TRADE, GROWTH AND INCREASING RETURNS TO INFRASTRUCTURE : THE ROLE OF THE SOPHISTICATED MONOPOLIST

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1. Introduction

What factors determine whether a country becomes an industrial exporter, or remains primarily agrarian? Even within the subset of industrial exporters, can non-policy factors influence the extent of trade, potentially driving apart economies with similar underlying parameters? In this paper, we hope to shed light on these issues by examining a model of trade which synthesizes increasing returns in the non-traded input to industry – "infrastructure"- with an analysis of how the effect of openness varies drastically depending on whether the infrastructure provider(s) act like Level-1 "naïve" agents in cognitive hierarchy (C-H) models, or in a more sophisticated manner. Thus we use a somewhat unorthodox angle to deliver new insights on the role of trade as an engine of structural transformation in the presence of scale economies.

Guha (1981) showed how economies of scale in manufacturing may, in the presence of transport costs, create insuperable barriers to the industrialization of a poor economy. Producers located in the poor country cannot achieve economies of scale on the basis of domestic demand; and, if they seek to do so by export, they run into high distribution costs. They are unable therefore to compete with rivals based in rich markets abroad and may not even be able to hold their own at home.

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However, if scale economies are sufficiently strong, multiple equilibria may emerge: a Great Leap Forward in industrialization may then justify itself in the world market, a possibility that a closed economy would have precluded.

All this, of course, echoes a familiar theme in development literature, dating back at least to the poverty traps of Rosenstein Rodan (1943) or even earlier, to Allyn Young (1928), a theme that has been revived more recently by Murphy et al (1987). While Murphy et al looked at scale economies and multiple equilibria in a closed economy, later literature dealt with openness as well. The decade of the nineties has seen contributions from Krugman (1991), Rodriguez-Clare (1996), Venables (1996), Duranton (1998) and Puga and Venables (1999) among others. Krugman (1991) has rigorously modeled a similar theme in terms of the multiple equilibria of a general equilibrium system with competitive agriculture and monopolistically competitive manufactures producing differentiated products (which enter into Dixit-Stiglitz consumer utility functions) under increasing returns. Krugman assumes perfect mobility of industrial labor between the different markets. Puga and Venables (1999) retain the traditional trade theory assumption of labor immobility: further, their differentiated manufactures are not just final consumer goods which enter utility functions but also intermediates that enter CES production functions for each other *a la* Ethier (1982). In both these models, food is perfectly mobile and all produced goods are tradable (though with iceberg transport costs).

We depart from product differentiation as a source of increasing returns to scale, and choose instead to focus on the role of infrastructural inputs to industry. Thus we deal with a variety of scale economies that is very important in the less developed world : infrastructural economies associated with power plants, roads, railways, communication networks etc. We also do not use the Ethier production function. Our choice reflects the fact that in the Ethier production function increasing returns stem from an increase in the number of intermediates - all close substitutes of each other - in actual use (as against the number available). It is not clear why a large number of closely substitutable inputs should be simultaneously employed. Moreover, infrastructural intermediates are mostly mutually non-substitutable as well as non-tradable.

Manufacturing dominated by such infrastructural factors is characterized by scale economies that are external to the firm but internal to the manufacturing sector as a whole. The final product industries in such a system could well be competitive; and there is a long tradition in international trade literature from R. C. O. Matthews (1950) to Herberg and Kemp (1969) to Panagariya (1981) (MHKP) of competitive general equilibrium models with an increasing return industry. A problem with most of these constructs arises from the fact that the source of increasing returns is never explicitly modeled. In the real world, external economies in manufacturing may arise from two sources – (1) through irreversible learning processes *a la* Arrow (eg. the growth through learning-by-doing of a skilled labor force or the cross-fertilization of research), (2) the fall in prices of intermediate inputs as supplier industries grow and realize internal economies of scale. The MHKP models are static with reversible scale economies: they cannot accommodate learning by doing. Nor do they have room for a third intermediate sector which uses resources under internal economies of scale. Thus the external economies in these models appear out of nowhere like manna from heaven. This has the advantage that competitive assumptions can be applied to the whole economy and production equilibrium necessarily occurs on the production possibility curve (rather than inside it) – but it detracts severely from realism. In contrast, we explicitly model an infrastructural sector with internal economies of scale, capable of generating pecuniary externalities in manufacturing. We model two possible market forms for this sector – monopoly and Cournot oligopoly.

Some papers in the literature have indeed attempted to introduce an intermediate good responsible for external economies in a final goods sector. These include Venables (1996) in which the relevant intermediate is a tradable input, and Okuno-Fujiwara (1988) in which the intermediate is not traded. Interestingly, our findings depart from these, as well as from other papers dealing with increasing returns, in several key aspects. In spite of the presence of increasing returns, we find that the closed economy equilibrium is *unique*. This contrasts with the findings of others. We also find that opening up the economy may give rise to multiple equilibria if the infrastructure provider is "naïve" (in a manner to be clarified shortly) but unlike Okuno-Fujiwara, these equilibria need not involve complete specialization. Some of these multiple equilibria may involve manufactures being exported even if the world price of manufactures is lower than the autarky price. For some parameter ranges, there can only be a unique, purely agrarian, equilibrium. If the infrastructure provider(s) is (are) "sophisticated", however, not behaving in accordance with Level 1 reasoning in C-H models, we find a unique open economy equilibrium, which, for a wide range of parameter values, involves more industrialization than do any of the "naïve" equilibria. Moreover, to our knowledge, none of the other papers have attempted to model the infrastructure provider as a monopolist operating a natural monopoly. Our focus on the extent of rationality and on equilibrium versus cognitive hierarchy type reasoning by the infrastructure provider(s) is also not a feature of these other models.

This brings us to another strand of the literature relevant to our paper. A recent body of literature has developed "cognitive hierarchy" models. Some examples include Camerer, Ho and Chong (2004), Crawford (2004) and Crawford and Iriberri (2005). These papers argue that agents do not always reason the way equilibrium models posit they do. They instead form an often simplistic assumption about the behavior of other players, and play their best response given this assumption. They categorize agents according to "levels" where a "Level-k" agent assumes that other agents are at the level k-1 and plays his best response to type k-1. A "level zero" agent either behaves "randomly" or follows a (non-optimizing) rule while a "Level 1" agent in these models optimizes assuming that other agents are level zero. The rationale underlying these models is that experimental evidence has shown that most agents do not reason in the complex and sophisticated manner suggested by equilibrium analysis[1]. In our paper, we adapt ideas from this body of work to incorporate them into our particular context.

Before going on to our model, we briefly discuss our modeling of infrastructure. In the literature, infrastructure has been modeled in two distinct ways. In the older tradition of Arrow – Kurz (1970) and Barro (1990), it is visualized as an input in the production process, an input that could be either appropriable or non-appropriable. More recently, Martin and Rogers (1995) have examined it as the determinant of the proportion of output that evaporates before reaching the consumer; in their formulation, it is essentially a public good supplied by the state. Infrastructure is indeed heterogeneous in the extreme, ranging from electricity on the one hand to the legal and administrative machinery on the other. Our focus however is on infrastructural services as private goods; we wish to examine the part they play in the frequent failure of market processes to generate growth without assuming the problem away by assigning an indispensable role to the state in their provision. We revert therefore to the Arrow-Barro tradition in which infrastructural services enter the production function. We assume in addition that they are private goods: the basic model is that of electricity, frequently identified in many poor countries (such as India) as the critical bottleneck on growth. This does not mean that they are necessarily provided by the private sector; indeed, in a later section, we compare public supply of infrastructural services with private monopoly.

What are the distinctive implications of infrastructure in such a context? We stress two.

First, infrastructure requires fixed investment, which occurs only if the rate of return on this fixed cost at least matches the rate of interest. Thus the possibility exists of a low-level equilibrium without infrastructure and therefore without industry, a pure agrarian economy which must import all its manufactures.

Secondly, the non-tradable character of infrastructural services ensures that the scale economies they generate are localized. In models with increasing returns in the final goods industry (whether arising from direct increase in output or from increase in the number of intermediates in use), one must postulate transport costs of tradable goods to localize scale economies in a particular country. One must also explain how differences in scales arise by postulating differences in consumption patterns between countries (due to factors like population size or Engel effects on the demand for manufactures). Though our model accommodates both transport costs on final products and Engel effects, its results are independent of these assumptions. Thus, its conclusions are not undermined by the secular decline in the share of transport costs in world prices.

In section 2, we set up our model. We derive results for the closed economy in section 3 and for a small open economy in section 4. In section 5 we discuss how our results change if the infrastructure provider acts in a more sophisticated manner than

"Level 1" agents in cognitive hierarchy models. In section 6 we consider the case of public ownership of infrastructure, while in section 7 we show that our results generalize to the Cournot oligopoly case. Section 8 concludes with a discussion of some implications.

2. The Model

Our model has two final products, food and manufactures produced under constant returns to scale and one intermediate, infrastructural services, produced under increasing returns. Agriculture uses labor and the fixed endowment of land to produce food. Infrastructural services are provided by labor operating fixed equipment under decreasing marginal cost; this equipment is indivisible, it costs a fixed amount F and is imported. Manufactures are produced using labor and infrastructural services under CRS.

Investment in infrastructure is financed by free mobility of capital at the fixed world interest rate r.

Internal economies of scale in the infrastructural activity rule out perfect competition: we assume that the industry is a natural monopoly. The rest of the economy is competitive. While the infrastructure monopolist[2] is the sole supplier of his product, he must compete in the labor market with all other manufacturers and with farmers.

For the rest of this section as well as for sections 3 and 4, we consider the possibility that the infrastructure monopolist behaves in a "naïve" manner, which we argue is similar to the behavior of Level 1 agents in C-H models. Specifically, the monopolist takes wages and the manufacturer's employment choices as given. He does not recognize his potential leadership role – the fact that his production decisions will affect the demand for labor (and the wage rate), both directly through their impact on infrastructural employment and indirectly through their induced effects on manufacturing employment.

Why is this similar to a Level 1 C-H agent? Standard equilibrium reasoning by the infrastructure monopolist would lead him to recognize and take into account his leadership role. Just as a Level 1 agent plays his best response assuming that other agents are not playing in *their* best interest (but instead following a simple rule, or randomizing), the infrastructure monopolist fails to take into account the fact that manufacturers will best-respond to his own employment decisions while setting their employment levels. Although he does not assume random behavior on their part, he does underestimate their capacity to act in an optimal fashion. In a later section, we analyze the consequences of allowing the infrastructure provider to behave in a more "sophisticated" manner in line with Stackelberg models. We note at this point that as we consider a static game, there is no scope for analyzing learning behavior.

The infrastructural service is non-tradeable while food and manufactures are perfectly mobile in international trade.

We eliminate distributional considerations by assuming Stone-Geary utility functions with a subsistence term for food, implying linear expenditure functions.

2.2 *Infrastructure Monopoly*

We assume Cobb-Douglas production functions

$$A = L_a^{\alpha} N^{1-\alpha} \tag{1}$$

for food and

$$M = L_m^{\beta} I^{1-\beta} \tag{2}$$

for manufactures where L_a and L_m are labor inputs in the two sectors, N is the fixed endowment of land and I the infrastructural service. Infrastructure requires a lumpy investment, F. The production function for the latter is iso-elastic in labor, once the initial investment F is made:

$$I = L_i^{\delta}, \qquad \delta > 1 \tag{3}$$

where L_i is the labour input in the infrastructural activity. Such a production function could result, for instance, from the division of labor as the output of the infrastructure service increases. We can choose the unit of land so that N = 1.

The utility function is

$$U = M_d^{\mu}(A_d - \overline{A})^{1-\mu} \tag{4}$$

where M_d and A_d are the consumptions of manufactures and food respectively implies that expenditure on manufactures is a fixed fraction μ of the surplus of income over subsistence $\overline{A}$:

$$pM_d = \mu(pM + A - \overline{A}) \tag{5}$$

where p is the price of manufactures in terms of food.

Labor market equilibrium requires that the wage rate

$$w = \alpha L_a^{\alpha-1} \tag{6}$$

$$= \beta p(L_m / I)^{\beta-1} \tag{7}$$

Labor is supplied inelastically and the wage-rate adjusts flexibly to ensure full employment.

$$L_a + L_m + L_i = L \tag{8}$$

The price q of the infrastructural service is its marginal value product in manufacturing

$$q = (1-\beta)p(L_m / I)^{\beta} \tag{9}$$

We consider pure monopoly in the infrastructural activity. The inverse demand function for the monopolist's product is represented by (9). Following Venables (1996), we let the infrastructure producer presume that manufacturers typically commit themselves to employment contracts first; subsequently, they decide on their output and buy infrastructural services in the light of the price that clears the market for the latter. Thus, the monopolist takes the manufacturer's employment level as given when figuring out the derived demand for his product. He then perceives the elasticity of this demand as $1/\beta$ so that the profit-maximizing equality of the monopolist's marginal revenue and marginal cost would require

$$q(1-\beta) = \partial(wL_i)/\partial I \tag{10}$$

$$= w\partial I^{1/\delta}/\partial I \tag{11}$$

$$= wI^{-(1-1/\delta)}/\delta \tag{12}$$

subject of course to the condition that profits are non-negative:

$$qI \geq wI^{1/\delta} + rF \tag{13}.$$

A necessary condition for this is

$$q > wI^{-(1-1/\delta)} \quad (14).$$

(11) and (13) together imply

$$1/\delta > 1 - \beta \quad (15).$$

(15) also happens to be the second order condition for the monopolist's maximization exercise – which is thus subsumed in the condition for non-negative profits.
For the present, we assume that (13) is satisfied, so that the fixed cost rF can be ignored, as it is in the short run.

Simple manipulations now yield

$$I = (\beta/\delta(1-\beta)^2)^{-\beta\delta/\sigma} M^{\delta/\sigma} \quad (16)$$

where $\sigma = \beta + (1 - \beta)\delta$ is a weighted average of δ and 1 and therefore larger than unity. Manufactured output and infrastructural services are, not surprisingly, increasing functions of each other.

Further, we have

$$w = \alpha[L - \lambda M^{1/\sigma}]^{\alpha-1} \quad (17)$$

where $\lambda = \{1 + \frac{\beta}{\delta(1-\beta)^2}\}\{\frac{\delta(1-\beta)^2}{\beta}\}^{\beta/\sigma}$.

The wage rate rises as manufactures expand - since the growth of manufacturing diverts labor both directly and indirectly (through the expansion of infrastructural activity that it induces) from agriculture, thus raising the marginal productivity of labor in terms of food.

However, there are increasing returns to infrastructural activity, so that q, the price of the infrastructural service, is subject to two conflicting forces as manufacturing and infrastructure grow - the upward pressure of rising wages and the down-thrust of economies of scale (indicated by the negative exponent of I in (12)). When the industrial sector is small, the latter dominates and infrastructure cheapens as it expands. The effect may well be reversed in an industrialized economy.

The unit cost of manufacturing in turn may increase or diminish with manufactured output according to the balance between economies of scale in the production of infrastructural inputs and wage pressures. Some cumbrous but simple algebraic manipulation yields

$$p = w/\tau M^{1-1/\sigma} \qquad (18).$$

where $\tau = \{\delta(1-\beta)^2\}^{\delta(1-\beta)/\sigma}\beta^{\beta/\sigma}$

As $M \to 0$ (and $L_a \to L$), *w* converges to the non-zero limit $\alpha L^{\alpha-1}$ and p to ∞. On the other hand, as $L_a \to 0$ and *M* to the finite maximum that this implies, *w* and p both tend to ∞. The inverse supply function of manufactures p = φ(M) appears to be U-shaped, a conjecture that is confirmed by differentiation, yielding

$$dp/p = \{\frac{1-\alpha}{\sigma}(\frac{L-L_a}{L_a}) - \frac{\sigma-1}{\sigma}\}dM/M \qquad (19)$$

Thus, $M\varphi'(M)/\varphi(M) \leq 0$ or $M\varphi'(M)/\varphi(M) \geq 0$ as

$$(L-L_a)/L_a \leq (\sigma-1)/(1-\alpha) \text{ or } (L-L_a)/L_a \geq (\sigma-1)/(1-\alpha) \qquad (20)$$

As the economy industrializes, the share of industrial to agricultural labor rises from 0 to ∞, ensuring a unique minimum to the supply curve of manufactures. External economies of scale continue to dominate manufacturing till the share of agriculture in the labor force dwindles to $(1-\alpha)/(\sigma-\alpha)$. Thereafter they are swamped by wage pressures.

Further, equation (19) indicates that

$$0 > M\varphi'(M)/\varphi(M) > -(1-1/\sigma) > -1 \qquad (21).$$

So much for the domestic supply of manufactures. What of the domestic demand ? Inserting the agricultural production function in (5), we have

$$pM_d = \mu(pM + L_a^\alpha - \bar{A}) \qquad (22).$$

If we substitute for L_a in terms of M, we would have the implicit domestic demand for manufactures as a function of domestic supply:

$$M_d = \mu[M+\{(L-\lambda M^{1/\sigma})^\alpha - \bar{A}\}/\varphi(M)] = \theta(M) \qquad (23)$$

for p $\geq \underline{p}$, the minimum supply price of manufactures and

$$M_d = \mu(L^\alpha - \bar{A})/p \qquad (23a)$$

for $p < \underline{p}$.

3. The Closed Economy

A solution of the equation $M = M_d = \theta(M)$ is a closed economy equilibrium.

Proposition 1: The closed economy equilibrium exists and is unique.

Proof: In the appendix.

This is illustrated graphically in Figs.1 and 2. The upper part of each diagram shows $\psi(M)$, the supply price of manufactures, as a function of the output M. Any output M determines a price $\psi(M)$, which, together with M, determines domestic demand M_d. The supply curve of manufactures is depicted by a U-shaped curve in the upper part of the figure. In the lower part, however, domestic demand for manufactures is plotted against the output and represented as $\theta(M)$. We prove in the appendix that $\theta(M)$ starts on the left of the 45° line and ends on its right, so that it must cross the latter; We also prove that only one intersection is possible – at U corresponding to P in the top quadrant, where supply and demand for manufactures are equal at the price PT. Q is the minimum point of the curve $\psi(M)$ and QN the corresponding minimum supply price of manufactures. Since $\psi(M)$ is U-shaped, any price above QN is associated with two possible outputs and therefore with two possible demands for manufactures, one corresponding to each output. At prices below QN, no manufactures are produced; a demand for manufactures arises out of agricultural surplus over subsistence.

However, $\theta(M)$ can intersect the 45° line either to the left of the minimum point of the supply curve (as in Fig. 1) or to its right (as in Fig. 2). Autarky equilibrium might occur with unexhausted economies of scale or it may occur on the rising segment of the supply curve.

Some simple substitutions show that if $\bar{A} = 0$ (there are no subsistence requirements), autarky equilibrium occurs when the ratio of non-agricultural to agricultural labor reaches $\mu\{\delta(1-\beta)^2 + \beta\}/\alpha(1-\mu)$. If the subsistence term is positive, the share of non-agriculture in the labor force would be larger than this under autarky. However, it is significant that nothing much changes if we dispense with the subsistence requirement with its non-homotheticity implications. Our model accommodates differential income-elasticities of demand , but is not driven by them.

Autarky equilibrium will occur with unexhausted economies of scale if the relative share of industry to agriculture in the labor force is smaller under autarky than at the minimum point of the supply curve of manufactures. A sufficient condition is $\mu\{\delta(1-\beta)^2 + \beta\}/\alpha(1-\mu) < (\sigma-1)/(1-\alpha)$. The smaller is μ, the budget share of manufactures in the consumer's surplus income over subsistence, and the larger is α, the elasticity of labor supply to the industrial sector, the likelier it is that this condition will be met. However, even if the condition is unfulfilled, a large enough subsistence requirement $\bar{A}$ can result in an autarky equilibrium on the down-sloping segment of the supply curve of manufactures.

4. The Small Open Economy

In a small open economy, the system of equations can no longer be closed by equating M_d to M, but by taking p as exogenously determined by the world market. Because of the U-shape of the supply curve, our system generates multiple equilibria when opened up to trade. We maintain the assumption in this section that the infrastructure monopolist is "naïve".

There are two possible cases here, depending on whether autarky equilibrium exhausts or does not exhaust economies of scale; the parameter space within which each of these cases holds has already been discussed. Further, each case can be partitioned into two subcases according to whether the world price $\tilde{p}$ (ignoring transport costs for the present) exceeds the autarky price p* or falls short of it.

1. In case 1, autarky equilibrium occurs in the decreasing return phase of the supply curve (Fig. 2). Now,
   (a) if $\underline{p} < \tilde{p} < p^*$ (the world price lies between the autarky price and the minimum supply price just like the price OE), there will be excess demand for, and imports of, manufactures; however, thanks to the U-shaped supply curve, two such import equilibria will exist: the price OE will just cover the cost of producing either the output EH or the smaller output EF; given the same price, the difference in output patterns will imply different

income levels and therefore different domestic demand levels for manufactures;

(b) if $\tilde{p} > p^*$ (as with world price OV), this may generate a large manufactured output VZ, implying exports; but it is also consistent with the smaller output VX and imports.

2. In case 2, with increasing returns ruling in autarky equilibrium (Fig.1),

(a) if $\underline{p} < \tilde{p} < p^*$ (OE in Fig. 1), this could lead to either of the outputs EG or EI (with associated domestic demands that are both less than domestic supply), implying manufactured exports in either case**;**

(b) if $\tilde{p} > p^*$ (OV in Fig. 1), this may induce an output of VZ with exports; but it could imply the smaller output VW and imports.

Imperfect international mobility of goods does not change the picture in its essentials. Assume that transport costs to and from the rest of the world absorb a fraction $(1 - 1/t_a)$ of food and $(1 - 1/t_m)$ of manufactures. This defines a price band $t_a t_m p^* > p > p^*/t_a t_m$ around the autarky price p* within which autarky can be sustained. If the world price were outside this band, arbitrage would erode autarky. Apart from the replacement of the single price p* by this price band, our analysis goes through unchanged.

Our economy therefore faces a multiplicity of possible equilibria at different levels of industrialization. Once however we relax the assumption that condition (13) is satisfied everywhere, several of these short run equilibria are no longer profitable in the long run. Recall that profits in the infrastructure monopoly

$$\pi = qI - wI^{1/\delta} - rF. \qquad (24).$$

Substitutions from (12) reduce this to

$$\pi = wI^{1/\delta}[1/\delta(1\text{-}\beta) - 1] - rF. \qquad (25)$$

If inequality (14) is not fulfilled, positive profits can never be made in the infrastructure activity, no investment will ever be made in infrastructure and the economy is doomed to remain permanently agricultural. If however (14) is satisfied, profit becomes an increasing function of both wages and infrastructural services. Since both of these increase with manufactured output, so does profit. The possibility now emerges of profits being negative at low levels of manufactured output, but positive at higher levels. With a multiplicity of short run equilibria, the ones at higher output levels could well be sustainable even if those at lower levels are not. This underlines the "big-push" flavor of our open economy multiple equilibria model. We note that equilibria can be supported where manufactures are exported in spite of their autarky price exceeding the world price, provided economies of scale were unexhausted in autarky equilibrium : similarly, it is possible to support equilibria where manufactures are imported in spite of the world price of manufactures being higher than the autarky price, if scale economies had been exhausted in autarky.

The "naïve" equilibria described above point to the multiplicity of outcomes that could emerge in small open economies, potentially causing divergence of economies with similar underlying parameters. This divergence could happen either if the infrastructure provider(s) in the different economies were all naïve, or alternatively if they were naïve in some but not in others. We will show in the next section how the outcome differs for a "sophisticated" infrastructure provider, yielding a unique prediction for the open as well as for the closed economy.

We show below that of all the "naïve" equilibria described, the equilibrium which yields the most profits for the infrastructure monopolist for any given set of parameters involves the greatest degree of industrialization – as profits are directly related to manufactured output. However, as long as the infrastructure monopolist does not recognize his role as a "leader" there is no guarantee that co-ordination on this particular equilibrium will occur. In the next section, we will argue that a "sophisticated" Stackelberg-type monopolist will, for a wide range of parameters, choose an equilibrium with an even greater degree of industrialization than the most profitable of the "naïve" equilibria. Thus, whether the monopolist behaves as a sophisticated agent in equilibrium models[3], or as a level-1 agent in C-H models, can drastically affect whether the economy experiences successful industrialization.

4.2 *Profits, Wages and National Incomes in the Naïve Equilibria*

We turn to a comparison of profit and wage levels in the trading equilibria and the autarky equilibrium in the naïve case. The competitive final goods industry of course converges to zero profit equilibria in all cases. Wage rates however differ - and so do profit levels in infrastructure monopoly.

The wage equations - (7) or (17) - show wages to be an increasing function of manufactured output. The increased demand for labor as manufacturing expands drives up wages in terms of food. Equation (18) indicates that w/p, the product wage in terms of manufactures, is also positively related to M. Wages in terms of both final goods will therefore be higher in (1) the industrial exporter than in the autarkic economy and (2) the autarkic economy than in the industrial importer.

As for the profit level π in the infrastructure monopoly,

$$\pi = qI - wI^{1/\delta} - rF. \qquad (26).$$

Substitutions from (12) reduce this to

$$\pi = wI^{1/\delta}\{\frac{1}{\delta(1-\beta)} - 1\} - \text{rF} \qquad (27).$$

The condition for non-negative profit (14) ensures that π will be an increasing function of both w and I; and since both increase with manufactured output, so will the profit level. Industrialization necessarily increases profits in the infrastructure monopoly. This holds good even if we measure profits in terms of manufactures rather than of food as in equation (25). Divide both sides of this equation by p: profits in terms of manufactures π/p will be seen to be an increasing function of I and the product wage in manufacturing w/p - both of which increase with industrialization.

Since however the return to land diminishes with industrialization, we cannot indicate an unambiguous direction of change for national income or welfare. National income in terms of food

$$\text{Y} = \text{A} + \text{pM} \qquad (28).$$

Differentiation and some manipulation yields

$$dY/dM = \sigma\tau[\lambda\{\frac{(1-\alpha)pM}{wL_a} - 1\} + 1] \qquad (29)$$

$$\text{Thus } dY/dM \geq 0 \text{ as } pM/wL_a \geq 1/(1-\alpha)[1-1/\lambda] \qquad (30)$$

$$\text{or as } pM/A \geq \alpha/(1-\alpha)[1-1/\lambda] \qquad (31).$$

When manufactures account for a negligible fraction of total output, industrialization depresses national income in terms of food. However, as inequality (20) shows, the value of manufactured output rises with M, agricultural output falls - and, once the relative share of industry crosses the threshold indicated by (30), further industrialization adds to national income.

These results involve a comparison of various "naïve" equilibria and establish that, among these, the most highly industrialized generates the highest profits, the highest wages and, beyond a point, the highest national income.

5. Sophistication and the Stackelberg Equilibrium

What if the monopolist plays the role of a full Stackelberg leader in factor, as well as product, markets? A Stackelberg leader is defined here as a producer who is aware of and takes into account the impact of his decisions on the labor market and, through that, on the rest of the economy. He believes, correctly, that other agents adjust their behavior to any given set of product and factor price-parameters, and best-respond to *his* own decisions : he maximizes his profits on the basis of this belief. He therefore departs from the naïve reasoning that characterizes Level-1 cognitive-hierarchy reasoning, and does not make the assumption, attributed to him in the earlier part of this paper, that manufacturers' employment levels are given.

Would sophisticated reasoning by the infrastructure monopolist necessarily involve an even higher degree of industrialization? This cannot be established in general. However, even without deriving a full Stackelberg equilibrium (which would involve an excursion into a forest of convoluted algebra), we can establish a sufficient, but by no means necessary, condition for Stackelberg behavior to result in increased industrial output: in particular, a Stackelberg leader would certainly increase industrial output whenever there are unexhausted (external) economies of scale in manufacturing.

A Stackelberg leader would not accept (9) as the demand curve for his product. He would instead maximize π, subject to equations (1) to (8). Now

$$\pi + rF = qI - wL_i$$

$$= (1 - \beta)pM - wL_m. L_i/L_m$$

$$= (1 - \beta)pM - \beta pM.L_i/L_m$$

$$= pM\{1 - \beta(1 + L_i/L_m)\}. \qquad (32)$$

A sufficient, but not necessary, condition for profits to be an increasing function of the value of manufactured output is that the relative share of non–agricultural to agricultural employment should lie below a minimum:

$$(L_i + L_m)/L_a < (1 - \beta)(\delta - 1)/(1 - \alpha). \qquad (33)$$

For proof, use (1) – (3) and (6) – (8) to derive

$$dw/w = (1 - \alpha)(L_i/\delta L_a \; dI/I + L_m/L_a \; dL_m/L_m) \text{ and}$$

$$dw/w = (1 - \beta)(dI/I - dL_m/L_m).$$

Eliminating dw/w, we get

$$dL_m/L_m = \frac{L_a(1-\beta)pM - \dfrac{L_i}{\delta\{\beta(1-\alpha)pM + \alpha(1-\beta)A\}} + L_m(1-\beta)\{(1-\alpha)pM - \alpha A\}}{L_a(1-\beta) + L_m(1-\alpha)} \qquad (34)$$

Now, if $(L_i + L_m)/L_a < (1 - \beta)(\delta - 1)/(1 - \alpha)$, a little manipulation yields

$$\frac{\delta(1-\beta)L_a - (1-\alpha)L_i}{\delta(1-\beta)L_a + (1-\alpha)L_m} > 1. \qquad (35)$$

(35) has two implications. First, since the denominator of the LHS is positive, the numerator must also be positive; but then equation (34) ensures that dL_m has the same sign as dI. Further (34) and (35) together imply

$$I/L_m \; dL_m/dI > 1/\delta$$

$$\text{i.e.} > I/L_i \; dL_i/dI \qquad (36)$$

Inequality (36) implies that any increase in infrastructure and therefore in manufactured output (since the other input in manufacturing L_m grows with I) reduces the ratio of infrastructural to manufacturing employment L_i/L_m. It thus raises the coefficient of pM in equation (32). Infrastructure profits (over variable cost) rise more than proportionally with manufactured output. Thus, if condition (33) is fulfilled, a Stackelberg monopolist will necessarily expand output beyond any profitable position he may initially be at. A little manipulation however shows that (33) is in fact identical with (20), the condition that defines the region to the left of the minimum point of the supply curve of manufactures, in which external economies of scale dominate over rising wage pressures.

6. Public Ownership of the Infrastructure Industry

How would all this compare with the social optimum? In particular, would the profit-maximizing monopolist aim at a higher degree of industrialization than welfare-maximizing public ownership of infrastructure? We show below that the opposite is in fact the case. We make the admittedly heroic assumption that production efficiency is independent of the regime, so that the same production functions can be used in the two cases.

As is well-known, a necessary, though not sufficient, condition for social optimality is a production equilibrium that maximizes Y, the value of output at world prices, since this enables the economy to climb onto its highest consumption possibility locus. Y is affected by increased provision of I through its impact on outputs in agriculture and manufacturing.

$$dY/dI = p dM/dI + dA/dI.$$

Agricultural output is impaired by the withdrawal of labour into infrastructural and manufacturing employment.

$$dA/dL_a$$
$$= \alpha L_a^{\alpha - 1} = \alpha A/L_a$$

The manufacturing output effect is an average of the proportionate changes in I and manufacturing employment, weighted by their relative output shares.

$$dM/M = (qI/pM)\, dI/I + (wL_m/pM)\, dL_m/L_m.$$

Manufacturing employment, in turn, is subject to two forces: the growth in I accompanied by a proportionate rise in manufacturing labor demand (if wages were unchanged) and the rise in wages that induces a fall in the labor-infrastructure ratio.

$$dL_m/ L_m = [1 - \{1/(1 - \beta)\}(dw/dI)I/w]\, dI/I$$

Meanwhile, infrastructural employment rises with elasticity $1/\delta$ as I increases and agricultural employment falls (with elasticity $-1/(1-\alpha)$) as wages rise.

$$I dL_i/dI = L_i/\delta.$$

$$w dL_a/dw = - L_a/(1 - \alpha)$$

Wages rise just enough to equilibriate the labour market (through an induced restriction of agricultural employment) in the face of the rise in labor demand from the infrastructure and manufacturing sectors.

$$\{L_a/(1-\alpha)\}\ (dw/dI)\ I/w = L_i/\delta + L_m[1 - \{1/(1-\beta)\}(dw/dI)I/w]$$

from which

$$dw/w = \frac{(L_i/\delta + L_m)(1-\alpha)(1-\beta)}{L_a(1-\beta)+L_m(1-\alpha)}\,dI/I$$

It is now a matter of simple substitutions to work out the changes in manufacturing and agricultural employment and therefore in manufacturing and agricultural output that follow a change in infrastructure. The impact on national income can then be worked out as follows:

$$dY/dI = \frac{L_a(1-\beta)pM - \dfrac{L_i}{\delta\{\beta(1-\alpha)pM + \alpha(1-\beta)A\}} + L_m(1-\beta)\{(1-\alpha)pM - \alpha A\}}{L_a(1-\beta)+L_m(1-\alpha)}$$

Simplification of the numerator shows that $dY/dI \geq 0$ as $L_m(1-\beta)/\beta \geq L_i/\delta$. Given the fact that $(1-\beta)/\beta = qI/wL_m$, this reduces to the condition $qI \geq wL_i/\delta$.

A necessary condition for the maximization of national income (which is a necessary condition for social optimality) is $qI = wL_i/\delta < wL_i$. The infrastructure sector will be making losses in this situation. Further, if $qI > wL_i$, so that the infrastructure industry can at least cover its variable cost, $dY/dI > 0$: social optimality will require an expansion of infrastructural output till losses are made. Obviously, therefore, the Stackelberg (or any free-market) equilibrium will imply a smaller infrastructural output and a lower degree of industrialization than social welfare-maximising state ownership of infrastructure. We repeat that this conclusion requires our implausible assumption that efficiency levels are independent of the ownership pattern.

7. Contestable Cournot Oligopoly in Infrastructure

A question of some importance relates to the sensitivity of our results to our assumption that infrastructure is provided by a monopolist. While natural monopoly is typical of many major elements of infrastructure, an alternative market specification which has been frequently used is that of Cournot oligopoly with free entry. In this section, we assume n identical infrastructure firms playing a Cournot game. With the inverse demand function of the infrastructure industry defined by (8), the marginal revenue of each Cournot firm is (1-β/n)q, while its marginal cost is $\frac{w}{\delta}(I/n)^{1/\delta-1}$ (where I/n is its output). The equation of marginal revenue and marginal cost then implies

$$\frac{\delta(1-\beta/n)}{n^{1-1/\delta}}=\frac{w}{qI^{1-1/\delta}} \tag{37}$$

$$=\frac{\beta I}{(1-\beta)L_m I^{1-1/\delta}} \tag{38}$$

from which

$$L_m=\frac{\beta I^{1/\delta}n^{1-1/\delta}}{\delta(1-\beta)(1-\beta/n)} \qquad (39).$$

Labor in the infrastructure is related to I:

$$L_i=n(L_i/n)=n(I/n)^{1/\delta}=n^{1-1/\delta}I^{1/\delta} \tag{40}$$

From (39) and (40),

$$L_i+L_m=\{1+\beta/\delta(1-\beta)(1-\beta/n)\}n^{1-1/\delta}I^{1/\delta} \tag{41}$$

Now, inserting the expression (31) for L_m in the manufacturing production function,

$$M=\{\frac{\beta n^{1-1/\beta}}{\delta(1-\beta)(1-\beta/n)}\}^{\beta}I^{\sigma/\delta} \tag{42}$$

Manipulation of (41) and (42) yields

$$M=\frac{\beta^{\beta}\{\delta(1-\beta)(1-\beta/n)\}^{\delta(1-\beta)}(L_i+L_m)^{\sigma}}{\{\delta(1-\beta)(1-\beta/n)+\beta\}^{\sigma}n^{(\delta-1)(1-\beta)}} \tag{43}$$

n is endogenously determined. Free entry into the infrastructure industry reduces excess profits to zero. Now the marginal revenue/average revenue ratio is $(1-\beta/n)$ and the marginal cost/average cost ratio $1/\delta$: zero profits (a.r. = a.c.) imply that the former ratio is equal to the latter:

$$1-\beta/n=1/\delta \qquad (44).$$

Thus,

$$n=\beta\delta/(\delta-1) \qquad (45).$$

Insertion of the value of n in (43) yields

$$M = (1/\beta - 1)^{\delta(1-\beta)}(1 - 1/\delta)^{(\delta-1)(1-\beta)}\beta(L_i + L_m)^{\sigma}$$

$$M = (1/\beta - 1)^{\delta(1-\beta)}(1 - 1/\delta)^{(\delta-1)(1-\beta)}\beta(L_i + L_m)^{\sigma} \qquad (46).$$

Then, using (7), (39), (45) and (46), we derive

$$p = \frac{w\beta^{(\sigma-1-\beta)/\sigma}}{(1-\beta)^{(1-\beta)/\sigma}(1-1/\delta)^{1-1/\sigma}M^{1-1/\sigma}} \qquad (47)$$

(47) is identical with (18), apart from a scalar transformation. Thus qualitatively, the shapes of the supply curves of manufactures under infrastructure monopoly and free-entry infrastructure Cournot oligopoly are identical. Equations (and inequalities) (19) to (23a) hold without any change under Cournot oligopoly - and the geometric analysis above can therefore be repeated. Our conclusions regarding multiple equilibria under infrastructure monopoly are replicated where infrastructure is provided by Cournot oligopolists in a contestable market. The "naivete" assumption in the previous part of the paper is maintained for this analysis – the oligopolists do not take into account their possible impact on manufacturers' employment decisions, or on the wage.

If integer constraints are considered, the equations (45)-(47) will be replaced by inequalities setting upper and lower bounds to n, M and p. The algebra becomes infinitely more cumbrous without changing the qualitative characteristics of the system.

8. Some Implications

How do the size of the labor force and the elasticity of labor-supply to the industrial sector affect this model? As inequality (20) indicates, the larger is α, the higher must the share of industry in the total labour force rise before increasing returns in manufacturing are exhausted. α, on the other hand, is positively related to the elasticity of the demand for labor in agriculture and therefore to the elasticity of labour supply to industry (as shown by the wage equation (20)). The larger the total labour force L, the larger will be the absolute size of total industrial employment for any given share of industry in total labor. Thus, a large volume and elasticity of labor supply increase the likelihood of an autarky equilibrium with unexhausted economies of scale in industry and the possibility of asymmetric trading equilibria. Industrial growth prospects *a la* Arthur Lewis open up for densely populated agrarian economies with highly elastic labor supply in manufacturing - if international trade provides an outlet for their manufactures. This, of course, is the story of much of East Asian growth, of the development over the past four decades of Korea, Taiwan, Thailand, Indonesia, China and now Vietnam. Unlike Lewis, however, we do not have to assume zero marginal labor product or surplus labor in agriculture: indeed, the agricultural production function that would favour this result most strongly is one that is near-linear in labor.

A major implication of the analysis is that the extent of the infrastructure provider's sophistication in decision-making (whether he acts as a Level-1 player in a C-H model, or as a Stackelberg monopolist in an equilibrium model) drastically affects the equilibrium outcome and the extent of industrialization that a small open economy can achieve. We have argued that while the closed economy equilibrium is unique – itself a departure from most papers on the theme of increasing returns in trade – multiple equilibria with different patterns and magnitudes of trade are possible when the economy opens up, if the infrastructure provider is naïve. If he is sophisticated, however, a unique equilibrium emerges even in an open economy, involving a greater degree of industrialization than any of the "naïve" equilibria, as long as the initial size of the non-agricultural sector relative to the agricultural sector was below a threshold – which might well be the case in most poor economies. We have pointed out how economies with similar underlying parameters may diverge if infrastructure providers in some, though not necessarily all, of these countries behave in a naïve manner. With naïve behavior, it is possible that opening up an economy will lead to a lower degree of industrialization than under autarky – a deindustrialization without Dutch disease. However, this will not happen with a sophisticated infrastructure provider. It is possible, of course, that parameters are such that infrastructure providers cannot make profits so that the economy remains purely agrarian – but this does not happen as a result of opening up.

To sum up, if international trade in manufactures is indeed opened up, the prospects of rapid industrialization through the market depend on the beliefs and model of reasoning of the infrastructure monopolist. Our model focuses sharply on the key role of the entrepreneur in economic development – the role so dramatically, if informally, expounded by Schumpeter. We provide an interpretation of the distinctive function of the Schumpeterian entrepreneur in terms of the theory of cognitive hierarchies.

However, the possibility of multiple equilibria also widens the role that government may play in industrial policy. This might become important if agents indeed tend to use less complex reasoning than most equilibrium models suggest. Expansion of the infrastructure sector, through entrepreneurial initiative – if entrepreneurs are sufficiently sophisticated in their reasoning - or otherwise because of government ownership or because of government persuasion[4] of less adventurous entrepreneurs, could be crucial in catalyzing industrial growth and the realization of economies of scale. As we have already shown, such expansion would justify itself in terms of higher profits. The present model is static, of course, and does not depict irreversible growth processes. It would be simple however to lock history into the production function for manufactures by adding a multiplicative productivity parameter that grows with manufactured output through learning-by-doing. Could this be the secret of the success of East Asian governments in nudging their industrialists down the path of industrial export growth, a path that led directly to the East Asian miracle?

Appendix

Proof of Proposition 1: We prove that one and only one equilibrium exists in the closed economy.

As $M \to 0$, $L_a \to L$ and

$$M\psi(M) = w\, M^{1/\sigma}/\tau \to \alpha\, L^{\alpha-1} M^{1/\sigma}/\tau \to 0$$

$$\text{Now } M/\theta(M) = \frac{M\psi(M)}{\mu\{M\psi(M) + L^{\alpha} - \overline{A}\}}$$

$$\to \frac{M\psi(M)}{\mu\{M\psi(M) + L^{\alpha} - \overline{A}\}} = 0.$$

Thus for small M, $\theta(M) > M$.

M assumes its maximum value M_{max} when agricultural employment dwindles to zero.

At this limit, $\theta(M) = \mu M < M$.

Since $\theta(M)$, a continuous function, passes from values greater than M to values less than it as M increases from 0 to M_{max}, it must have a fixed point.

Now, differentiation and some manipulation show that

$$M\theta'(M) = \mu M[1 - \frac{\lambda\tau\{1-(1-\alpha)\bar{A}/A\}}{\alpha\sigma} + \frac{\tau(1-1/\sigma)(A-\bar{A})}{wM^{1/\sigma}}]$$

while $\theta(M)$ can be written as

$$\theta(M) = \mu M+\mu[\tau M^{1-1/\sigma}(A-\bar{A})/w] \quad \text{(using (18) and (23))}$$

Comparing the expressions for $M\theta'(M)$ with that for $\theta(M)$ we see that the first term μM is common to both and the second term in $\theta(M)$ exceeds the sum of the second and third terms in $M\theta'(M)$:as

$$\sigma>0,\ 1-1/\sigma <1$$

so

$$\mu M[\tau(A-\bar{A})/wM^{1/\sigma}] > \mu M[\frac{\tau(1-1/\sigma)(A-\bar{A})}{wM^{1/\sigma}}]$$

$$> \mu M[\frac{\tau(1-1/\sigma)(A-\bar{A})}{wM^{1/\sigma}} - \frac{\lambda\tau\{1-(1-\alpha)\bar{A}/A\}}{\alpha\sigma}]$$

$$\text{or} \qquad M\theta'(M) < \theta(M)$$

$$\text{Thus, } d\ln\theta / d\ln M < 1.$$

If $\theta(M^*) = M^*$ is a closed economy equilibrium, we have, for any $M > M^*$,

$$\int_{M^*}^{M} d\ln\theta < \int_{M^*}^{M} d\ln M$$

$$\text{Or } \ln\theta(M) - \ln\theta(M^*) < \ln M - \ln M^*$$

$$\text{Or } \theta(M) < M \text{ for all } M > M^*.$$

Similarly, we can prove that $\theta(M) > M$ for all $M < M^*$.

Thus, the closed economy equilibrium is unique.

Notes

[1]Experimental evidence indicates that most agents are either “Level 1” or “Level 2”, with a slight dominance of the “Level 1” types (Crawford and Iriberri, 2005).

[2]In a later section we consider the case of Cournot oligopoly in infrastructural provision.

[3]This is reminiscent of the role of the Schumpeterian entrepreneur.

[4]It is possible that the government may play a “co-ordinating” role persuading naïve infrastructure providers to choose the most highly industrialized of the “naïve equilibria”. However, this attributes a high degree of foresight to the government.

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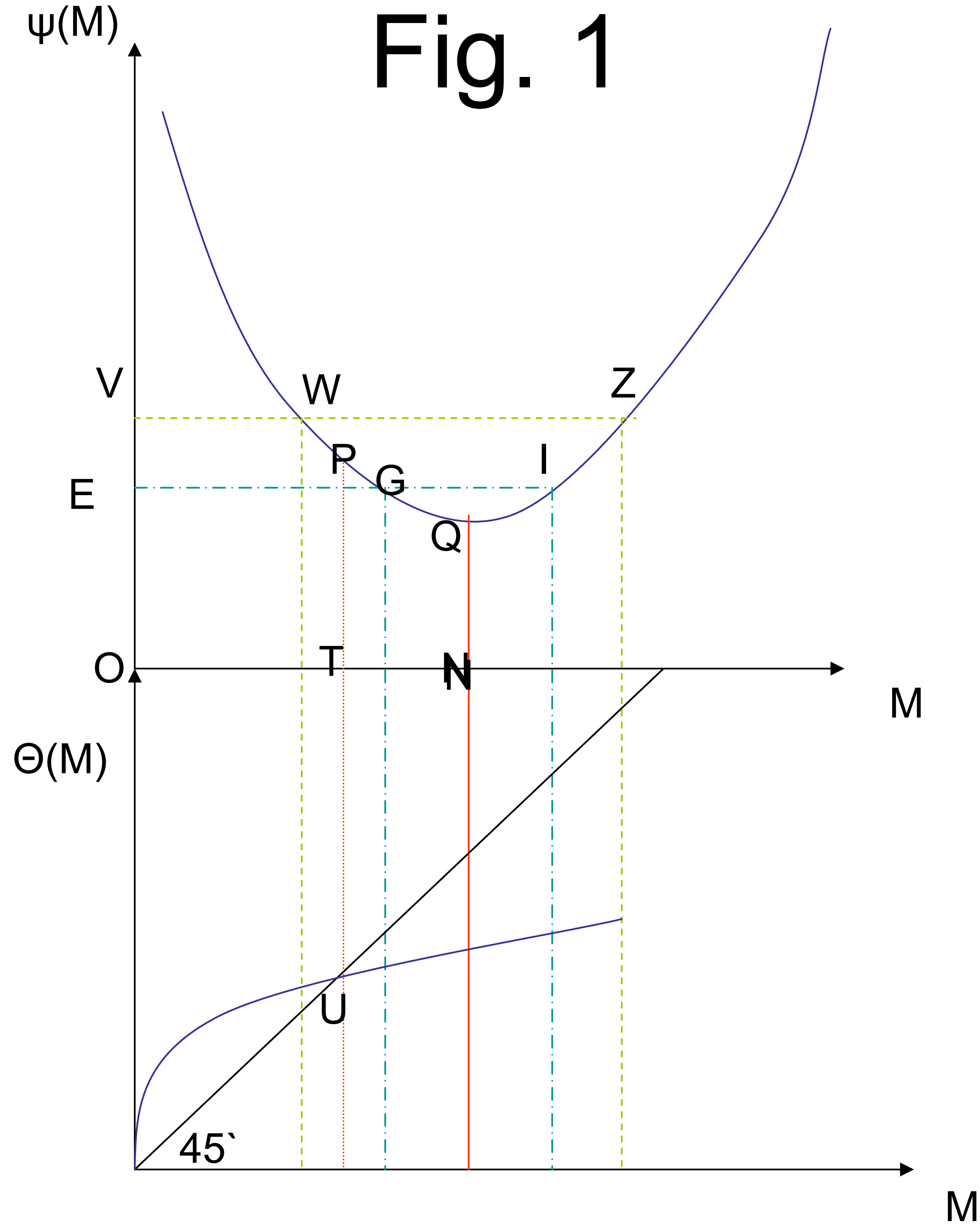
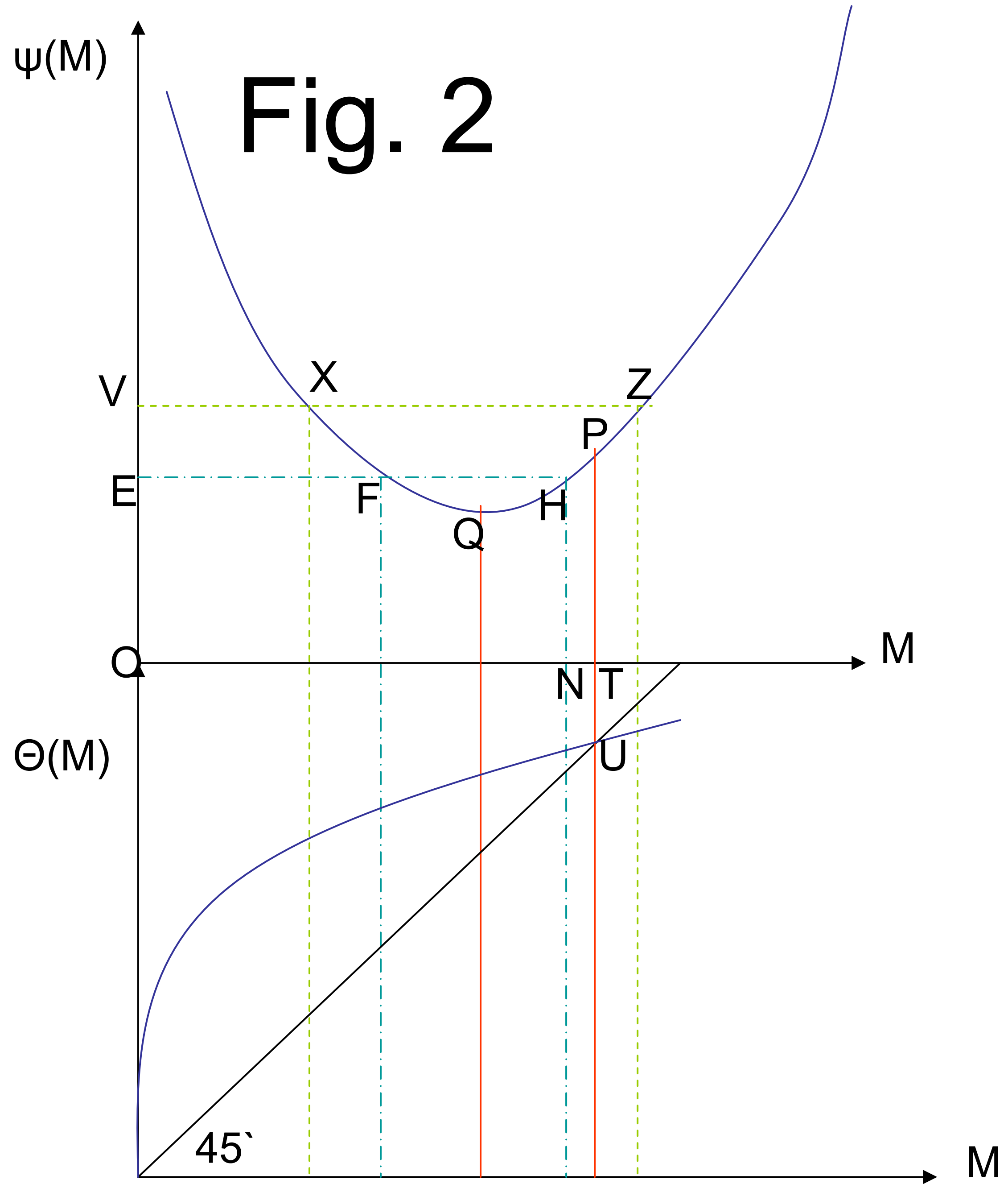
Fig. 1





ψ(M)
Fig. 2
V
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Θ(M)
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