Growth Theory Needs an Institutional Structure

De-Xing Guan*

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<u>Abstract</u>

In this short paper I argue that both Robert Solow's neoclassical model and the endogenous growth theory, pioneered by Paul Romer and Robert Lucas, are inadequate to deal with facts of economic growth in real life because they lack an *institutional structure*. By this structure I mean a framework in which knowledge accumulation and spillover can be well explained and meaningfully determined. Though Solow had failed to explain where the purely public technology input comes from, endogenous growth theory also could not tell us why there is a *free* spillover of useful knowledge and why the patented period of R&D has to be infinite, rather than a finite one such as 20 years or so as in reality. Traditional arguments focus on whether perfect competition or monopolistic competition is not necessary and primarily miss the point. Should we introduce *transaction costs* of generating and transmitting knowledge into growth theory, we could realize why increasing returns are an *unnecessary* assumption in most economic growth literature, and why the classical emphasis on decreasing returns and aggregate constant returns to scale has still been very useful in explaining growth phenomena in the real world.

^{*} Department of Economics, National Taipei University, email: guan@mail.ntpu.edu.tw. Comments are welcome.

I. Introduction

The theory of economic growth is concerned with the *mechanics* of changes in the level and growth rate of per capita income. It has usually been characterized by an aggregate production function, which describes the technological relations between various inputs and outputs. For example, let Y = F(A, K, L), where *A* is technology factor, *K* is capital, *L* is labor, and *Y* is final output. In Solow's (1956) neoclassical growth theory *A* is a pure public good, and *F* is homogeneous of degree one in *K* and *L*, but not in *A*, since the underlying market structure of this theory is perfect competition. The weakness of Solow's model is that we could not use it as a framework to discuss the R&D behavior of business firms because the intentionally invented ideas could hardly be purely public. And even if we ignore the importance of R&D in generating long-run growth, a continuous increase in technology factor *A* would still be necessary for sustaining per capita income growth in the long run. But this is inconsistent with empirical facts. In reality technological changes would only occur in discrete times.

To modify this weakness some economists such as Romer (1986) and Lucas (1988) initiated a program which tried to endogenously determine the source of growth, not just letting it be a residual as in Solow's model. They had put knowledge or human capital in the forefront of their models, and then economic growth is a by-product of knowledge spillover or *externality*. Every individual accumulates her human capital through schooling or on-the-job-training and this contributes to the total amount of human capital in society. The larger is the aggregate human capital or knowledge, the larger is the rate of per capita income growth because there are positive external effects generated by aggregate knowledge.¹

Unsatisfied with the knowledge-as-by-product explanation of economic growth, Romer (1990) introduced the profit-maximizing motives of business firms into the model, and since then R&D has become the dominant figure in many economists' stories of economic growth. Because firms would have positive profits in long-run equilibrium when undertaking R&D, the conventional assumption of perfect competition, as used by Solow as well as Romer and Lucas in the 1980s, would be inappropriate to discuss R&D behavior. As a result and thanks to the contribution of Dixit and Stiglitz (1977), Chamberlin's (1933) theory of monopolistic competition has been the workhorse of Romer (1990) and many follow-up works.²

¹ A more recent example has been Lucas, who said that "What is central, I believe, is the fact that the industrial revolution involved the emergence...of a *class* of educated people, thousands—now many millions—of people who spend entire careers exchanging ideas, solving work-related problems, generating new knowledge." (2009, p. 1)
² There are other people who also disagree with perfect competition, but for different reasons. A most recent example might be the *Black Swan* phenomenon introduced by Taleb (2007), who emphasized the impact of rare and unpredictable events. Nevertheless, there was no uncertainty in Romer's models. And Lucas, Romer's teacher at the University of Chicago, disagreed with monopolistic competition as a framework to discuss economic growth. For example, he said that "...patents and "intellectual property" more generally play a very modest role in the overall growth of production-related knowledge. I have sought a formulation that emphasizes individual contributions of

Either knowledge externality or R&D would result in *increasing returns* and *nonconvexities*. Constant returns to scale or diminishing marginal returns to capital has disappeared ever since Romer and Lucas wrote their seminal papers. But unfortunately increasing returns have never passed the empirical tests. Both Jones (1995) and Basu and Fernald (1997) provided evidences against the assumption of aggregate increasing returns. They favored aggregate constant returns to scale (CRS). So we have a *puzzle*: to have intentional R&D a monopolistic competition setup was adopted, but this contradicts empirical facts of aggregate CRS; and to accommodate CRS an unexplained by-product of knowledge accumulation was assumed, but this has nothing to do with R&D behavior. We could not have R&D and aggregate CRS simultaneously. We can only choose one. How can we get rid of this puzzle? And by which criterion can we choose between perfect competition and monopolistic competition? These questions are still open and I try to propose some solutions to them in this paper.

The two cases in this puzzle have something in common. They had both ignored economic institutions. In the case of knowledge externality as the engine of growth, both Romer and Lucas ignored the fact that useful knowledge could *never* be free and any free knowledge must be either useless or purely public, and people would not pay for common knowledge. This sounds like a restatement of the arguments of Hayek (1945). If Hayek was right, then why would people accumulate knowledge? They cannot get anything in return in a Romer/Lucas world. And were knowledge not accumulated in the first place, there would be no external effects of knowledge, and the economic growth would eventually come to an end, according to the models of Romer and Lucas.

In the case of Romer's R&D model it was required that the patents of R&D, once granted, would prevail perpetually. This obviously contradicts the fact that in reality a typical patent lives only for less than 20 years. Someone might say that this weakness could be overcome because it is only a modeling strategy to simplify mathematics. But this is not the case. It is a necessary assumption if you want to use Chamberlinian monopolistic competition to model R&D behavior. The problem is that Chamberlin's model is *inadequate* to deal with R&D because the firm could not keep the monopoly rent in his model if the property rights of those patents had not been effectively protected.³ We will discuss this further in Section III.

The issues the above two cases had ignored are, for the first case, why there is a free positive externality from knowledge, and for the second one, why there is an infinite life for

large numbers of people, in which the role of market power is minimized..." (Lucas (2009, p. 18)) ³ This model has also been applied to trade theory and Paul Krugman was awarded last year's Nobel Prize for his contributions in international trade and economic geography. A most recent application was Grossman and Rossi-Hansberg (2008), which discussed task trade between similar countries. But both this work and those of Krugman suffer from this *inadequacy* problem in monopolistic competition.

R&D patents. To answer these questions we must get back to the Pigou/Knight debate in the 1920s. This is the famous *two-road problem*. A good but narrow road attracts more vehicles than a bad but broad road does. Then there would soon be congestion and overinvestment for the good road. To achieve social optimum of using roads the government could impose a *Pigovian tax* on users of the good road such that in equilibrium the speed of these two roads would be the same. This is the solution proposed by Pigou (1920) in *The Economics of Welfare*. Almost every economist has ever since believed that this solution would be right, and it has also been the foundation of modern welfare economics. And it offers a job to the government: to levy a tax when there is a negative externality, and a subsidy when the externality is positive. Probably Frank Knight was among the few economists who felt uncomfortable towards Pigou's solution. And Knight's (1924) alternative explanation of the two-road problem had paved the way for Ronald Coase (1960) to propose his famous (*Coase*) *Theorem* 36 years later.

What Knight had done was to show that the *thing-in-itself* of the two-road problem is not about taxation, but about *property rights* of the roads. He claimed that if the rights of owning or using these roads were delimited, then the owner of the good road would collect a toll on those who use it at exactly the same taxation which government would otherwise impose. One thing left unresolved was why this is a better solution in terms of social optimum. This was answered once and for all by Coase (1960). Both delimiting property rights and using government would have *transaction costs*, and because the cost of using markets is usually lower than that of using government, the delimitation of property rights is usually a better solution in terms of a larger aggregate production for society as a whole.⁴

This paper is organized as follows. Section II uses the aggregate production function to discuss why a free externality is implausible. Section III extends the discussion further to the question why R&D could not happen if there were no transaction costs. Section IV uses examples to illustrate how we can build an institutional structure which makes growth theory more useful in explaining facts in real life. Section V concludes.

II. There's No Such Thing as a Free Externality

The building block of the endogenous growth theories of Romer (1986) and Lucas (1988) was the positive externalities of aggregate knowledge capital. For example, Romer had used

⁴ The essence of Coase Theorem is that "It is necessary to know whether the damaging business is liable or not for damage caused since without the establishment of this initial delimitation of rights there can be no market transactions to transfer and recombine them. But the ultimate result (which maximises the value of production) is independent of the legal position if the pricing system is assumed to work without cost." (Coase (1960, p. 8))

the following aggregate production function:

(1) $Y = AK^{\alpha}L^{1-\alpha}\overline{K}^{\gamma}$,

where \overline{K} is the aggregate knowledge capital, assumed to be a perfect substitute for the aggregate physical capital K. The parameter $\gamma > 0$ indicates the positive external effects of aggregate knowledge. Then the growth rate of per capita income would be positively related to the externality parameter. Since physical capital is endogenous, so is knowledge capital, and therefore this is an endogenous growth model.⁵ Now aggregate production function in equation (1) has increasing returns to scale (IRS), and there is long-run per capita income growth if there is a positive externality. In this world, according to Pigou as well as Romer and Lucas, the government could stimulate long-run economic growth by subsidizing knowledge accumulation. In fact this is even unnecessary because only a tiny but positive externality could do all the work. What the government needs to do is to choose the targeted rate of growth. What a wonderful but unrealistic world this theory would lead us to!

So what's wrong with this theory? First of all, according to Hayek (1945), the use of knowledge has costs. Knowledge which could generate positive externality must be useful. The question is what the price of such useful knowledge would be.⁶ Both Knight (1924) and Coase (1960) had shed light on this question. As discussed in the two-road problem, if there is a negative externality, say congestion, then people would have incentives to internalize it by establishing property rights of the roads. When rights are delimited market transactions would then proceed. The toll users of the good road have to pay is the payment for the owner of the property (good road). In such a situation most of the externality has been internalized.

One thing should be noted here. Because the delimitation of rights needs costs, it could not be complete. This means that the internalization of externalities could never be complete. The only possibility for complete internalization would be that there are no transaction costs. When delimiting property rights are costless all rights must be completely delimited, and this means that all externalities must also be internalized. Externality would be just like a productive factor which has a market price, and the external effects are just the output of using this factor, which could never be a *free lunch*.

⁵ When labor is exogenous and normalized to unity, and when $\alpha + \gamma = 1$, equation (1) becomes known as the *AK* model, which is a special case of Romer's original framework.

⁶ What Hayek emphasized was that the price system is the best way to organize localized and dispersed knowledge of various people. But not all people look in this way. For example, Taleb, an admirer of Hayek, had reached a different conclusion. He said "...the reason free markets work is because they allow people to be lucky, thanks to aggressive trial and error, not by giving rewards or "incentives" for skill. The strategy is...to collect as many Black Swan opportunities as you can." (2007, p. xxi)

The welfare solutions provided by Romer and Lucas, namely Pigovian tax or subsidy, are also misleading. For example, from equation (1) we can calculate the private and social marginal product of knowledge capital respectively as

(2)
$$MPK(P) = \alpha A K^{\alpha - 1} L^{1 - \alpha} \overline{K}^{\gamma}$$
,

which takes aggregate knowledge as given, and

(3)
$$MPK(S) = (\alpha + \gamma)AK^{\alpha - 1}L^{1 - \alpha}\overline{K}^{\gamma}$$

since \overline{K} is endogenous to the social planner and $K = \overline{K}$ if labor is normalized to unity. Dividing (2) by (3), we would have

(4)
$$\frac{MPK(P)}{MPK(S)} = \frac{\alpha}{\alpha + \gamma}$$
.

Equation (4) implies that social marginal product of capital is larger than the private one if there is a positive externality from knowledge capital. A Pigovian subsidy is now called for by the government because private sectors produce too little knowledge from a social point of view. This seemingly right conclusion is unfortunately wrong because there is no such thing as a free externality. When there is a positive externality any person who has the right of the useful knowledge would like to get returns from those people who use it. This compensation scheme internalizes the externality through price mechanism. The internalization of externalities would in general be incomplete because there are transaction costs in doing this, but it would never be costless. What Romer and Lucas had ignored was that there would be no knowledge spillover effects if creating and transmitting useful knowledge had not incurred costs, as assumed implicitly in their models as well as in Pigou's. But all externalities should already be internalized if there were no transaction costs. If there were such thing as a free externality of knowledge, it must be the situation where the knowledge would be useless in production or soon be exhausted by too many free riders.

III. Monopolistic Competition Is Not the Solution

Inspired by the work of Dixit and Stiglitz (1977), Paul Romer (1990) had finished a second-generation growth model using Chamberlin's (1933) monopolistic competition as a

framework to address the intentional R&D behavior of business firms. Romer's model could be reduced to the following simplest form:

(5)
$$Y = L^{1-\alpha} \sum_{i=1}^{A} K_i^{\alpha}$$
,

where there are differentiated capital inputs which could be ordered by the number of the subscript. A bigger number means a more advanced technology embodied in that capital input, which is therefore introduced into the economy more recently. These inputs have a constant elasticity of substitution among each other, which is equal to $1/(1 - \alpha)$. This Chamberlinian monopolistic competition has a long-run equilibrium in which the marginal firm earns zero profit and the long-run average cost curve (LAC) would be tangent to the demand (or average revenue) curve. The very distinction between this model and the one with perfect competition is that the former has a fixed cost which would not disappear even in the long run. The usual economic explanation of this fixed cost is that it represents the cost of R&D or that of introducing the newest technology or commodity into the economy. Hence for the marginal firm there is also an equilibrium condition that requires the fixed cost be equal to the discounted sum of future returns of having the newest good. In this sense it is actually a *rent* of this new good. We will come back to this issue later.

Since the demand curves for capital are negatively sloped if their markets are monopolistically competitive, the economic profit would be positive (which is equal to the fixed cost), though the accounting profit would just be zero, as required by the implicit assumption of free entry and exit made by Chamberlin. His original idea was transformed into mathematics by Dixit and Stiglitz (1977), which has been the workhorse for many fields in economics since late 1970s, such as trade, economic geography, and economic growth. Equation (5) was actually a modification of Dixit and Stiglitz's setup by Romer. In a world of monopolistic competition there are increasing returns to scale (IRS) and nonconvexities in the production possibility set. For example, in a symmetric Dixit-Stiglitz solution to equation (5) each firm's capital can be denoted by *K*, and the aggregate production function would become to

(6)
$$Y = L^{1-\alpha} \sum_{i=1}^{A} K^{\alpha} = L^{1-\alpha} (AK^{\alpha}) = AK^{\alpha} L^{1-\alpha},$$

which looks the same as the aggregate production function in Solow's (1956) model. Though they look similar, the interpretation of them is quite different. In equation (6) the technology index is an endogenous variable which can be determined from the profit-maximization behavior of firms. It is not a pure public good. On the other hand, the technology factor in Solow's model is purely public, which is an exogenous variable. This means that equation (6) has the property of IRS because

(7) $\lambda Y < (\lambda A)(\lambda K)^{\alpha}(\lambda L)^{1-\alpha}, \forall \lambda > 1,$

but it should be an equality in equation (7) for the Solow model because duplicating a purely public and intangible good such as knowledge is meaningless. The result is that in Romer (1990) the aggregate production function might be IRS but it is a CRS technology in Solow's model. If the empirical facts of Jones (1995) and Basu and Fernald (1997) are not our concern, then what is the main shortcoming of Romer's monopolistic competition framework? The answer rests again on the ignorance of property rights issue by Romer, just as that by Pigou in the two-road problem.⁷

As mentioned above the fixed cost of R&D is just the monopoly rent of the useful knowledge created. This has close connections with the literature in public finance. For example, the well-known problem of *the tragedy of the commons* would be very useful in explaining why Chamberlin had provided a *lame* workhorse for all his followers. This tragedy could be best explained by the overfishing problem of Scott Gordon, as explored by Cheung (1970). When there are many fishermen and all of them have non-exclusive rights to fish in the common fishing ground, each of them would only obtain very few fishes. The solution to this problem would be to establish property rights for fishing, say issuing licenses, such that fishermen with better skills could keep more harvest, and the waste of social resources used in fishing would be minimized. But to delimit exclusive rights, either ownership or use right, needs costs. When there are no transaction costs in establishing property rights, there would be no exclusive rights to fish, and as a result there would be a tragedy of using the common resource.⁸

There are two shortcomings in Romer's (1990) R&D model. First, there is an infinite life for a R&D patent. This contradicts facts in real life, which are usually less than 20 years. Second and more importantly, in long-run equilibrium the marginal firm can keep a positive economic profit, the equivalent of monopoly rent, without incurring any costs in protecting this profit or rent. According to the arguments of the tragedy of the commons, if the firm that

⁷ Ironically, Romer was not fully ignorant of this issue. For example, Barro and Romer (1987) had mentioned the two-road problem and also Knight's (1924) arguments in their paper on ski-lift pricing. What they lacked was the recognition of the role of transaction costs in establishing property rights. They only compared the solution of Pigou with that of Knight but failed to see the connection between property rights and transaction costs.

⁸ This could also be considered as a special case of the well-known *Coase Conjecture* (see Coase (1972)). Actually I believe that Romer knew this problem, but what he had done was to assume it away! In p. S82 of his 1990 paper he said that "It is also easier to assume that the firm that buys a design…rents its durables instead of selling them outright…this shows that there are market mechanisms that avoid the usual durable-goods-monopoly problem."

invents the newest knowledge does not register the exclusive rights in owning or using it, then there would be no patents to prevent other firms from using it freely, and the monopoly rent would simply dissipate. The resulting equilibrium would therefore no longer be a monopolistically competitive one. The *dissipation of rent* is an unavoidable result in Romer's model unless the transaction costs in establishing and enforcing property rights would be incorporated into his model. In fact, all models using Chamberlin's monopolistic competition will have the same problems as Romer's model has had. Economists who dislike perfect competition would have a wrong choice because Chamberlin did not offer a better alternative. Models with monopolistic competition would either have the same equilibrium as that in perfect competition if there are no transaction costs, or reach other equilibrium such as that in overfishing problem if there are no well-defined property rights of fishing because the fisherman could not afford the transaction costs needed to establish those rights. In either case monopolistic competition would not provide us with better explanation of facts in real life.

IV. The Institutional Structure We Need

Beginning with the Pigou/Knight debate in the 1920s, externalities, together with transaction costs and property rights, have been among the most important but unresolved problems in economics. Following the suggestion of Alfred Marshall, Pigou put the emphasis on the distinction between external economies and diseconomies, or positive and negative externalities in modern words, and had laid the foundation of modern welfare economics by providing the government with simple tools to correct the wrongdoings of the market: the Pigovian tax and subsidy. No one had questioned the policy recommendations of Pigou except Knight (1924) and Coase (1960), though Frank Knight had challenged Pigou just four years after *The Economics of Welfare* was published. Unfortunately Pigou deleted the two-road problem in his later editions of that book. This was why the debate had never been heated before Coase wrote his famous 1960 paper. But even after Coase had offered his doubts towards the Pigovian tradition, most economists had still stood by the side of Pigou. This can explain why the arguments of Knight and Coase have only appeared in one page, in a footnote, or even entirely disappeared in many textbooks in economics.

Then what had been done in this important and lasting debate? Knight's (1924) contribution has been to emphasize the importance of property rights in solving the problem stemming from externalities. He had also questioned the relevance of increasing returns, an idea emphasized by his teacher Allyn Young and adopted later by both Romer (1986) and Lucas (1988). But Knight failed to recognize the role played by the transaction costs in

delimiting property rights. When studying the behavior of the Federal Communications Commission (FCC) Ronald Coase had found the *reciprocal nature of the problem* (of externality). This finding had inspired him to bring transaction costs, an idea he created in early 1930s, to the study of property rights and externalities. He had recognized that property rights are the prelude of market transactions, and delimiting these rights needs costs. And finally he had reached a conclusion that "...the problem is one of choosing the appropriate social arrangement for dealing with the harmful effects. All solutions have costs and there is no reason to suppose that government regulation is called for simply because the problem is not well handled by the market or the firm." (1960, p. 18)

The main points of Coase's arguments were that both using markets and using the government would incur transaction costs. The problem is to compare with one another the total costs (including transaction costs) in using different institutions. These institutions might be markets, firms, or the government. In this sense the institutional structure of society is actually about how the transaction costs are determined and how they would influence the behavior of households, firms, markets, and the government. Different societies would have different institutions just because they have different transaction costs, and these costs are the result of complicated interactions of various agents in society. There is no such thing as a perfectly competitive market just because there would never be zero transaction costs for a society. And Chamberlin had also missed the point because monopolistic competition, just like perfect competition, would be meaningless if there were no transaction costs, for the reason described above. Of course, neither Chamberlin nor Dixit-Stiglitz and Romer had mentioned transaction costs. This is the major problem in all models using a Chamberlinian framework.

So what can we do to find such an institutional structure for the theory of economic growth? This is a difficult and complicated problem to which we still have no solutions. But we can use an example to illustrate how the problem could be solved if there are transaction costs. The following example, adapted from Jones (2002, Chapter 4), is the simplest one I can find in growth theory. Suppose that there is an aggregate production function Y = X - F, $X \ge F$, where *Y* is output, *X* is input, and *F* is the fixed R&D cost of inventing new ideas in terms of the input. The LAC associated with this production function would be decreasing because there is a fixed cost. Specifically, the LAC could be represented by LAC = X/Y = 1 + (F/Y), which is obviously decreasing in output. When the output grows, the LAC will decline to the marginal cost which is equal to unity in this case. The decreasing LAC indicates that there are both IRS and nonconvexities with this production function.

If we stay with Romer in the world of monopolistic competition, then the story would end

up with the standard result, in which the equilibrium is not optimal in Paretian sense, and the government should subsidize the firm that had created this novel idea. But this is definitely not the happy ending in a Coasian world where there are positive transaction costs. As discussed above, the fixed R&D cost is a monopoly rent authorized to the inventor of the newest idea. Without the establishment and enforcement of property rights, no protection of the rights or patents is guaranteed, and this means that this rent would eventually dissipate. To keep the rent the inventor has to register the property rights, and the protection and enforcement of rights require the government to establish laws to enact and protect patents. This legal process is essential to the progress and prosperity of society if the invention of new and better ideas is important for the economic performance of society.

Now let the transaction costs in establishing property rights be *C*. The aggregate production function turns out to be Y = X - F + C, since transaction costs are expenditure for firms. As in the overfishing problem if the rights of fishing are not exclusive the rent could not be kept. This indicates that the rent dissipated is related to the costs incurred in establishing property rights. If there are no other uses of the resources such that *Y* is the only output and *X* is the only input, then the decrease in total transaction costs would be equal to the increase in total rents in producing this output, or $-\Delta C^T = \Delta R^T$.9

Note that the fixed cost is not a cost. It is a rent. And rent is not cost.¹⁰ The resources devoted to the invention of new idea could be saved if the firm would know the fact that there would be a tragedy of the commons if there were no property rights. The firm would therefore like to incur costs to establish and protect its rights. The costs incurred would be equal to the rent earned if there are no other inputs and outputs and if there are no other opportunities for this firm to rearrange these inputs or outputs in different ways.

The last equation of this simplest example needs more elaboration. First, the total transaction costs in the overfishing case have two parts: those incurred to establish property rights and those reduced had property rights established. No overfishing would occur were license of fishing needed. The former part of the transaction costs must be no larger than the latter one in absolute values; otherwise no property rights would be established in the first place.¹¹ The absolute value of the transaction costs reduced ($-\Delta C^T$) must be equal to that of the rents increased (ΔR^T), if there are no other uses of these resources. If we assume that

⁹ This condition is not always right because most of the time the resource would have other uses. When this happens the relation between the dissipation of rent and the change of transaction costs would be more complicated. I am currently working on such a model in which resources have multiple uses. The current example is a special and also the simplest case of the general model in that paper.

¹⁰ All costs in economics should be *opportunity costs* and, according to Coase, rent is the difference between what a factor of production earns in the activity under discussion and what it could otherwise earn. Obviously, they are different concepts.

¹¹ These two transaction costs must be equal to each other in absolute values if there are no other uses of these resources. The former must be smaller than the latter in absolute values if there are other uses of the resources.

once the fishing rights are established there would never be overfishing and no other resources would be wasted, then $C = -\Delta C^T$. Because there is no rent if there are no property rights, and assume that initially transaction costs are zero, then the monopoly rent is the total rent increased, or $F = \Delta R^T$. Consequently, we have C = F. With this equality the aggregate production function is now simply Y = X, which is convex with CRS property.

It seems that this technology is indifferent from that in perfect competition. But this is wrong. They have very different interpretation. In perfect competition there are no transaction costs, so there would be no rent, and no R&D behavior exists because firms would have no incentives to undertake the research work necessary for inventing new goods. But in the last example we have shown both R&D and rent are present, and it is property rights such as patents that give firms incentives to bring new ideas into existence. The lesson we have learned from this would be that a nonconvex and IRS technology is *unnecessary* for dealing with R&D behavior. A standard convex and CRS aggregate production function could do the same work without contradicting empirical evidences of Jones (1995) and Basu and Fernald (1997). The conclusion is obvious: we need a theory of competition with transaction costs. This is the foundation of the institutional structure of economic growth. This theory, if created, would be very different from perfect competition because the latter is defined as a theory without transaction costs.

One view held by most economists should be modified were the institutional structure accepted. The welfare theorems, independently verified by Kenneth Arrow and Gerard Debreu in 1951, are mathematically correct but of little use in analyzing government policies in the real world. The equivalence between Pareto optimum and competitive equilibrium is a mathematical truth, but both of these two concepts describe a world we are not living in!¹² The world they try to explain is one with zero transaction costs. In this world there would be no firms, no government, and even no markets. After all, it is not surprising to realize that an ideal world in the sense of Pareto could be sustained by perfect competition, a world without transaction costs. In addition, the idea of Pigovian tax and subsidy should be abandoned unless transaction costs are explicitly taken into account. In practice it is difficult to know what are the appropriate tax and subsidy to achieve social optimum because the government does not have enough information to do right decisions. Policies based on the Pigovian scheme would very probably be misleading.

Transaction costs would never be zero in reality. They must be positive. We need a competitive theory with positive transaction costs. Government policies should be evaluated

¹² Even Pareto himself had not thought that these results could be applied to policies in the real world. For example, Hayek had said that "This is something altogether different from showing how the allocation of resources satisfying these conditions can be found in practice. Pareto..., far from claiming to have solved the practical problem, in fact explicitly denies that it can be solved without the help of the market." (1945, p. 529)

by comparing with one another the total costs (production costs plus transaction costs) of using various institutions. Different transaction costs would result in different institutions, and the resulting institutional change would in turn change the transaction costs in the original institutions. The interactions between transaction costs and institutional changes would form what we have called the institutional structure of society. Government policies should be based on this structure such that we will be comparing a real, not hypothetical, model with facts in real life.

V. Concluding Remarks

The study of economic growth has been the focus of macroeconomics since Romer and Lucas published their seminal papers in the 1980s. There are two basic schemes in growth theory, one with perfect competition and knowledge spillover effects and the other with monopolistic competition and intentional R&D. Both schemes had stressed the importance of knowledge or ideas in generating long-run growth. Though these theories have raised interesting questions they have not addressed the core problem of a knowledge-based economy, that is why and how would the useful knowledge be used in society? To this question Hayek (1945) had given a heuristic answer, though he did not pay any attention to the theory of economic growth.

In the first scheme of growth theory, pioneered by Romer (1986) and Lucas (1988), the useful knowledge was a by-product of the external effects of aggregate knowledge. But as forcefully argued by Hayek, if the knowledge is useful, otherwise it could be helpless for economic growth, the possession and use of it would involve costs. In other words in a world without transaction costs, such as the one in Romer and Lucas, the externality of useful knowledge must be either very insignificant or even nonexistent. The engine of growth in their models seems to lose its power.

On the other hand, Romer (1990) had proposed that the engine of growth should be R&D of the firm. New ideas from R&D are the key to economic growth. But again he had ignored that the establishment of property rights of R&D, say patents, would need costs. Without assuming transaction costs in his model Romer could not have reached the monopolistically competitive equilibrium, in which firms would have earned positive economic profits or monopoly rents. These rents would simply dissipate were there no transaction costs needed in protecting them. The R&D engine still does not work.

To solve this paradox in growth theory we need a theory of competition with positive

transaction costs. This theory would be neither perfect competition nor monopolistic competition. In fact they are indistinguishable from each other if there are no transaction costs. A theory with transaction costs would provide us with useful tools to deal with the problem of externality and to meaningfully evaluate the effects of government policies. Based on such a theory we can also try to create institutions with less transaction costs, more economic rents, and therefore higher rate of economic growth. The resulting institutional structure would be complicated. We are still in the beginning of finding such an institutional structure. Hopefully, we will be creating more knowledge and better institutions and, based on them, will be more effectively utilizing the useful knowledge in society through the price system. This would be the most powerful engine of growth we can find both in theory and in reality.

References

- Barro, Robert J. and Paul M. Romer (1987): "Ski-Lift Pricing, with Applications to Labor and Other Markets," *American Economic Review*, 77, 875-890.
- Basu, Susanto and John Fernald (1997): "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy*, 105, 249-283.
- Chamberlin, Edward (1933): *The Theory of Monopolistic Competition*, Cambridge, MA: Harvard University Press.
- Cheung, Steven N. S. (1970): "The Structure of a Contract and the Theory of a Non-Exclusive Resource," *Journal of Law and Economics*, 13, 49-70.
- Coase, Ronald H. (1960): "The Problem of Social Cost," *Journal of Law and Economics*, 3, 1-44.
- --- (1972): "Durability and Monopoly," Journal of Law and Economics, 15, 143-149.
- Dixit, Avinash and Joseph Stiglitz (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67, 297-308.
- Grossman, Gene and Esteban Rossi-Hansberg (2008): "Task Trade between Similar Countries," NBER Working Paper No. 14554.
- Hayek, Friedrich A. von (1945): "The Use of Knowledge in Society," *American Economic Review*, 35, 519-530.
- Jones, Charles I. (1995): "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics*, 109, 495-525.
- --- (2002): Introduction to Economic Growth, 2nd ed., New York: Norton.
- Knight, Frank H. (1924): "Some Fallacies in the Interpretation of Social Cost," *Quarterly Journal of Economics*, 38, 582-606.
- Lucas, Robert E., Jr. (1988): "On the Mechanics of Economic Development," *Journal* of Monetary Economics, 22, 3-42.
- --- (2009): "Ideas and Growth," *Economica*, 76, 1-19.
- Pigou, Arthur C. (1920): The Economics of Welfare, London: Macmillan.
- Romer, Paul M. (1986): "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 94, 1002-1037.
- --- (1990): "Endogenous Technological Change," Journal of Political Economy, 98, S71-S102.
- Solow, Robert M. (1956): "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70, 65-94.
- Taleb, Nassim N. (2007): *The Black Swan: the Impact of the Highly Improbable*, New York: Random House.