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ECONOMIC PERFORMANCE THROUGH TIME: A GENERAL EQUILIBRIUM MODEL

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Abstract: This paper presents a simple general equilibrium model of economic performance through time. The model incorporates 4 main determinants of economic performance: technology, capital investment, the division of labor and institutions. It demonstrates that growth is not automatic even with technological progress. In order to maintain economic growth, it is important to continuously implement new technologies through capital investment. It also shows that institutional improvement promotes the social division of labour, which is an independent source of economic growth.

Key words: economic growth, savings and investment, transaction costs, division of labor, financial and production institutions

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Economic Performance Through Time: A General Equilibrium Model

1. Introduction

Both exogenous and endogenous (including the semi-endogenous varieties) models rightly identify technological progress as the most important driver of long-term economic growth. The main difference between the two types of models is that the former e.g., Solow (1956) does not explain technology progress, but instead takes it as something determined by forces outside of the models. In contrast, the latter provides a theory on why or how technology advances take place Barro (1997). For example, Arrow (1962) points to learning by doing as a source of productivity improvement. Others suggest that the discovery of new technologies depends on purposive R&D activities Aghion and Howitt (1992, Grossman and Helpman (1991, Jones (1995, Romer (1987, (1990).

However, technological progress by itself is unlikely to sustain long-term economic growth for several reasons.

First of all, technologies are typically embodied in capital goods, and new technologies often require new types of capital goods Landes (1969). Since the implementation of new technologies requires capital investment, it may be that it is capital rather than technological advance per se is the binding constraint on economic growth. Indeed, according to Hicks (1969), the most notable achievement during early periods of the Industrial Revolution was the manufacturing of many products that had been invented much earlier, and a main cause of delay in commercialising these inventions was the lack of capital. The link between growth and investment in capital goods (especially equipments) in recent times has been emphasised by De Long and Summers (1991, (1992).

Moreover, the discovery and implementation of new technologies requires a good institutional environment. On the one hand, as the work of North and Thomas (1973), Rosenberg and Birdzell (1986) and North (1990) demonstrates, historically rapid technological progress and capital accumulation tended to take place in countries with

good institutions including formal rules, informal norms and enforcement characteristics. On the other hand, the dismal returns from most foreign aid to third world countries suggest that without good institutions, technology and capital cannot bring growth miracles Bauer (1976).

Perhaps most importantly, the implementation of new technologies does not occur in isolation; it is intimately related to the level of the social division of labor. As is well known, Adam Smith (1776) considered the division of labor to be the mainspring of productivity improvement. Smith also explicitly pointed out that a key benefit of the division of labor is that it facilitates the use of machines that complements with specialized labor, which suggests that the division of labor tends to facilitate the implementation of new technologies. In fact, the causation also runs the other way, that is, the implementation of new technologies tends to facilitate further division of labor. This is because new technologies introduce new products or better ways of producing existing products, both increasing the scope for further division of labor.

Thus in our view, while technological advance is an important factor behind economic growth, it has to work with other factors to realise its potential. The purpose of this paper is to investigate the joint effects of technological progress, capital investment, favourable institutional environment and the division of labor on economic growth. In doing so, we construct a simple general equilibrium model of economic performance through time. The model demonstrates that growth is not automatic even with technological progress. In order to maintain economic growth, it is important to continuously implement new technologies through capital investment. It also shows that institutional improvement promotes the social division of labour, which is an independent source of economic growth.

We present our model in the following section, and discuss its results and implications in section 3. Section 4 concludes.

2. The model

2.1 Setup of the model

Consider an economy with many *ex ante* identical individuals who derive utility from a single final good, Z (fish), over an infinite time horizon. The individual's utility function is:

$$U = \sum_{t=1}^{\infty} \beta^{t-1} Z_t \quad (\beta < 1)$$

The final good, Z , can be produced with either labor (l) alone or a combination of labor and a capital good, net (N). N is produced with labor only. There are thus 3 different tasks:

- (1) producing Z with labor
- (2) producing N
- (3) producing Z with labor and N .

There is a cost to learn each task. The learning cost is incurred only once if an individual continues to perform one task. If he switches between tasks, then he has to re-learn each time he switches to a different task. For simplicity, learning cost is assumed to be equal to a fraction $(1-s)$ of total labor input. Each individual is assumed to be endowed with L units of labor per period.

The two technologies are described by the following production functions:

(1) With learning costs:

$$Z = sl$$

or

$$Z = A \min(sl, N), \text{ and } N = sl$$

(2) Without learning cost

$$Z = l$$

or

$$Z = A \min(l, N), \text{ and } N = l$$

The second (capital-using) technology is more productive than the first technology.

An individual chooses a production technology and decides whether or not to engage in specialisation. The aggregate of all individual choices results in 3 different structures as illustrated in Figure 1.

[insert figure 1 here]

We discuss the features of each structure below.

(1) Structure A: Autarky with no capital goods.

In this structure, all individuals choose to fish with labor only; no capital good is used, no trade takes place. An individual's utility over the infinite is determined by technology and time preference as follows:

$$U_A = (s + \frac{\beta}{1-\beta})L$$

(2) Structure B: Autarky with capital goods

In this structure, each individual catches fish in period 1 with labor only. The individuals consume half of the catch in period 1, and save the rest for consumption in period 2.¹ In period 2, the individual makes nets which are used together with labor to fish in period 3. For simplicity, N is assumed to be completely depreciated after one period. So in Period 4, the individuals make N again for use in period 5. The 2-period Net-making – fishing cycle repeats itself from period 2 onwards. Since the individuals perform a different task each period, they have to incur a learning cost each period. The individuals' consumption pattern over time is characterised as follows:

$$Z_1^c = Z_2^c = sL/2$$

$$Z_n^c = sAL/2 \quad (n \geq 3),$$

An individual's utility in Structure B is:

$$U_B = \frac{sL}{2} + \frac{\beta sL}{2} + \beta^2 \frac{sAL}{2} + \beta^3 \frac{sAL}{2} + \dots = \frac{sL}{2} (1 + \beta + \frac{\beta^2 A}{1-\beta})$$

(3) Structure C: Division of labor with capital goods

¹ Alternative we can assume that the individual saves the minimum amount required to sustain life for the period when he makes N. However this assumption generates an oscillating consumption pattern and complicates computation without adding much to illuminating the main thesis of the paper.

In this structure, half of the individuals specialise in fishing, the other half specialise in making nets. In period 1, fishermen fish with labor only. They consume some and sell the rest to Net-makers in exchange of nets at the end of period 1. In period 2, fishermen use N and labor to produce Z , and exchange with net makers at the end of the period to replace the nets that have been completely depreciated. This production and trade pattern repeats itself from period 2 onwards.

We assume that there is a transaction cost associated with market exchange. Transaction costs are not simply transportation costs, but include the costs of information, of specifying and enforcing contracts. An important determinant of the level of transaction costs is the quality of institutions. For instance, market exchange typically requires the development of institutional structures that permit individuals to have confidence in dealing with strangers. How costly the transactions will be if they take place at all depends on the extent to which market participants can rely on the establishment of property rights, enforcement of contracts, and the existence of norms to constrain opportunistic behaviour of parties North (1987). For simplicity, we assume that only the net-maker incurs the transaction cost directly, and the transaction cost takes the “ice-berg” form. That is, for every unit of fish the net-maker buys, a fraction, k , ($k \leq 1$) is lost in transit, only $(1-k)$ unit is left for consumption. Thus the net-maker’s consumption in period 1 is

$$Z_{n1}^c = ksLP_1$$

where P_1 is the price of net relative to fish, k is the transaction efficiency coefficient, s is the fraction of labor devoted to fish after learning cost has been incurred.

The fisherman’s period 1 consumption is

$$Z_{f1}^c = sL - P_1sL$$

From period 2 onwards, fish is caught with nets, thus

$$Z_2 = A \times \min(l, N_1) = sAL$$

where s denotes both the fraction of labor devoted to making nets and the fraction of labor devoted to fishing with nets, after learning costs have been incurred.

The fisherman’s and the net-maker’s consumption per period are, respectively

$$Z_{f2}^c = sAL - P_2L$$

and

$$Z_{n2}^c = kLP_2$$

Since all individuals are assumed to be *ex ante* identical and the choice to specialise in either profession is free, the utility of the fisherman and that of the net-maker equalise in equilibrium. From the utility equalisation condition we obtain the equilibrium utility for each individual in Structure C, which is:

$$U_C = \frac{kL}{1+k} \left(s + \beta sA + \frac{\beta^2 A}{1-\beta} \right)$$

Table 1 summarises individuals' consumption patterns and utility levels for each structure.

[Insert Table 1 here]

2.2 Equilibrium

The general equilibrium structure is the structure that no individuals have an incentive to move away from. This means in our model that the general equilibrium structure is the structure that gives the highest level of individual utility. Thus,

Structure A is the general equilibrium structure iff

$$U_A > U_B \text{ and } U_A > U_C$$

Structure B is the general equilibrium structure iff

$$U_B > U_A \text{ and } U_B > U_C$$

Structure C is the general equilibrium structure iff

$$U_C > U_A \text{ and } U_C > U_B$$

The above conditions define the parameter subsets within which different structures emerge as the general equilibrium structure. These conditions are summarized in Table 2.

[Insert Table 2 here]

From Table 2, we can make a number of observations.

First, Structure A is likely to emerge in general equilibrium if individuals have strong time preference, i.e., if β is small. In other words, if individuals are very impatient, they are likely to consume all their present goods, and do not engage in savings or capital formation.

Second, Structure B and Structure C are likely to emerge in general equilibrium if individuals' time preference is sufficiently weak. Whether Structure B or Structure C will emerge in general equilibrium depends importantly on the trade-off between the benefit from the division of labor and transaction costs. In our model, the benefits from the division of labor come from two sources. First, as individuals do not switch between tasks, the production of final goods is continuous, and the cost of re-learning, $(1-s)L$, is avoided. It is easy to show that $U_B < U_C$

$$\text{if } s < \frac{2k\beta^2 A}{1 - \beta^2 + \beta^2 A - k - 2k\beta A + 2k\beta - k\beta^2 + 3k\beta^2 A}$$

That is, the higher the learning costs, the higher the benefits of the division of labor, and the more likely Structure C will emerge in equilibrium. Second, the division of labor enables earlier use of the capital-using technology. In Structure C, capital goods are used from period 2. In Structure B where the division of labor is absent, capital goods are not used until period 3. The benefit of earlier capital utilization is greater if individuals have strong time preference, thus *ceteris paribus*, Structure C is more likely to be the general equilibrium structure than structure C when β is small, as can be shown that $U_B < U_C$, if

$$\beta > \frac{2kLs(A-1)}{[sL(1+k)(A-1) - 2(1-s)kLA]\beta} - \frac{sL(1-k)}{sL(1+k)(A-1) - 2(1-s)kLA}$$

The cost of the division of labor is the transaction costs associated with market exchange. If transaction costs are large (i.e., k is small), then structure B will be more likely to be the general equilibrium structure than Structure C. By rewriting the above inequality, we can show that $U_B > U_C$ if

$$k < \frac{s(1 - \beta^2 + \beta^2 A)}{s + 2\beta s(A-1) + \beta^2(s + 2A - 3sA)}$$

In the extreme case where $k=1$, it is straightforward to show that Structure C always produces higher real income than Structure B.

Summarizing the above observations, we have

Proposition 1. (1) *If individual time preference is sufficiently weak, the general equilibrium structure will involve capital formation and capital use. (2) The general equilibrium structure is more likely to involve the division of labor if the cost of learning and relearning is high and if transaction efficiency is high.*

3. Discussion

In our model, technologies are exogenously given, however technological progress is not entirely exogenous. Since the more advanced technology is embodied in the capital good, N , technological progress only takes place when individuals choose to save and engage in capital accumulation. For example, if Structure A is the general equilibrium structure, new technology is available but not adopted for lack of capital, and the economy stagnates as a result. Thus our model illustrates that advances in technology alone do not automatically generate economic growth.

Economic growth in our model can occur within a structure, and the sources of growth are learning and the adoption of new technology embodied in capital. Within Structure A, growth only occurs in period 2 as a result of learning in period 1. Within Structure B, growth occurs in period 3 as a result of adoption of new technology. Within Structure C, growth occurs in period 2 as a result of adoption of new technology, and in period 3 as a result of learning (to use the new technology in period 2).

Economic growth can also be driven by structural changes. Structural change in our model occurs as a result of changes in exogenous variables such as individuals' time preference, learning costs, and transaction costs. To illustrate, suppose given a set of parameters at the beginning of period 1, the general equilibrium structure is Structure A. If in time n ($n > 2$), individual time preference has weakened then the equilibrium structure may shift to Structure B. This is because given the changed preference, accumulated individual utility from period n onward in Structure A is

$$\beta^{n-1}(L + \beta L + \beta^2 L + \dots) = \frac{\beta^{n-1}L}{1 - \beta}$$

And the accumulated individual utility from period n onwards in Structure B is

$$\beta^{n-1} \left(\frac{L}{2} + \beta \frac{L}{2} + \beta^2 \frac{AsL}{2} + \dots \right) = \beta^{n-1} L \left[\frac{1+\beta}{2} + \frac{\beta^2 As}{2(1-\beta)} \right]$$

An individual gains a higher utility level in Structure B from n period onwards if

higher in Structure B than in Structure A if $\beta^2 > \frac{1}{As-1}$. Similarly, if starting from

Structure B, after m (m>3) periods transaction efficiency improves such that

$k > \frac{s}{s + \beta^2(1-2s)}$ then the general equilibrium structure will shift to Structure C.

As discussed earlier, the level of transaction costs depends on the quality of institutional environment, especially the extent to which the institutions protects property rights and limits the individuals' opportunistic behaviour when participating in market exchange. Our model shows that if institutional quality improves so as to lower transaction costs (i.e., increase transaction efficiency) to a threshold level, economic structure can change which leads to social division of labor and higher per capita real income. This result is consistent with the finding of North and Wallis (1994) that institutional change and falling transaction costs were a significant source of economic growth over the last two centuries.

Notably within our model long-term growth does not occur. This may be thought as a weakness of the model. However in our view, long-term economic growth inevitably comes with continuous structural change – even in the case of a single final good, different technologies typically mean different capital goods, different lengths of the production chain and different specialists and structures of production. It is extremely difficult if not impossible to predict structural changes because the path of change is not smooth, but is instead characterised by discontinuous shifts at irregular intervals. Hence, instead of attempting to model long-term growth, our model has a much more modest goal of illustrating elements of the growth process. In particular it shows that long-term growth requires continuous implementation of better technologies, which requires capital investment. It also highlights the importance of institutional change in promoting the division of labor and economic performance.

4. Conclusion

In this paper we have presented a simple model that links four main drivers of economic growth: technological progress, capital investment, division of labor and institutions. It shows that the benefits of new technologies are realized through capital investment, and that by promoting the division of labor, improvement in institutions can lead to better economic performance.

A noteworthy technical feature of our model is that it explicitly describes the production process through time and characterises different economic structures. Given the temporal aspect of production, individuals must produce before they can consume and save. They must save before capital goods can be made which embody new technology, and the return on their investment is realized after the final goods have been produced. The multiple economic structures mean that for a pre-existing set of parameters at the beginning of period 1, our model predicts that a corresponding structure will be the general equilibrium structure with its own path of economic performance. If parameters change over time, the general equilibrium structure will change, in which case, economic growth is accompanied by structural changes.

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Figure 1. Structures

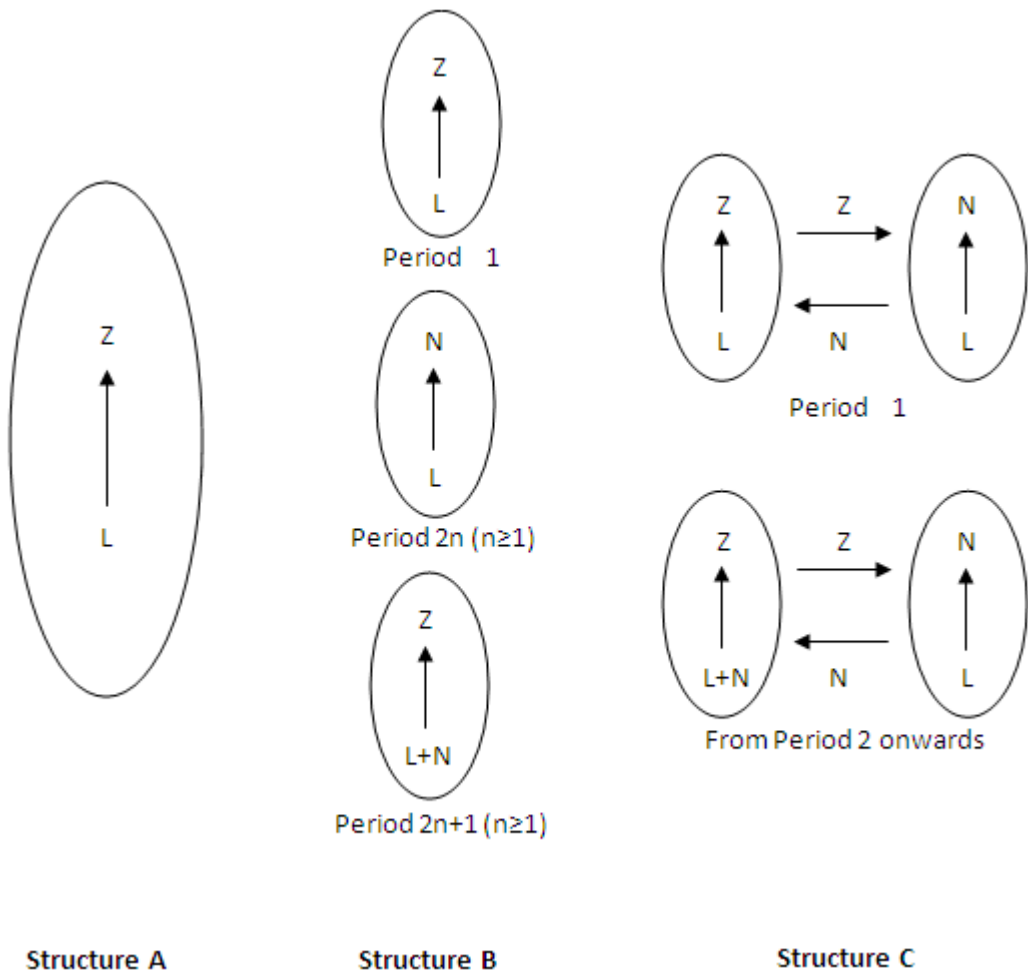


Table 1. Consumption patterns and utility levels

	Structure A	Structure B	Structure C	
			Fisherman	Net-maker
Period 1 consumption	sL	$\frac{sL}{2}$	$sL - P_1sL$	$ksLP_1$
Period 2 consumption	L	$\frac{sL}{2}$	$sAL - P_2L$	kLP_2
Consumption after period 2	L	$\frac{sAL}{2}$	$(A - P_3)L$	kLP_3
Individual utility	$U_A = (s + \frac{\beta}{1-\beta})L$	$U_B = \frac{sL}{2}(1 + \beta + \frac{\beta^2 A}{1-\beta})$	$U_C = \frac{kL}{1+k}(s + \beta sA + \frac{\beta^2 A}{1-\beta})$	

Table 2. Conditions for general equilibrium structures

General equilibrium structure	Conditions
Structure A	$\beta < \min(\frac{2(1-s)}{s(A-1)} + \frac{1}{(A-1)\beta}, \frac{k(1-sA)}{kA(1-s)} + \frac{1}{kA} + \frac{s}{kA(1-s)\beta})$
Structure B	$\beta > \max(\frac{2(1-s)}{s(A-1)} + \frac{1}{(A-1)\beta}, \frac{2kLs(A-1)}{B\beta} - \frac{sL(1-k)}{B})$
Structure C	$\frac{2kLs(A-1)}{B\beta} - \frac{sL(1-k)}{B} > \beta > \frac{k(1-sA)}{kA(1-s)} + \frac{1}{kA} + \frac{s}{kA(1-s)\beta}$

Where $B \equiv [sL(1+k)(A-1) - 2(1-s)kLA]$