(10), factor returns are

$$w = \frac{\alpha}{1-\alpha-\beta} A_M p_T^{\frac{1}{\alpha+\beta}} \left(\frac{K_M}{L_M}\right)^{\frac{\beta}{\alpha+\beta}} = \frac{\beta}{1-\alpha-\beta} A_S p_S^{\frac{1}{\alpha+\beta}} \left(\frac{K_S}{L_S}\right)^{\frac{\alpha}{\alpha+\beta}} \tag{18}$$

$$r = \frac{\beta}{1-\alpha-\beta} A_M p_T^{\frac{1}{\alpha+\beta}} \left(\frac{L_M}{K_M}\right)^{\frac{\alpha}{\alpha+\beta}} = \frac{\alpha}{1-\alpha-\beta} A_S p_S^{\frac{1}{\alpha+\beta}} \left(\frac{L_S}{K_S}\right)^{\frac{\beta}{\alpha+\beta}} \tag{19}$$

$$v = \frac{\alpha+\beta}{1-\alpha-\beta} A_E p_T^{\frac{1}{\alpha+\beta}}. \tag{20}$$

For later use, note that dividing equation (18) by (19) obtains

$$\frac{K_M}{L_M} = \left(\frac{\beta}{\alpha}\right)^2 \frac{K_S}{L_S}. \tag{21}$$

The static model is now complete and I consider comparative statics, asking what happens if a country discovers natural resources. That is, what is the effect of a rise in R? I first show that it leads to a rise in the real exchange rate p_S/p_T and then consider the impact on output and factor returns.

3 The static impact of a resource discovery

3.1 The real exchange rate

A rise in R increases income and hence aggregate demand, but has no impact on the supply function of S because the natural resource sector does not share any scarce factors of production with the rest of the economy. This implies that the real exchange rate p_S/p_T must rise. The argument can be made formally using duality theory, following Neary (1988). For now we take the prices of tradables, p_T and p_T, as fixed, dropping equation (6), which set the price of the final good as the numeraire. Let e be the expenditure function and g the revenue function, or GDP. Define the *trade expenditure function* as the *excess* of home expenditure e over income from home production g, i.e. the current account deficit (which we will set to zero). The only varying price is p_S so with representative utility u, factor endowments as above, and assuming current account balance, we have

$$E\left(p_S, u, R\right) = e\left(p_S, u\right) - g\left(p_S, R\right) = 0 \tag{22}$$

where I suppress other variables that are kept constant (p_T and p_T in both e and g, preference parameters in e, and production parameters and L and K in g).

Let V_p be the partial derivative of variable V with respect to p_S. Thus E_p is the excess demand for the non-traded good, and

$$E_p = e_p - g_p$$

where duality theory informs us that $e_p\left(p_S, u\right)$ is the utility-compensated or Hicksian demand function for Y_S, and $g_p\left(p_S\right)$ the supply function for Y_S. Thus e_{pp} is negative and g_{pp} is positive and we define $B \equiv -E_{pp} = g_{pp} - e_{pp}$, which is positive.

Market clearing implies that supply and demand for the non-traded S are equal, so

$$E_p\left(p_S, u, R\right) = 0. \tag{23}$$

Totally differentiate (22), using (23) and choosing units so that the price of one util, E_u, is equal to 1, to obtain

$$du = -E_R dR. \tag{24}$$

Now totally differentiating (23) and using (24) produces

$$dp_S = B^{-1} dR \left(E_{pR} - E_R E_{pu}\right). \tag{25}$$

We know that $g_{pu} = 0$ because g is not a function of u; $e_R = e_{pR} = 0$ because e is not a function of R; and $g_{pR} = 0$ because g_p, the supply of Y_S, is also not a function of R. This all implies that

$$\begin{aligned} E_{pR} - E_R E_{pu} &= e_{pR} - g_{pR} - \left(e_R - g_R\right)\left(e_{pu} - g_{pu}\right) \\ &= g_R e_{pu} > 0 \end{aligned}$$

so

$$dp_S = \Lambda dR$$

where $\Lambda = B^{-1} g_R e_{pu} > 0$. That is, a rise in R induces a rise in p_S and thus a rise in the real exchange rate p_S/p_T.

3.2 De-industrialization and factor returns

With no resource movement effect from the non-resource economy to the resource sector, the impact on Y_M, Y_S, w and r works solely through p_S/p_T which, we have just seen, rises. Sectors M and S comprise a two-sector, two-factor Hecksher-Ohlin model augmented by the inclusion of machines. Standard results apply with the rise in p_S/p_T inducing a rise in Y_S and a decline in Y_M as both labour and capital are drawn away from M and into S. Thus there is de-industrialization, or Dutch disease. However, the existence of machines in the model exacerbates this effect: the rise in p_S/p_T implies that relative to the price of machines (bringing equation (6) back into the picture), p_T falls and p_S rises. Thus, through the terms in p_T and p_S in the production functions (16) and (17), fewer machines are employed in Y_S and more in Y_M so the use of machines amplifies the impact on output in both sectors.

Turning to factor returns, the Stolper-Samuelson theorem tells us that the return to the factor used intensively by S rises by more than p_S, and thus enjoys a real increase, while the return to the other factor falls nominally and therefore also in real terms.[6]

As discussed earlier, however, the total aggregate of non-resource real income is also of interest as the primary (pre-fisc) income of households, or the private sector. So consider the non-resource economy, comprising households that own labour and capital and produce Y_M and Y_S, and assume that the government or a small number of private agents owns the natural resource. Then $wL + rK$ accrues to households while vR accrues to the resource owner. What is the effect of a resource discovery on the real primary income of households?

We can consider the non-resource economy, i.e. households, and the resource owner as two economies trading with one another, with households 'exporting' Y_S to the resource sector. Then the rise in the real exchange rate represents an improvement in the terms of trade for households, and therefore a rise in utility. I show this using the same form of argument as above, now taking E^N to be the trade expenditure function of the non-resource economy, with e^N and g^N the expenditure and revenue functions. Then g^N is not a function of R so

$$E^N(p_S, u) = e^N(p_S, u) - g^N(p_S),$$

where again I suppress other parameters that are kept constant.

[6] The classic analysis of Jones (1965) applies. The existence of machines in production implies a minor change in the price-cost equations, which does not affect the directions of change. With a_{ij} the unit requirement of factor i in sector j, labour and capital costs are related to prices as

$$wa_{Lj} + ra_{Kj} = (\alpha + \beta) p_j.$$

The remainder, $(1 - \alpha - \beta) p_j$, accrues to entrepreneurs.

Now current account balance means trade balance between the non-resource economy and the resource owner, so

$$E^N(p_S, u) = 0. \tag{26}$$

Above we also had $E_p = 0$ because the non-tradability of Y_S implied domestic demand equalled domestic supply. Now Y_S is 'exported' to the resource owner so

$$E_p^N(p_S, u) = e_p^N(p_S, u) - g_p^N(p_S) < 0. \tag{27}$$

Now when we totally differentiate E^N we find

$$du = -dp_S E_p^N > 0, \tag{28}$$

so $\frac{du}{dp_S} > 0$ and the rise in p_S causes a rise in the utility, or real income, of households.

4 Endogenizing directed technical change

The above demonstrates that standard results in static trade theory hold in the model. Thus a resource boom implies a rise in the real exchange rate, a rise in non-resource factor income, and deindustrialization. I now turn to the dynamic analysis to see how these outcomes are affected by directed technical change over time.

I assume that technology adoption in each sector Z is proportional to the number of entrepreneurs N_Z in the sector, while the total exogenous stock of entrepreneurs is N. Assuming that steady state growth is possible requires that technical change also be proportional to the level of technology in the sector, so current entrepreneurs stand on the shoulders of their predecessors. Thus

$$\begin{aligned} \dot{A}_E &= \eta_E A_E N_E \\ \dot{A}_M &= \eta_M A_M N_M \\ \dot{A}_S &= \eta_S A_S N_S \\ N_E + N_D + N_S &= N \end{aligned}$$

where η_Z is the inverse of the cost of an innovation in sector Z, so that one entrepreneur in sector Z generates $\eta_Z A_Z$ new varieties of machine.

The entrepreneur's maximization in equation (11) implies profits π in the different sectors of

$$\begin{aligned}
\pi_E &= (\alpha+\beta)\, p_T^{\frac{1}{\alpha+\beta}} R \\
\pi_M &= (\alpha+\beta)\left(p_T L_M^{\alpha} K_M^{\beta}\right)^{\frac{1}{\alpha+\beta}} \\
\pi_S &= (\alpha+\beta)\left(p_S L_S^{\beta} K_S^{\alpha}\right)^{\frac{1}{\alpha+\beta}}.
\end{aligned}$$

For technology adoption to take place in all sectors requires that it be equally profitable to enter any sector, so $\eta_E A_E \pi_E = \eta_M A_M \pi_M = \eta_S A_S \pi_S$. Observe that from (15)-(17), profit π_Z is proportional to $\frac{p_Z Y_Z}{A_Z}$. Thus the technology market clearing condition is

$$\eta_E p_T Y_E = \eta_M p_T Y_M = \eta_S p_S Y_S. \tag{29}$$

When this condition holds we have can steady state growth in which each sector grows at the same rate and relative output, relative prices and relative factor returns are constant.

What is the growth rate? On a balanced growth path with growth rate h we have

$$\frac{\dot{A}_E}{A_E} = \frac{\dot{A}_M}{A_M} = \frac{\dot{A}_S}{A_S}$$

so

$$\eta_E N_E = \eta_M N_M = \eta_S N_S,$$

from which it follows that for each sector Z,

$$N_Z = \frac{N}{\eta_Z} \frac{\eta_E \eta_M \eta_S}{\eta_E \eta_M + \eta_E \eta_S + \eta_M \eta_S}.$$

Hence

$$h = N \frac{\eta_E \eta_M \eta_S}{\eta_E \eta_M + \eta_E \eta_S + \eta_M \eta_S},$$

so the growth rate is proportional to the number of entrepreneurs. The growth rate is therefore exogenous, though the sectoral allocation of technical change is not.

Below we will see that the balanced equilibrium above is not stable, and that stable equilibria can involve technical change in only one of the two traded sectors E and M. Then if the economy is in equilibrium with growth in A_S and A_Z for $Z = E$ or M, and no growth in the other tradable sector, then the number of entrepreneurs in each of the two growing sectors will be

$$N_S' = N\frac{\eta_Z}{\eta_Z + \eta_S} \qquad N_Z' = N\frac{\eta_S}{\eta_Z + \eta_S}$$

and the growth rate in each of the two growing sectors will be

$$h' = N\frac{\eta_Z \eta_S}{\eta_Z + \eta_S} > h.$$

As the other traded sector diminishes as a share of total output the aggregate growth rate asymptotes to h', so the economy grows at a faster rate than in the three-sector equilibrium.

4.1 Stability

We can now establish when the dynamic equilibrium between sectors is stable, using (29). In order to do so, define σ_Z as the elasticity of substitution between Y_S and Y_Z, for $Z = E$ or M. First I present the following lemma.

Lemma 1 *Let σ_Z be the elasticity of substitution between Y_S and Y_Z for $Z = E$ or M. Then (i) σ_Z is a decreasing function of Y_Z/T , (ii) $\sigma(Y_Z/T) \geq \varepsilon$, and (iii) $\sigma_Z \to \varepsilon$ as $Y_Z \to T$ and $\sigma_Z \to \infty$ as $Y_Z \to 0$.*

Proof. The elasticity of substitution between Y_S and aggregated tradables T is ε. From the definitions of σ_Z and ε,

$$\begin{aligned}
\sigma_Z &\equiv -\frac{\partial\left(Y_S/Y_Z\right)}{\partial\left(p_S/p_Z\right)}\frac{p_S/p_T}{Y_S/Y_Z} \\
\ln\sigma_Z &= \ln\frac{\partial Y_S}{Y_S}-\ln\frac{\partial Y_Z}{Y_Z}+\ln\frac{\partial p_T}{p_T}-\ln\frac{\partial p_S}{p_S} \\
&= \ln\varepsilon+\ln\frac{\partial T}{T}-\ln\frac{\partial Y_Z}{Y_Z} \\
&= \ln\varepsilon+\ln\frac{\partial T/\partial Y_Z}{T/Y_Z}
\end{aligned}$$

where $\ln\frac{\partial T/\partial Y_Z}{T/Y_Z}$ is the elasticity of T with respect to Y_Z and is greater than one, since the other tradable good $T-Y_Z$ is held constant (a 1% rise in T requires a more-than 1% rise in Y_Z if $T>Y_Z$). Then $\ln\frac{\partial T/\partial Y_Z}{T/Y_Z}$ is a decreasing function of Y_Z/T (bounded below at zero) so $\sigma_Z\left(\frac{Y_Z}{T}\right)$ is decreasing in Y_Z/T. As $Y_Z\to T$ then $\ln\frac{\partial T/\partial Y_Z}{T/Y_Z}\to 0$ so $\sigma_Z\to\varepsilon$. Conversely, as $Y_Z\to 0$, $\ln\frac{\partial T/\partial Y_Z}{T/Y_Z}\to\infty$ so $\sigma_Z\to\infty$. ∎

The intuition is as follows, taking the example of σ_M. If p_S/p_T rises by 1% then we know that Y_S/T falls by ε%. Then we ask: with fixed Y_E, how much does Y_M have to rise to achieve this ε% fall in Y_S/T? If $Y_E=0$, so $T=Y_M$, then it requires an ε% rise in Y_M/Y_S. But the smaller is Y_M relative to T, the larger the proportional rise in Y_M that is required to raise T by ε% and hence the larger is $\sigma_M\left(Y_M/T\right)$.

With this established, I now prove the following proposition (again, $Z=E$ or M).

Proposition 1 *(i) In a stable equilibrium only one of A_E and A_M can be growing.*

(ii) If $\sigma_Z<1$ then equilibrium between A_S and A_Z is stable.

(iii) If $\varepsilon\geq 1$ then equilibrium between A_S and A_Z is unstable.

(iv) If $\sigma_Z\geq 1$ and $\varepsilon<1$ then in the long run the equilibrium between A_S and A_Z is unstable only in one direction, namely if A_S is growing and A_Z stagnates. The system does return to equilibrium if A_Z is growing and A_S is stagnating.

Proof. (i) Consider stability between A_E and A_M. Suppose that there is technical progress in E and not in M, with[7]

$$\frac{Y_E}{Y_M} > \frac{\eta_M}{\eta_E}. \tag{30}$$

The right hand side of (30) is constant, so stability requires that the left hand side declines in order to move back to equilibrium. In fact, the left hand side rises, because the rise in A_E raises Y_E. This exacerbates the inequality, moving the economy further away from equilibrium. The same argument applies for the converse case in which the inequality in (30) is reversed and A_M rises.[8] Thus any stable equilibria will involve technical progress in only one of the two tradable sectors.

(ii) Now consider disequilibrium between A_S and A_Z, with $Z = E$ or M. Suppose that A_S is growing and A_Z is constant, so

$$\frac{Y_S}{Y_Z} > \frac{\eta_Z p_Z}{\eta_S p_S}. \tag{31}$$

Y_S/Y_Z rises as A_S rises, and the equilibrium is stable if and only if p_Z/p_S rises faster. This depends on the elasticity of substitution between Y_S and Y_Z, σ_Z, which by definition is the rate of change of Y_S/Y_Z with respect to p_S/p_Z. If $\sigma_Z < 1$ then p_Z/p_S rises faster than Y_S/Y_Z, so the equilibrium is stable.

(iii) If $\varepsilon \geq 1$ then Lemma 1 implies that $\sigma_Z \geq 1$. Thus in (31) p_Z/p_S rises no faster than Y_S/Y_Z, so the system does not return to equilibrium and is therefore unstable.

(iv) Suppose $\sigma_Z \geq 1$ but $\varepsilon < 1$. If A_S is growing and A_Z stagnates as in (31), then p_Z/p_S rises no faster than Y_S/Y_Z, so the system does not return to equilibrium and is unstable. However, suppose the converse of (31) holds, so A_Z is growing while A_S stagnates. Then Y_Z grows in relation to T (we have already seen that the other

[7]Thus we assume that $\eta_E p_T Y_E \geq \eta_S p_S Y_S$ so that there is technical progress in E and may or may not be in S.

[8]In both cases there is also a real exchange rate effect: the rise in output of tradables causes the real exchange rate p_S/p_T to rise, and this draws factors out of Y_M and into Y_S, reducing Y_M. This exacerbates the instability in the case of growing A_E. If A_M is growing then it slows down the instability, but it cannot reverse it because the real exchange rate effect occurs only to the extent that Y_M is indeed rising.

traded good will be stagnating), and by Lemma 1 σ_Z therefore declines towards ε. Eventually σ_Z will fall below one, and then the system will start to return to equilibrium. In the long run it is therefore stable. ■

Stability thus depends primarily on the elasticity of substitution between tradables and non-tradables, ε, being less than one. A small number of empirical studies have estimated this ε for a range of countries. A series of studies by the Inter-American Development Bank estimate it for four Latin American countries: Argentina, Bolivia, Costa Rica and Uruguay (respectively González Rozada et al., 2004, Barja Daza et al., 2005, Arce and Robles, 2004, and Lorenzo et al., 2005). For Argentina, Bolivia and Uruguay, all estimates are less than one, lying between 0.40 and 0.75. In Costa Rica it is found to be substantially below one in annual data (in the interval (0.22, 0.28)), but greater than one in quarterly data (in the interval (1.46,2.14)). Cashin and McDermott (2003) estimate it for the five developed countries Australia, Canada, New Zealand, UK and US. It is significantly above one at the 5% level for Australia and Canada, and at the 10% level for the UK. The estimate for the US is not statistically different from zero owing to large standard errors, and the estimate for New Zealand is significantly below one and above zero. Thus within this small group of studies most estimates for developing countries put ε below one, but several estimates for developed countries put it above one. If one considers tradables as dominated by agriculture and manufactures, while non-tradables include housing, transport, and haircuts, it would appear intuitive that the two sectors have a low degree of substitutability, but the data do not appear to be consistent across countries on the question.

4.2 The dynamic impact of a resource discovery

The above section showed that there is no stable equilibrium between the two traded sectors E and M, and that the existence of a stable equilibrium between non-traded S and one of E and M requires that $\varepsilon < 1$. So in order to analyse the impact of a resource discovery - or alternatively, the difference between a resource-poor and resource-rich economy - consider the case of a country starting out with a small natural resource sector relative to other tradables, and in a stable equilibrium with Y_M and Y_S growing at rate h', and with no growth in Y_E. Thus $\varepsilon < 1$ and $\sigma_M < 1$, and $\eta_M p_T Y_M = \eta_S p_S Y$. Now imagine that the country discovers a large enough stock of natural resources that $\eta_E p_T Y_E > \eta_M p_T Y_M = \eta_S p_S Y_S$. Then all entrepreneurs will migrate out of sectors M and S and into sector E. What are the dynamics of the economy following the resource discovery?

As implied by Proposition 1 (ii) and (iv), the economy will end up in a stable equilibrium with $\eta_E p_T Y_E = \eta_S p_S Y_S$, with both Y_E and Y_S growing at rate h', and Y_M stagnating. To recap, the two cases are $\sigma_E < 1$ and $\sigma_E \geq 1$. If the resource discovery is large enough, then Y_E/T will be large enough that $\sigma_E < 1$ (since, recall, large Y_E/T implies that σ_E is close to ε). Then the entrepreneurs in E raise A_E and thus raise $\eta_E p_T Y_E$, but the effect on the real exchange rate will raise $\eta_S p_S Y_S$ at a faster rate, moving the economy towards the new stable equilibrium. If the resource discovery is not this large and $\sigma_E > 1$, then at first $\eta_E p_T Y_E$ will rise faster than $\eta_S p_S Y_S$ and the economy will move further away from equilibrium. But over time Y_E will tend to T and σ_E will tend to $\varepsilon < 1$. When σ_E falls below one then $\eta_S p_S Y_S$ will start to rise faster than $\eta_E p_T Y_E$, and the economy will again converge to the same stable equilibrium with $\eta_E p_T Y_E = \eta_S p_S Y_S$.

Thus Y_S grows at the same rate in the old and new equilibria, but in the old equilibrium Y_M grew while Y_E stagnated, and in the new equilibrium Y_E grows while Y_M stagnates. The implications for output are summarized in the following proposition.

Proposition 2 *An economy that starts out in a stable equilibrium with Y_M and Y_S growing at rate h' and no growth in Y_E, which then discovers a stock of natural resources large enough to move entrepreneurs into sector E, will end up in a stable equilibrium with Y_E and Y_S growing at rate h', and no growth in Y_M.*

This proposition immediately implies the following corollary.

Corollary 1 *A resource discovery as in Proposition 2 causes dynamic de-industrialization in the sense that output of import-competing tradables Y_M declines over time as a share of GDP, with the share tending to zero.*

This dynamic de-industrialization reinforces the static de-industrialization discussed above. The static effect is that the resource discovery immediately draws factors of production out of Y_M and into Y_S, reducing the level of output of Y_M. The dynamic effect is to draw entrepreneurs out of Y_M and into Y_E, bringing a halt to technical progress and thus growth in Y_M.

4.2.1 The dynamic effect on factor incomes

The effect of the resource discovery on the real income of resource owners is obviously positive, as growth in A_E raises the productivity of natural resources. More interesting is the effect on the real income (or utility) of the non-resource sector, i.e. households. To establish this effect I analyse the impact on household real income of a rise in each of the A_Z's for $Z = E$, M or S. It is useful first to confirm the following lemma.

Lemma 2 $\frac{dp_S}{dA_E} > 0$, $\frac{dp_S}{dA_M} > 0$, *and* $\frac{dp_S}{dA_S} < 0$.

Proof. A rise in A_E has the same effect as a rise in R, so to show that $\frac{dp_S}{dA_E} > 0$ we can apply a parallel argument to that of Section 3.1. I show by contradiction that $\frac{dp_S}{dA_M} > 0$. Suppose A_M rises, but p_S does not rise. Then from (18) either (A) K_M/L_M has to fall or (B) K_S/L_S has to rise to maintain equal wages across sectors. From (19), either (C) K_M/L_M has to rise, or (D) K_S/L_S has to fall. (A) and (C) are contradictory and (B) and (D) are contradictory, so we need either (A) and (D), or (B) and (C). But from (21), K_M/L_M is proportional to K_S/L_S so they rise or fall together, giving us a contradiction. The converse argument shows that $\frac{dp_S}{dA_S} < 0$. ■

Now we consider the change in household utility du under changes in each of the A_Z's. Define Δ_Z as the change in household utility due to the growth in A_Z created by one entrepreneur in sector Z for one period, where Z is now any sector. Again consider households and the resource owner as two economies trading with one another, with households 'exporting' Y_S to the resource sector, and both producing and importing Y_M. So E^N is the trade expenditure function of the households, with e^N and g^N its expenditure and revenue functions. Then

$$E^N(p_S, u, A_M, A_S) = e^N(p_S, u) - g^N(p_S, A_M, A_S),$$

where again I suppress other parameters that are kept constant. As before we have

$$\begin{aligned} E^N(p_S, u, A_M, A_S) &= 0 \quad (32) \\ E_p^N(p_S, u, A_M, A_S) &= e_p^N(p_S, u) - g_p^N(p_S, A_M, A_S) \equiv -H < 0 \quad (33) \end{aligned}$$

where H is 'exports' of services to the resource sector and is positive.

First consider Δ_E. Totally differentiate E^N with respect to A_M (again setting $E_u^N = 1$) to find

$$\Delta_E = du = dp_S H. \quad (34)$$

Since $\frac{dp_S}{dA_E} > 0$, $\Delta_E > 0$ because the rise in p_S raises the real exchange rate and thus the internal terms of trade for households. This dynamic real exchange rate effect is the counterpart to the static real exchange rate effect of a rise in R, discussed in Section 3.2.

Now consider Δ_M, the rise in household utility due to a rise in A_M:

$$\Delta_M = du = dA_M g_{A_M}^N + dp_s H. \quad (35)$$

With $H > 0$ and $dp_S > 0$, both terms on the right hand side imply a utility gain so $\Delta_M > 0$. The first term represents the output effect, or the utility gain due to the rise in output of the non-resource sector caused by the rise in A_M. The second term represents the dynamic real exchange rate effect as p_S rises: just as occured for Δ_E, a rise in output of tradables increases demand for Y_S and therefore raises the real exchange rate.

Turning to Δ_S,

$$\Delta_S = du = dA_S g_{A_S}^N + dp_s H. \quad (36)$$

With $dp_S < 0$ in this case (Lemma 2), the sign of Δ_S depends on whether $dA_M g_{A_S}^N > dp_s H$.

I now determine the dynamic effect on household incomes of the resource discovery described above. For the resource discovery to attract entrepreneurs into sector E it must be large enough that

$$\eta_E Y_E > \eta_M Y_M. \tag{37}$$

As we saw above, the long run effect is for entrepreneurs to switch out of sector M and into sector E. In the long run, therefore, the effect on household income is determined by the comparison of Δ_E and Δ_M.

First I quantify the effect of A_E and A_M on p_S, by totally differentiating the economy-wide E_p from equation (23) and using (34) and (35). Changes in A_E and A_M imply changes in p_S of

$$dA_E \frac{dp_S}{dA_E} = dp_S = B^{-1} dA_E g_{A_E} e_{pu} > 0 \tag{38}$$

$$dA_M \frac{dp_S}{dA_M} = dp_S = B^{-1} \frac{dA_M g^N_{A_M} e_{pu} - g_{pA_M}}{1 - e_{pu} H B^{-1}} > 0, \tag{39}$$

both of which are positive by Lemma 2. Equation (39) contains the term g_{pA_M}, which is the marginal change in supply of Y_S due to a change in A_M, holding prices constant, and is therefore negative.[9] Both H and B were defined above as positive, and e_{pu} is the marginal propensity to consume Y_S associated with a rise in utility and is therefore also positive.[10] Thus while a rise in A_E raises p_S only by raising demand, a rise in A_M raises p_S both through this demand effect and through a reduction in the supply of Y_S.

[9] This can be seen diagrammatically from the production possibility frontier between Y_M and Y_S: a rise in A_M shifts the PPF out in the direction of Y_M, so the constant price line is tangent with the new PPF at higher Y_M and lower Y_S. Formally this can be seen from the factor return equations for labour and capital by setting $F_Z(L_Z, K_Z) \equiv Y_Z/A_Z$: $w = p_S A_S \frac{\partial F_S}{\partial L_S} = p_T A_M \frac{\partial F_M}{\partial L_M}$ and $r = p_S A_S \frac{\partial F_S}{\partial K_S} = p_T A_M \frac{\partial F_M}{\partial K_M}$. Then a rise in A_M with constant prices requires both L_S and K_S to fall, so Y_S falls.

[10] Choosing utility units so that the marginal price of one util is 1, i.e. $e_u = 1$ as assumed earlier in section 3.1, implies that e_{pu} is the marginal propensity to consume Y_S out of income, which is positive.

Note that $dA_Z g^N_{A_Z}$ is the marginal product of an extra entrepreneur in sector Z, and from the envelope theorem $dA_Z g^N_{A_Z} = \eta_Z p_Z Y_Z$.[11] Then using (38) and (39) to substitute for dp_S in (35) and (36),

$$\Delta_E = e_{pu} HB^{-1} \eta_E p_T Y_E \quad (40)$$

$$\Delta_M = \frac{\eta_M p_T Y_M - HB^{-1} g_{pA_M}}{1 - e_{pu} HB^{-1}} \quad (41)$$

where, recall, $g_{pA_M} < 0$. As we saw, both a rise in A_E and a rise in A_M cause an improvement in the non-resource sector's internal terms of trade - the real exchange rate effect - and thus a rise in real household income. But the rise in A_M has the additional effect of increasing the output of the non-resource sector, while the rise in A_E has no such effect (or rather, this effect is enjoyed by the resource sector instead).

Thus for households to be better off in the long run with the resource discovery, the discovery has to be large enough that each entrepreneur moving from M to E induces a large enough real exchange rate effect to outweigh both the lost real exchange rate effect due to A_M, and the lost output effect due to A_M. In particular, from (40) and (41) it requires that

$$\eta_E p_T Y_E > \frac{\eta_M p_T Y_M - HB^{-1} g_{pA_M}}{e_{pu} HB^{-1} \left(1 - e_{pu} HB^{-1}\right)}. \quad (42)$$

This condition is more than four times as strong as (37): $-HB^{-1} g_{pA_M} > 0$ and the denominator is positive (since equation (39) implies that $1 - e_{pu} HB^{-1} > 0$) but, since the denominator is of the form $x(1-x)$, the maximum value it can take is $1/4$, when $e_{pu} HB^{-1} = 1/2$.

[11] Define $V_Z = (L_Z, K_Z)$ and let Y^*_M, Y^*_S be the solutions to the maximization of g^N. Taking the example of $g^N_{A_M}$,

$$\begin{aligned} g^N_{A_M} &= \frac{\partial \left(p_T Y^*_M (A_M, V_M) + p_S Y^*_S (A_S, V_S)\right)}{\partial A_M} \\ &= p_T \frac{\partial Y^*_M}{\partial A_M} + p_T \frac{\partial Y^*_M}{\partial V_M} \frac{\partial V_M}{\partial A_M} + p_S \frac{\partial Y^*_S}{\partial V_S} \frac{\partial V_S}{\partial A_M} \\ &= \frac{p_T Y^*_M}{A_M} \end{aligned}$$

where $p_T \frac{\partial Y^*_M}{\partial V_M} \frac{\partial V_M}{\partial A_M} + p_S \frac{\partial Y^*_S}{\partial V_S} \frac{\partial V_S}{\partial A_M} = 0$ by the envelope theorem, and $\frac{\partial Y^*_M}{\partial A_M} = \frac{Y^*_M}{A_M}$ when we hold V_M constant.

Thus a resource discovery that does not make households worse off has to be more than four times as large as a resource discovery that is just large enough to attract entrepreneurs out of other sectors. Putting together (37) and (42), households are made worse off in the long run when

$$\frac{\eta_M p_T Y_M - HB^{-1} g_{pA_M}}{e_{pu} HB^{-1} \left(1 - HB^{-1} e_{pu}\right)} > \eta_E p_T Y_E > \eta_M p_T Y_M. \tag{43}$$

It should be noted that the rise in R also produces the static rise in household real income analysed in the previous section, but over time this will be swamped by dynamic effects. This discussion yields the following proposition.

Proposition 3 *A resource boom that is big enough to attract entrepreneurs into the resource sector will lead to higher growth in household incomes in the long run only if the boom is big enough to satisfy (42), which represents a threshold more than four times as large as the threshold for a resource discovery to attract entrepreneurs into the resource sector. If it is not this large and instead satisfies (43), then the resource boom will cause household incomes to grow more slowly.*

5 Conclusion

The natural resource sector, including the upstream energy sector, is one of the most technologically advanced in the global economy. In resource-rich developing countries it also offers entrepreneurial individuals better opportunities than are available in other sectors of the economy. In contrast to existing discussions of entrepreneurs in the natural resource sector, this paper suggested that these individuals may be just as productive in the resource sector as in other parts of the economy.

However, by interpreting entrepreneurs as drivers of technological progress the model showed that a resource discovery may bring a halt to growth in the non-resource economy by attracting the limited stock of entrepreneurs into the resource sector. In equilibrium, growth returns to the non-traded sector, but the non-resource tradable sector (including manufacturing) ceases to grow. Thus over time the dynamic effect of the resource discovery is to exacerbate the static de-industrialization found in this and other trade theory models.

In analysing factor returns I assumed that households, or the private sector, own labour and capital, while resource revenues accrue to the government. I then considered the impact of a resource discovery on household primary income. As in standard trade theoretic models, the static effect of the resource discovery is to raise the real exchange rate and thereby raise household real incomes. Dynamically, entrepreneurs in the resource sector cause this real exchange rate effect to grow over time as technological progress in the sector increases its output. However, entrepreneurs in the manufacturing sector also produce a real exchange rate effect over time, but have an additional positive effect on household incomes by increasing household output of manufactures. A resource discovery that attracts entrepreneurs out of manufacturing therefore lowers the growth rate of household incomes, unless the resource sector is large enough for its real exchange rate effect to outweigh both the real exchange rate effect, and the output effect, of the manufacturing sector.

The model therefore illustrates that the dynamic impact of a resource discovery may be somewhat different from its static impact. Even if entrepreneurs are productive in their chosen sector, their movement out of non-resource tradables and into the resource sector will have distributional implications. Households in resource-rich economies may find their primary incomes growing more slowly than in other economies, making the question of who receives resource revenues, and how they are spent, all the more important.

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