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Dynamic Coalitions: Engines of Growth

By EDWARD C. PRESCOTT AND JOHN H. BOYD*

In this study we consider an equilibrium model with sustained growth, in which a dynamic coalition production technology plays a key role. The technology has three major implications. First, even without exogenous technological change, there is sustained growth in per capita output and consumption. Second, unlike the neoclassical growth model, policy can have important effects on *average* growth rates. Specifically, any policy which distorts investment-consumption decisions will alter the equilibrium growth rate. In the economy studied here, such policies are not necessary for efficiency, but in slightly different environments they could be. Third and finally, equilibrium in this model has an interesting industrial organization implication. That is, firm (coalition) size may vary cross sectionally, but there is no tendency for the size distribution to collapse on a single point or, on the other hand, to spread over time. Neither is there any tendency toward a single monopoly firm.

We believe these industrial organization implications are consistent, at least in a highly stylized way, with what is actually observed. This we think is important, for most previous studies have had difficulty in simultaneously accounting for growth and firm-size observations. The problem is, to have growing per capita output, returns to capital cannot diminish. But for the usual production technologies with a labor input, when returns to capital are constant (or increasing), there are also increasing returns to scale. Increasing returns to scale leads to a single monopoly firm, or at least precludes the existence of a competitive equilibrium.

In the environment studied here, the emphasis is on technological knowledge, which is embodied in workers and is partly organi-

zation specific. Hereafter, we refer to this knowledge as “coalition capital” for short. Physical capital is not included in the analysis, although it could harmlessly be added. Returns to investment in coalition capital are “constant” in a sense which will be made precise in the following section. This results in the possibility of long-run sustained growth without exogenous technological change.

A key assumption here is that workers’ productivity depends not only on their own human capital but also on that of their co-workers. Thus, from the perspective of individual agents there is an externality: their personal human capital acquisition decisions affect the productivity of others. And, if such decisions were made in a decentralized market, the expected result would occur: namely, the rate of coalition capital formation would be too low. We do *not* have in mind, however, that this technological interdependency exists between all workers—so that when one invests in his own human capital, it shifts out the production frontier for the nation or world. Rather, such interdependencies are assumed to exist only for workers who are members of the same coalition and have previously worked together. The organizational structure of coalitions allows for richer contracting arrangements than those observed in decentralized markets, and this permits the coalition to correctly reward each member’s capital investment. In fact, the above-mentioned “externality” effectively disappears because it is internalized inside the coalition. Importantly, coalitions have no monopoly power, and none can earn rents in equilibrium—they just earn the market returns on their coalition capital.

Our results are different from those obtained elsewhere in one extremely important respect. In the neoclassical model, economic advancement is determined by exogenous technological change. The model is incapable of delivering any important insights into

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how growth rates are determined or what growth rate is best. In a recent study (Paul Romer, 1986), equilibrium growth is endogenous to the model, but that growth is strictly due to external effects which are not reflected in market prices or private contracts.¹ Thus, the *laissez-faire* equilibrium growth rate may be positive, but it will generally be too low. Obviously, in these environments policy interventions will be welfare improving, at least if the government knows how to set the right policies. In our environment, by contrast, equilibrium growth is due to production externalities which are fully accounted for in coalition contracting. Thus, equilibrium growth is not only endogenous to the model, it is endogenous to the coalitions themselves. Although policy interventions can affect equilibrium growth rates, they are not necessary for efficiency.

We recognize that ours is an extreme characterization of the world and that the truth probably lies somewhere between the two extremes. It seems likely that the economic returns to investing in knowledge are partly but not entirely captured by the individual agents or groups of agents who do the investing. Yet, if such investments are genuinely important in determining equilibrium growth rates, as is widely believed, so too are the institutions and arrangements which determine growth under *laissez-faire*. The fact that there are persistent differences in growth rates across countries suggests the need for models which focus on the institutional arrangements within countries as well as those factors affecting technology. We view our exercise as a first step in that direction.

I. The Economy

Initially, there is some given number of old agents. Each period, that number of young agents are born, and they live for two

periods. Thus, at all points in time there are equal numbers of young and old. Those born in period t for $t=1,2,\dots$ have utility function $u: R_+ \times R_+ \rightarrow R_+$:

$$u(y_t, z_{t+1}) = \ln y_t + \beta \ln z_{t+1}$$

where y_t is consumption when young, z_{t+1} is consumption when old, and β is a parameter, $0 < \beta < 1$. The utility function of an initial old agent is simply $\ln z_0$.

All production activities are carried out by coalitions of agents which are the "firms" in this economy. We have described and discussed such coalitions in some detail elsewhere (see our forthcoming paper), arguing that for some purposes they may be a better representation of the firm than is the standard one (a technology specified as a subset of the commodity space). We discuss these coalitions only briefly here.

Coalitions are groups of agents, all of whom have access to the same blueprint technology. All agents are identically endowed, but may choose to accumulate knowledge at different rates. Thus, over time coalitions may differ too, depending on the decisions of their members which jointly and cumulatively determine coalition capital. Each coalition is composed of young members and old members, all of whom employ their labor services in producing the consumption good. Also produced is the human capital of young coalition members. In the next period they will become old members, and the more human capital they carry with them, the greater the production possibilities of the coalition—both for producing the consumption good and for producing more productive workers in the future. Although individual agents only live two periods, coalitions endure forever in this economy. Formally, the technology is as follows.

Technology

A coalition is characterized by its size in terms of number of experienced old workers M and the expertise of each of its members k . The coalition has young worker inputs N and produces the consumption good as well as new capital or expertise k' which is

¹See Romer for a review of the literature on competitive growth models with externalities. Robert Lucas (1985) also has a competitive model with sustained growth and no exogenous technological change. The key features of his model are that all capital including human capital is reproducible and that production technology displays constant returns to scale.

embodied in each of its young workers. Letting $n = N/M$ be the number of young workers per old, output of the consumption good produced per old, c , is constrained as follows:

$$(1) \quad c \leq kf(n) - h(n)k'n$$

where f is an increasing, differentiable, strictly concave, positive real-valued function and where h is an increasing, differentiable, strictly convex, positive real-valued function. Additional properties will be imposed on functions f and h that guarantee the existence of an equilibrium with positive growth.

It is important to note that the output of the consumption good c , like n and k , is per experienced member, while k' is expertise per young worker. In equilibrium all coalitions will select the same c, n, k' if they have the same k , independent of their coalition size. Consequently there is no "optimal" coalition or firm size to which coalitions converge. Rather, in equilibrium size differences persist with no tendency for big coalitions to become smaller or small coalitions to become bigger.

The rationale for this particular production constraint is as follows: If investment were zero (i.e., $k' = 0$), the output of the consumption good would be $kf(n)$, with $f(\cdot)$ being a standard strictly convex production function and k the "technology parameter." It is important that this function not be homogeneous of degree less than one in k , for then there cannot be sustained growth. As will be seen, the problems of "increasing returns" associated with $kf(n)$ are finessed by the dynamic coalition mechanism.

The second part of the constraint is the investment in new expertise. This output $k'n$ is costly in terms of output of the consumption good. The key assumption that differentiates this model from our earlier one (forthcoming) is that here, as the number of young per old increases, the cost of a given investment increases—that is, $h(\cdot)$ is an increasing function. This we think is a reasonable assumption, for it implies with more young workers per experienced worker, expertise transfer and enhancement become

increasingly costly in terms of the current consumption good.

Absent borrowing and lending between coalitions consumption at a given date is constrained as follows:

$$(2) \quad z + ny \leq c$$

with y being consumption of young and z consumption of old. We will show that in equilibrium there will be no borrowing and lending between coalitions and consequently that borrowing and lending markets need not be included.

II. Constant Growth Equilibrium

We seek a constant growth equilibrium. In this context, *constant growth* means that the capital stock and the consumption of young and old all grow at a common (gross) rate x . Unlike the neoclassical growth model's balanced or steady-state growth path, which is independent of initial capital, our steady-state growth path is proportional to the initial coalition capital k_0 . Summarizing the desired properties of constant growth:

$$(3) \quad k_t = k_0(x^*)^t$$

$$(4) \quad y_t = y^*k_0(x^*)^t$$

$$(5) \quad z_t = z^*k_0(x^*)^t$$

Equilibrium elements (x^*, y^*, z^*) are to be determined.

The key equilibrium condition is that the consumption-training mix offered young (i.e., the (y, k') pair) must be competitive in terms of the lifetime utility that the young will realize. It is competition for young workers by existing coalitions that determines the equilibrium allocation. The old maximize their consumption

$$(6) \quad z_t = \max_{n_t, k_{t+1}, y_t} \{k_t f(n_t) - h(n_t)k_{t+1}n_t - y_t n_t\}$$

subject to the (y_t, k_{t+1}) yielding at least the market indirect utility value for the young

members attracted. This constraint is

$$(7) \quad \ln y_t + \beta \ln(z^* k_{t+1}) \\ \geq \ln(y^* k_t) + \beta \ln(z^* k_t x^*) = u_t^*$$

or

$$(8) \quad \ln \frac{y_t}{k_t} + \beta \ln \frac{k_{t+1}}{k_t} \geq \ln y^* + \beta \ln x^*.$$

A final equilibrium condition is that the labor market clear. As there are equal numbers of young and old workers, this requires that

$$(9) \quad n_t^* = 1$$

for all t .

Letting $x = k_{t+1}/k_t$ and $y = y_t/k_t$, the optimization problem is

$$(10) \quad z^* = \max_{n, x, y \geq 0} \{f(n) - h(n)nx - yn\}$$

subject to

$$(11) \quad \ln y + \beta \ln x \geq \ln y^* + \beta \ln x^*.$$

The first-order conditions for this program when evaluated at equilibrium values $x = x^*$, $y = y^*$, $n = n^* = 1$ are

$$(12) \quad 1 = \lambda / y^*$$

$$(13) \quad h(1) = \lambda \beta / x^*$$

$$(14) \quad f'(1) - h'(1)x^* - h(1)x^* - y^* = 0$$

where λ is the Lagrange multiplier. Solving these necessary first-order conditions of this (nonconcave) program yields

$$(15) \quad x^* = \frac{\beta f'(1)}{\beta h'(1) + \beta h(1) + h(1)}$$

$$(16) \quad y^* = \frac{f'(1)h(1)}{\beta h'(1) + \beta h(1) + h(1)}.$$

Substituting these values along with $n^* = 1$

in (10), we obtain

$$(17) \quad z^* = [f(1)[\beta h'(1) + \beta h(1) + h(1)] \\ - f'(1)h(1)(1 + \beta)] / [\beta h'(1) + \beta h(1) + h(1)].$$

These elements are all nonnegative given our assumptions. By multiplying function h by a positive constant, y^* and z^* are unchanged, but x^* is multiplied by the reciprocal of that constant. Thus, for a suitable h , x^* will exceed one and there will be positive growth. We assume that h is such that this is the case.

Some additional conditions are needed to ensure that in equilibrium it is not in the interest of coalitions to borrow from and lend to each other. In particular, we want it *not* to be in the interest of a borrowing coalition to make a larger per capita investment in coalition capital and a lending coalition to make a smaller one. If this were to happen, coalitions would not remain identical in equilibrium and the above (x^*, y^*, z^*) would not define a constant growth competitive equilibrium.

A condition which assures that there are no gains from concentrating the capital in a fraction of the population is as follows:

$$(18) \quad \max_{n, x \geq 0} \{f(n) - h(n)nx + q^*nx \\ - (q^*x^*/\beta) - w^*n\} \leq 0$$

where

$$(19) \quad w^* = y^* + q^*x^*$$

$$(20) \quad q^* = h(1).$$

In the above, w^* is the equilibrium real wage divided by k and q^* the equilibrium price of new capital for an economy in which capital is tradeable. This technical issue is developed fully in Prescott (1986).

III. Concluding Remarks

This model, like those of Robert Lucas (1985) and Romer accounts for sustained growth in per capita income with little if any tendency for countries to converge to a common growth path. The hope, however, is that this structure will prove useful in accounting

not only for similarities, but also for differences in growth experiences, some of which are dramatic. Our theory predicts more rapid growth rates if the fraction of resources allocated to enhancing coalition capital is larger. This model also implies that young residents of low-income countries will gain income by moving to a high-income country. Perhaps improved time-allocation studies of people at work in organizations will confirm or refute the value of this abstraction.

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