Competition, Innovation and Economic Growth: Does competition encourage or discourage R&D and growth?

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Autumn Term 2005
Chapter 1

Introduction

It has long been well established amongst economists and policy makers alike that innovation and technological progress are the engine that drives economic growth. In the post-war era, Solow (1956) and Swan (1956) demonstrated the importance of technological progress in their pioneering work, now commonly known as the Neoclassical growth model. In this model, it is shown that, owing to the effects of diminishing marginal returns from the capital, income level per capital would cease to grow if there were no technological advancement.

Since then, there has been continuous development on theoretical models on economic growth. The 60s saw the incorporation of microeconomic foundations—optimising individual’s decision making process—into what is essentially a macroeconomic model of economic growth. While all models stressed the importance of technological progress on economic growth, they effectively assumed that the rate of technological progress was exogenously determined, rather than as an equilibrium outcome of conscious economic decision making. Towards the end of 80s saw models endogenising technology—the rate of technological advancement is derived in the model from the firms’ decision-making process. The works by Romer (1986, 1988) and Lucas (1988) are widely credited with this breakthrough although early attempts were made by Uzawa (1965), Shell (1966, 1967) and Phelps (1966) amongst others. These models are all casually known as endogenous growth models for obvious reasons.

1990s saw various redevelopments on the standard endogenous growth model by Romer. The models by Segerstrom, Anant, and Dinopoulos (1990), and by Aghion and Howitt (1992), which incorporate Schumpeter’s (1942) idea of “creative destruction” into endogenous growth models, became popularly known as Neo-Schumpeterian models. This class of models focuses on the relationship between intensity of competition in the market, the rate of technological progress and the resulting equilibrium growth path of the real output. Since the early 90s, variations of the Neo-Schumpeterian models have been created with conflicting implications on the relationship between competition, innovation and economic growth.

This dissertation focuses on these recent models of economic growth, and attempts to establish, if any, a relationship between the degree of competition in the product market and rate of economic growth. The organisation of this thesis is as follows: the next chapter critically surveys the literature. The conclusions, implications and hypotheses of this literature lead to chapter 3, in which an empirical analysis is conducted using methodology XXX. In light of the results obtained in chapter 3, chapter 4 questions the methodology adopted in the previous chapter, and estimates a new model using methodology XYZ. Chapter 5 interprets and evaluates the model/results. The last chapter concludes.

1See Koopmans (1965), Diamond (1965)
Disclaimer

The introduction chapter written above is a brief version of what I would write as an introduction to the “excellent” literature review of chapter 2. It is not to be taken as a model introduction to every dissertation. Its structure may not be ideal for other topics. The organisation of this handout is as follows: chapter 2 is an example of an excellent literature review on this topic. What it shows and why it is excellent will be explained in the lectures. Chapter 3 is an example of a bad literature review, which resembles a patchwork of other people’s works although the sources are all acknowledged. The bibliography at the end of chapter 3 applies to both literature reviews.

Also, please note that your dissertation must be double-spaced, not single-spaced as in this handout.
Chapter 2

Literature Review: Excellent

As mentioned in the introduction, the Solow growth model served to reignite the economists’ interests in economic growth theory. Its rather pessimistic conclusion that there is a balanced growth path that is determined by the rate of technological advancement, and that any attempt by policy makers to boost the national savings rate would only make the economy temporarily deviate from this path, prompted much further research into the relationship between technological progress and economic growth.

Since technological progress was successfully incorporated in the growth model and popularised by Romer (1986), recent models have focused on the relationship between the intensity of competition—both in the product market and in the intermediate goods used to produce the final consumption good—and the pace of innovative process and resulting economic growth. The current literature survey focuses on the modern endogenous growth models, starting with the early Neo-Schumpeterian models developed by Segerstrom, Anant, and Dinopoulos (1990) and Aghion and Howitt (1992)—hereafter referred to as the “standard” model—and its subsequent theoretical developments. In the next section, we start with a brief sketch of the simplest version of the standard models, in which growth is driven by technological innovations, which in turn is driven solely by intense competition amongst research firms to gain a competitive advantage in the product market. Subsequent sections of this chapter analyse variants of these models, grouped by the type of variations they introduce to the standard model. Section 2.2 introduces and analyses the multi-sector version of the standard model. The models reviewed in section 2.3, the agency cost models, question the assumption that the newly discovered innovation is immediately applied to production, which is implicit in the standard model, and introduces an element of managerial inefficiency into the model. Section 2.4 reviews a class of models related to the agency cost models. The research and development models again question the perfect efficiency of the standard model and concentrate on the flexibility of the innovative activities required to implement new technological paradigms. Models with tacit knowledge, reviewed in section 2.5, introduce a different structure for technological race into the standard model, while maintaining the basic assumption that the firms engage in technological race in order to gain a competitive advantage over their rivals in the product market. The last section concludes with an insight gained into the literature from the preceding survey.

2.1 The “Standard” Models

In the “standard” Neo-Schumpeterian models (see Grossmann and Helpman (1991) as well as the two mentioned above), a sustained economic growth is generated directly as a result of a random sequence of technological innovation which improves the quality of the final product (quality-improving innovations
are referred to as “vertical” innovations in the literature). The basic set-up of the model is as follows.

The economy is populated by a continuous mass of $L$ individuals each of whom supplies one unit of labour with no loss to their utility. The final good, the real output of the economy, $y$, is produced using intermediate product $x$. Innovations in the economy consist of a ladder of vertical innovations, meaning that with every new innovation, less amount of $x$ is required to produce one unit of $y$. For any innovation to occur, some labour input must be devoted to research, let’s denote this amount by $n$, to be employed by a number of firms engaged in the technological race, with $n < L$. The economy’s problem is to solve for the optimal level of $n$ to drive innovation forward.

The technological race is formalised according to the tournament model of patent races with free entry surveyed in Tirole (1988) and Reinganum (1989). In this setting, intellectual property rights are protected by the patent system, therefore the firm which has won the technological race with the latest invention holds the right to use their technology exclusively, in return for a complete disclosure of the knowledge embodied in the new discoveries. The capital market is assumed to be perfect, which implies that there is no barrier to enter this technological competition. This free-entry race structure, together with the patent system, means that the leader does not get a first-mover advantage. The time interval between two consecutive innovations is modelled by a probability distribution, and at any point in time, the probability that the next innovation arrives is a distinctly increasing function of $n$.

With each of successive innovations, the innovator gains a competitive advantage over the previous winner, leading to an efficiency advantage in the product market. The size of the efficiency advantage depends on the size of the innovative step. Most standard models assume that all innovations are “drastic” in the sense that innovative steps are large enough to drive out all competitors and monopolise the product market—the factor of obsolescence is incorporated in the model, “better products render previous ones obsolete” (Aghion and Howitt (1992, p323)). In this particular set-up, all past intermediate goods are perfect substitutes with each other, the only difference being that with every innovation, less $x$ is needed to produce a fixed amount of $y$. Then innovations can be regarded as drastic if the decrease in the amount of $x$ required using the new technology is sufficiently large to allow any successful innovator to engage in monopoly pricing without the fear of being displaced by his next efficient competitor in the market, i.e. the previous innovator. In such a set-up, the technological race exhibits the following characteristics:

1. Each successful innovator exploits his competitive advantage from his drastic innovation and becomes a monopoly in the product market
2. Once he has monopolised the market, the “incumbent” —the current technological leader—does not engage in research in equilibrium. Only the outsiders, losers of the last race, invest in research
3. Current technological leader is systematically replaced by an outsider, the *leapfrogging* pattern of technological process

The first of the above characteristics is intuitively explained by the structure of incentives. The current technological leader, who is also the current monopolist in the product market, has a weaker incentive to innovate than outsiders. By discovering a new technology, the leader would only gain an increase in his monopoly profit, while an outsider would gain the monopoly profit starting from his initial profit level of zero—this difference in incentives is known as Arrow’s (1962) *replacement effect*. Further, since the arrival of a new technology is characterised by uncertainty and the leader does not have first-mover advantages, the threat exerted by the outsiders’ investment is not sufficiently reflected in the leader’s incentive to innovate. As a result, the replacement effect settles the game: an outsider wins the patent race at every stage of innovative process and becomes the new monopolist in the market. Such an innovative process is commonly referred to as “creative destruction of monopolies”,
supported by the disclosure of the knowledge embodied in the new discoveries (patent system) and the high intensity of technological competition (free-entry patent races).

The equilibrium path of aggregate R&D investment solved in the model is set by the outsiders’ incentives to innovate, which are stronger than the incentive of the current leader. Therefore, the innovative process, and hence economic growth, is fostered by the intense technological competition amongst research firms. On the contrary, this model predicts the opposite outcome for the relationship between the intensity of competition in the product market and competition—since the monopoly profit is the outsiders’ prize in each patent race, a high degree of competition which lowers the monopoly rent serves to reduce the aggregate R&D investment and the rate of growth. This phenomenon is known as the appropriability effect.

The assumption of drastic innovations results in that at any point in time, the technological leader is the only one active in the product market as a monopoly. Consequently, in the standard models, the Schumpeterian trade-off between product market competition and growth is guessed from the negative impact a reduction of the leader’s profit would exert on the incentive to innovate. More precisely, the intensity of competition in the product market is measured by the inverse of the elasticity of demand, which equals the mark-up the leader charges when innovations are drastic. A more elastic demand reduces the monopoly profit associated with a new innovation, and hence the outsiders’ reward from innovating. Therefore, the effect of product market competition on growth, assessed through a comparative static exercise on elasticity of demand, is solved to be negative.

2.2 Multi-Sector “Standard” Models

As their name indicates, the multi-sector version of the standard model (see Caballero and Jaffee (1993)) introduces a continuum of intermediate goods, each of which is produced by a different sector or industry in the economy. All intermediate goods are employed to produce the final output. For each of these intermediate goods, there is a technological race driven by the intense competition to gain a competitive advantage, in exactly the same manner as the one described for the standard model above. The variety of intermediate goods, and hence the number of sectors in the economy, is exogenously determined. Each innovation improves the quality of the specific variety of intermediate good it targets. However, the R&D activity entails inter-industry spillover: each innovation can be used directly only in the industry targeted by the innovator, but it allows successive innovators in other sectors to discover slightly better technologies. In each industry, the innovative process exhibits the leapfrogging pattern we have described above for the standard model. A successful innovator, who is necessarily an outsider, replaces the previous technological leader and becomes the local monopolist in the industry targeted by his innovation.

As was the case in the one-sector model, this class of models demonstrates that an increase in the intensity of product market competition—that is, a higher elasticity of substitution among different varieties of intermediate goods in the production of the final good—diminishes the equilibrium level of investment in R&D and consequently the rate of growth. In the multi-sector models, however, the link between the intensity of competition and growth arises from a composition of three effects, one of them working in the opposite direction relative to the overall effect:

1. Appropriability effect (negative relationship): related to the reduction of the monopoly profits the successful innovator expects to gain in the specific industry targeted by its innovation, i.e. the direct effect of a higher elasticity of demand on the monopoly profit of the industry targeted by the innovator

2. Productivity (or Efficiency) effect (positive relationship): this is due to the successful innovator’s increased ability to exploit his efficiency advantage inter-sectorially (i.e. in competition with the
local monopolists of the other sectors) when different varieties of intermediate goods are closer substitutes.

3. An additional Obsolescence effect (negative relationship): this operates via the same channel as the efficiency effect. If the varieties of intermediate goods are closer substitutes, the occurrence of an innovation in one industry exerts a negative impact on the profits of the local monopolist in another industry. Consequently, the incentive to innovate in the second industry is weakened.

In these models, the productivity serves to obtain a positive relationship between product market competition and growth. However, whatever the parameters of the model, it has been shown that this is always outweighed by the other two effects, which work in the opposite direction.

2.3 Agency Cost Models

Agency cost models (Aghion, Dewatripont, and Ray (1997), (1999)) develop the multi-sector version of the standard model further by adopting a different definition of innovation. They embed two fundamental changes to the multi-sector model.

First, in these models the R&D technology is deterministic at the innovative firms’ level. Firms adopt innovations by paying a sunk cost instead of investing in a risky technology. This is upheld either by assuming that each firm employs a continuum of researchers engaged in uncorrelated risky projects, or simply by assuming that firms adopt new technologies already discovered. In any case, the highly competitive environment in the R&D activity that characterises the standard model is replaced by a process of adoption of new technologies which weakens the consequences of new discoveries on the market position of the firms active in the product market. Indeed, within the multi-sectorial framework discussed in the previous section, each firm is a local monopolist in the sector of his variety of the intermediate good. However, the arrival of an innovation in one sector of the intermediate good market does not cause the replacement of the current monopolist in this sector. Rather, the new technology is at the disposal of the current monopolist, which has only to decide the optimal adoption timing.

Second, these models introduce agency costs in the decision process of the innovative firms. The separation between ownership and control shifts the decision to adopt the new technologies to the managers. Managers decide, according to their own preferences, which depend positively on the private benefits associated with the control of the firm, and negatively on the private costs related to the adoption of new technologies, for instance, training costs or non-monetary costs from reorganising the firm in order to implement the new technologies.

If the decision to adopt the new technology is postponed, the firm will see a gradual decline of profits due to the obsolescence effect: the firm will gradually lose competitiveness relative to the rivals that are adopting new technologies in other sectors. This, together with the presence of fixed operating costs, imply that the firm could go bankrupt if the adoption of technology is delayed significantly. In general, whatever the managers’ preferences, the managerial firm will postpone the adoption of new technologies relative to the profit-maximising firm. This has a negative effect on aggregate growth performance of the economy since the rate of growth decreases with the average delay in adopting new technologies.

As for the relationship between the product market competition and growth, an increase in the intensity of competition—defined as the degree of substitutability amongst different varieties of intermediate goods as before—turns out to have a positive impact on economic growth. The reason for this is that a higher degree of substitutability amongst varieties strengthens the obsolescence effect. Therefore, for any given adoption-strategy of the new technologies, the profit flow of the managerial
firm worsens. This anticipates the critical instant of bankruptcy, forcing the managers to speed-up the adoption of new technologies.

In other words, a more intense competition in the product market operates as a disciplinary device on the managers’ slackness. The decrease in the free-cash flow available to the managers tightens the constraint conditioning the managers’ behaviour (i.e. the risk of bankruptcy and the consequent loss of the benefits of control), inducing them to choose a strategy closer to the profit-maximising one (that is, a faster adoption of the new technologies).

It is worth emphasising how the picture of the technical progress offered by this class of models is different from that of an innovative process driven by intense technological competition offered by the standard model. The (risky) activity of research, stimulated by a prospect of acquiring strategic advantages over the rivals, is replaced with an adoption process of new technologies forced by the threat of accumulating efficiency gaps leading to the failure of the firm. In other words, the positive effect on growth of a more intense competition in the product market is obtained by reducing drastically the intensity of technological competition.

2.4 Research and Development Models

The main characteristic of these models (Aghion and Howitt (1996), (1998)) consists in the parting of the research activity from the activity of development of new technologies: the first is oriented towards discovering new technological paradigms (Multi-Purpose-Technologies), while the second is concerned with the development and implementation of new inventions.

Skilled workers can move between the research and the development sectors, as well as within the development sector across product lines generated by discoveries of different vintages. The degree of mobility of skilled workers, both within the development sector and between the two sectors, depends on the degree of specificity of the investment (in training and qualification) required to perform the development activity on a particular product line. The higher the degree of developers’ mobility across product lines, the higher the speed with which the economy implements new technological paradigms. This strengthens the incentive to invest in research, which augments the pace of technological progress and the rate of growth.

The impact of product market competition on growth is assessed by using the degree of substitutability among different product lines as a measure of the intensity of competition. A higher substitutability of products fosters both the investment in less specific activities (research in particular) and the incentive to reduce the degree of specificity in developers’ training and qualification. As a consequence, skilled workers are more mobile among different product lines.

As in the agency costs models, also in the research and development models the image of technical progress is distant from that of a process driven by intense technological competition aimed at gaining strategic advantages in the product market. Rather, these models focus on the adequate degree of flexibility of the economic systems required to implement the new technologies. Flexibility favours research and technical progress, and depends, in turn, on the institutional framework being able to promote private incentives towards a lower degree of specificity in the innovative activities and higher mobility of skilled labour (i.e. lower switching costs).
2.5 Models with Tacit Knowledge; Internal Accumulation of Knowledge

In the standard Neo-Schumpeterian models reviewed in sections 2.1 and 2.2, the knowledge incorporated in each innovation is immediately disclosed. The new knowledge is perfectly codifiable, and the patent protection of intellectual property rights requires that the information incorporated in the new technologies is disclosed and verifiable. Therefore, the new knowledge can be utilised by any potential innovator racing for future discoveries on equal grounds with the current innovator.

By contrast, the main characteristic of the models we review in this section is that the knowledge incorporated in the new technologies remains to a great extent private information of the innovative firm. This characteristic of the innovative process, in turn, is motivated by the assumptions that innovations incorporate tacit knowledge which can be utilised only by the innovator and/or that the protection of intellectual property rights is based on trade secrecy rather than on the patent system.

A class of models with tacit knowledge, known as the step-by-step models (Aghion, Harris, and Vickers (1997); Aghion, Harris, Howitt and Vickers (2001); Encaoua and Ulph (2000)), are multi-sectors models with process innovations on the production cost of intermediate goods. There are two firms active in each sector (the current technological leader and the technological follower) competing in the market of their variety of intermediate good. The two firms are also engaged in technological competition to obtain process innovations which reduce the marginal cost of their variety. The technological leader can exploit the tacit knowledge incorporated in the more advanced technology. This enables him to target innovations which directly improve the leading technology. On the contrary, the technological follower must first engage in R&D in order to disclose the knowledge embodied in the more advanced technology before being able to innovate the leading technology. In each sector the innovative contest is restricted to the two firms active in the market, and evolves as a step-by-step run-up.

The product market of each variety is formalized as a duopoly with firms asymmetric in costs. The intensity of the product market competition is measured both via the comparison between different models of strategic interaction (i.e. Cournot competition versus Bertrand competition) and via the inverse of the elasticity of demand (which derives from the elasticity of substitution among different varieties of the intermediate good in the production of the final good).

The main results obtained by this class of models can be summarised as follows. First, a more intense competition in the product market increases the incentive to innovate for both firms when they are “neck-and-neck” in their technological contest. This is denoted by the authors as the escape from competition effect, to emphasise that the incentive to gain a technological lead gets stronger when firms are symmetric and therefore they exert each other an intense competitive pressure in the product market. Then, a higher intensity of competition in the product market fosters the incentive to escape from the competitive pressure of the rival.

Second, a higher intensity of competition in the product market tends to reduce the firms’ incentives to innovate (especially for the technological follower) when they are “distanced” in the technological race. This result is closely related to the appropriability effect we have discussed for the standard models.

Finally, an increase in the degree of product market competition tends to reduce the frequency in the economy of the sectors in which firms are “neck-and-neck” with respect to the frequency of the sectors in which firms are “distanced” in the technological race. This follows directly from the first two results, that is, from the positive (resp. negative) effect that product market competition exerts on the firms’ incentive to innovate starting from (and in order to exit) the “neck-and-neck” (resp. the “distanced”) state. Such a composition effect, in turn, works in the direction of a lower rate of
growth, since the frequency of the sectors where the incentives to innovate are stronger decreases. The intuition for the first two results is based on the different structure of the incentives to innovate in the two alternative states of the technological race: the “neck-and-neck” and the “distanced” states. In the “neck-and-neck” state, the profit effect (i.e. the difference between a firm’s expected profit from innovating and its current profit in the product market) has a weak impact on the incentives to innovate, while the competitive threat exerted by the rival (i.e. the difference between the profit of the winner and the profit of the loser in the technological race) exerts a stronger impact. A higher intensity of competition in the product market strengthens the competitive threat component of the incentive to innovate. On the other hand, in the “distanced” state, the structure of the incentives to innovate is more affected by the profit effect, which is weakened by a higher degree of product market competition.

From the three results above it follows that the overall effect on growth of a more intense competition in every sector of the economy is ambiguous. Indeed, the innovative process accelerates in the industries where firms are “neck-and-neck”, but it slows down in the industries where firms are distanced. In the steady state, the aggregate effect depends on the equilibrium distribution of the sectors of the economy over the two states of technological competition. In turn, the equilibrium distribution must respect a stability condition in terms of entries into and exits from the two states. Finally, the entry- and exit- flows are affected by the intensity of the incentives to innovate in order to change the initial state, and therefore, by the initial degree of product market competition. Therefore, the overall effect on growth of a general increase in the intensity of competition turns out to depend, critically, on the initial intensity of competition.

2.6 Conclusion

The preceding sections analysed several classes of models within the modern endogenous growth theory, all modelling the relationship between competition and equilibrium growth path of the economy. The standard Neo-Shumpeterian models have shown us that a high degree of competitiveness in the product market is detrimental to economic growth. Its multi-sector version, while introducing a channel for a possible positive relationship between competition and growth by introducing inter-industry technological spillovers, still demonstrated that the negative effects dominated the positive.

Subsequent redevelopments introduced various new elements of the economy into the standard models. In agency cost models, new technologies need not be invented, but simply bought from the innovator for a firm to gain a competitive advantage over others. It also introduced the possibility of managerial inefficiency when implementing the newly purchased technology. At the equilibrium of these models, it was shown that the product market competition has a positive impact on economic growth. Similarly, research and development models adopted different process for technological innovation and came to a similar conclusion as the agency cost models. Lastly, the step-by-step models replaced the free-entry patent-race system of technological competition with the possibility of trade secret, giving the incumbent technological leader a distinct first-mover advantage over the others when developing the next innovation. The impact of an increase in the product market competition on economic growth in this model was shown to depend crucially on the initial degree of competition that prevails in the economy. If the initial intensity of competition is low, the model predicts a positive impact, but on the other hand, if the initial degree of competition is high, a greater level of competition has a negative impact.

All the models which derived a positive relationship between competition and growth, in one way or another, did so by reducing the intensity of technological competition amongst innovators assumed in the standard models. The possibility to purchase technology instead of having to innovate, maintaining trade secrets, the incumbent firm regaining the first-mover advantage, all served to reduce
the intensity of technological race.

Also, the above analysis exposed what is possibly a major weakness in the standard models. Their conclusion that competition is detrimental to economic growth is driven by the assumptions of the model. The outcome of negative effect of product market competition on growth due to appropriability effect is inferred without an explicit analysis of different models and/or degrees of competitions in the product market—the product market, its competition level, is neither modelled nor endogenously determined.

Word Count: 4308


Chapter 3

Literature Review: Downright Awful

As mentioned in the introduction, it is the Solow Growth model, also commonly known as the Neoclassical Growth model, that came up with the basic proposition that the economic growth is unsustainable without technological advancement, due to diminishing marginal returns. It also concludes that there is a “steady-state” growth path of the economy from which only a temporary deviation is possible, should policy makers attempt to boost the economic growth rate.

In the Solow growth model, the economy has some endowment of capital $K$, labour $L$. These are combined to produce the final output $y$. In the model there is also a parameter representing the current state of technology available to the economy, denoted $A$. In its simplest form, $A$ can be assumed to take a value of unity and the amount of labour force available to the economy can also be normalised to unity, without loss of generality. In such case, a production function can simply be written as $y = f(k)$, output is a function of the amount of capital stock, where $f$ denotes the actual production function, commonly assumed to take the form of Cobb-Douglas in most cases. One important property any production function must have in this model is that there are diminishing returns to the capital. That is, if you continue to equip labour with more and more capital without inventing new uses for the capital, the effectiveness of that additional capital will initially increase, but will eventually cease to increase. So marginal product of capital will eventually decrease. This property is usually assumed satisfied by assuming that the first difference of $f$ is positive but the second difference is negative.

In this paper we follow Solow and assume that the nation continues to save a fraction $s$ of their income, so the total savings is $sY$, and that capital stock depreciates every year at rate $\delta$. Then net investment can be written as:

$$\Delta K = sf(Y) - \delta K$$

(3.1)

The above equation, often referred to as the most fundamental equation of the neoclassical growth model, shows the change in capital stock at any given point in time. The rate at which new capital stock accumulates must equal the total savings of the nation, $sY$, and as we said just above, the capital depreciation rate is $\delta$. This indicates that $\delta K$ of capital stock is lost every year. Therefore the difference between the two is the net capital accumulation. And together with the historical level of capital stock, this equation determines the entire time path of capital.

To see how this equation works in reality, let’s consider that at the moment the national capital stock level is very low, and saving exceeds depreciation of the capital. In such case, according to (3.1), the capital stock must be increasing. It will continue to grow until the gap between national saving and depreciation of capital is closed, after which point, there will be no dynamics within the economy for the capital stock level to change. Hence the level of capital where $sf(Y) = \delta K$ is the equilibrium level of capital stock, and this is referred to as the “long run steady state”. The economic intuition behind
this movement of capital in relation to income and saving is summarised nicely in an introduction to this model by Aghion and Howitt (1998):

“The economic logic of this dynamic is straightforward. When capital is scarce it is very productive so national income will be large in relation to the capital stock, and this will induce people to save more than enough to offset the wear and tear of the existing capital. Thus the capital stock $K$ will rise. But because of diminishing marginal returns, national income will not grow as fast as the capital stock, which means that saving will not grow as fast as depreciation. Eventually depreciation will catch up saving, and at that stop capital stock will stop rising.” (Aghion and Howitt (1988)).

The conclusion of the model is, in the absence of capital stock, the economy will cease to grow because the capital stock will stop growing. When there is population growth, the equilibrium growth rate of capital is the same as the population growth rate, which means that income per capital does not grow. Since population growth rate is exogenous, there is not much policy makers can do about the capital growth rate. Any attempt at fine tuning will only result in a temporary deviation from this steady state. The only sustainable growth is obtained by technological advancement.

The next breakthrough in the growth theory came with the Overlapping generations model, or the Diamond model, developed by Diamond (1965). It is a balanced growth model like the Solow model and its variation Ramsey-Cass-Koopman model, but the main contribution of this model is the incorporation of microeconomic foundation into the macroeconomic model of growth. The utility maximising behaviour of rational, optimising economic agents forms the basis of this model. In the Solow model, saving rate (and hence consumption) was exogenously given. This is refuted by, for example, by life-cycle hypothesis which maintains that people vary their saving rate in order to smooth out consumption over time.

The basic set-up of this model is as follows. Instead of a mass of infinitely lived individuals, we have a new generation being born and the old generation dying out. At time $t$, $L_t$ amount of individuals are born. The population growth rate is exogenously given, at rate $n$, so the next time period there are $L_{t+1} = L_t(1+n)$. All individuals live for two time periods: they work and save in period 1, and they spread the income and saving over two time periods in a way such that they maximise their intertemporal utility function. Let $C_{1t}$ and $C_{2t}$ denote the consumption level of people living the first period of their life (young) at time $t$, and the consumption levels of people living the second period of their life (old) at time $t$ respectively. Then the intertemporal utility function can be written as:

$$U_t = \frac{C_{1t}^{1-\theta}}{1-\theta} + \frac{1}{1+\rho} \frac{C_{2t+1}^{1-\theta}}{1-\theta}$$ (3.2)

where $\theta$ is the risk aversion factor, and $\rho$ is the discount factor. In order for them to consume in both periods, they need to generate income. The production function is labour augmenting:

$$Y_t = F(K_t, A_t L_t)$$ (3.3)

The real interest rate and wage rate are given by marginal product of capital and marginal product of labour respectively.

People maximise their intertemporal utility subject to their budget constraint. This is the classic problem of Lagrangian constrained optimisation problem:

$$\ell = \frac{C_{1t}^{1-\theta}}{1-\theta} + \frac{1}{1+\rho} \frac{C_{2t+1}^{1-\theta}}{1-\theta} + \lambda \left[ A_t w_t - \left( \frac{1}{1+r_{t+1}} C_{2t+1} - C_{1t} \right) \right]$$ (3.4)

Solving the first-order conditions gives us an equation which directly captures the relation between two different levels of consumption:

$$\frac{C_{2t+1}}{C_{1t}} = \left[ \frac{1 + r_{t+1}}{1 + \rho} \right]^{1/\theta}$$ (3.5)
What is of the most interest in this model however, is the steady-state path taken by the capital stock of the economy. In this setting, the capital stock today is determined by how much was saved by yesterday’s young, which in turn depends on the level of income yesterday:

$$K_{t+1} = sL_t A_t w_t$$

(3.6)

where $w_t$ is the wage rate at time $t$. This relationship between today’s capital and yesterday’s income and saving rate, which in turn depends on the real interest rate, gives us a nice equilibrium equation for the growth of capital. In per capita terms, this is given by:

$$k_{t+1} = \frac{1}{(1+n)(1+g)} s(r_{t+1})w_t$$

(3.7)

The above equation defines, implicitly, that tomorrow’s capital stock depends on today’s capital, since today’s wage rate is a function of today’s capital stock. Marginal product of labour depends on the amount of capital available in the economy. This equation essentially tells us the existence of a balanced growth path of capital stock. The per capita capital stock at equilibrium is the same today as tomorrow, indicating that at steady state, the capital growth rate is the same as the population growth rate. Indeed, once the economy reaches the balanced growth path, the behaviour of the economy can be shown to be the same as that in the neoclassical growth model. The convergence to the steady state differs slightly, however, as before, any deviation from this balanced growth path will be temporary, and will be eliminated by internal forces within the economy.

The models described above assume that the level of technology is exogenously determined outside the model. However, in the real world, new inventions often occur as a direct result of deliberate economic decision making process. Therefore the assumption that technological level is somehow determined outside is unrealistic. In order to correct this, we need to model research and development explicitly in the model. The models which do this are known as endogenous growth models. Early attempts were made in the seventies, however, the endogenous growth models were firmly established with the models created by Romer (1990), Aghion and Howitt (1992) and Grossmann and Helpman (1991). The set-up below explains the model developed by Aghion and Howitt (1992).

The economy consists of a continuum of infinitely lived individuals—quantity denoted by $L$ with identical intertemporal utility function defined over their lifetime. They each supply one unit of labour, and doing so does not result in loss of utility. There is the final good to be produced, the intermediate good that also needs to be produced since it must be employed in the production of the final goods. And there is a technological race in this model to improve the quality of this intermediate good, denoted $x$. The economy must optimally decide on the allocation of resources between the production of the final good, and the production of the intermediate good. The production function is generally written as:

$$y = AF(x)$$

(3.8)

where $y$ is the final good, and $A$ is a parameter that denotes the efficiency of $x$ in producing $y$. The usual conditions to ensure diminishing marginal returns apply.

“Research produces a random sequence of innovations. The Poisson arrival rate of innovations in the economy at any instant is $\lambda \phi(n,R)$, where $n$ is the flow of skilled labour used in research, $[R$ the flow of specialised labour only used in research,] $\lambda$ a constant parameter, and $\phi$ a constant-returns, concave production function. Both $\lambda$ and $\phi$ are given by the technology of research. There is no memory in this technology, since the arrival rate depends only upon the current flow of input to research, not upon past research. Assume that skilled labour is an essential factor in research: $\phi(0,R) = 0$. Then an economy that allocates no skilled labour to research will not grow, because it will experience no innovations.” (Aghion and Howitt (1992), p327)
The firms’ competition to innovate is characterised by a free-entry, patent-race system. The patent system requires the successful innovator to disclose the new knowledge in return for retaining exclusive right to use the technology. Instant disclosure of technology means that the unsuccessful innovators immediately get to learn the new innovation, and hence stand at equal footing with the successful innovator when attempting for the next stage of innovation. Free entry is a consequence of a perfect capital market.

As mentioned just above, innovations are vertical, and for the sake of simplicity assume that all innovations are drastic—that is, the new innovation sufficiently lowers the unit production cost of $y$, allowing the firm to monopolise the final good market. The firm’s problem is to select an optimal allocation of skilled labour and specialised labour at each point in time in a way such that they can maximise the flow of expected profits to research, which can be conveniently written as below:

$$
\lambda \phi(n, R)V_{t+1} - w_t n - w^s_t R
$$

where $V_{t+1}$ is the value of the $t+1$st innovation, $w_t$ is the wage rate of skilled labour and $w^s_t$ is the wage rate of specialised labour.

In a set-up such as this, the authors show that at every stage of technological process, research is conducted by outside firms (the losers of the previous race) and not by the current technological leader (the winner of the previous race). “The reason why the monopolist chooses to do no research is that the value to the monopolist of making the next innovation would be $V_{t+1} - V_t$, which is strictly less than the value $V_{t+1}$ to an outside firm.” (Aghion and Howitt (1992), p330). The set-up of this model creates this unique incentive scheme whereby the next winner of the technological race is always one of the losers of the previous. Therefore during the course of successive vintages of innovations, monopolies are systematically destroyed by creation. This is what Schumpeter (1942) referred to as “Creative Destruction” (Schumpeter (1942), p83).

From then on, the authors solve for the equilibrium path of output level and hence growth, which is an increasing function of $n$, labour investment into research. They demonstrate that there is a unique stationary equilibrium. Analysing this equilibrium path has also shown an interesting relationship between the degree of competition in the product market and rate of economic growth. They show that the higher the intensity of competition in the market for the final good, the lower the rate of economic growth. Again this stems from the incentive structure of the model. A very competitive product market means that the degree of substitutability between goods is high. This in turn implies that the elasticity of demand for one good is large. As we all know, the monopoly rents are given by the inverse of price elasticity of demand. If the firms engage in technological race in order to gain monopoly rents as the technological leader, the reduction in monopoly rents as a result of large elasticity of demand serves to reduce the incentive to innovate. Consequently there will be less innovation, and hence lower rate of economic growth.

Since this pioneering work by Aghion and Howitt (1992), various extensions of the model have been created. Most of them predict a negative relationship between the intensity of competition and economic growth. However, recent models (Aghion, Dewatripont, and Ray (1997), Aghion, Harris, and Vickers (1997), amongst others) show that by reducing the intensity of the technological race, there can be a positive relationship between the product market competition and economic growth.
Bibliography


