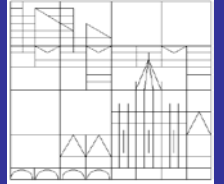




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Working Paper Series
2014-12

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Imitation Induced Innovation in General Equilibrium

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October 2014

Abstract

This paper analyzes the effect of imitation on the rate of technological progress in an endogenous growth model. Quality leaders protect themselves from imitation by secondary development, which increases technological progress. Nevertheless, lower intellectual property rights protection reduces the incentives to enter the research sector, which lowers innovation by outsiders. Simulations show that the net effect of increased imitation on the growth rate is ambiguous - it can be positive, negative, or inversely U-shaped, depending on the productivity of secondary research. Lower patent protection also reduces monopoly distortions in the aggregate economy so that output, the wage rate, and welfare is typically increased.

JEL Classification: L12, O31, O34

Keywords: Innovation, Intellectual Property Rights, Market Power

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I would like to thank my supervisors Leo Kaas and Matthias Hertweck, the members of the Seminar in Macroeconomics at the University of Konstanz, and the participants of the EBIM Doctoral Workshop on Economic Theory in Bielefeld (December 2013) for helpful comments.

1 Introduction

In this paper, I analyze the effect of imitation on the rate of technological progress in an endogenous growth model with active incumbents. For a long time, intellectual property rights (IPR) protection has been regarded as the principal condition to foster technological progress. Already Schumpeter (1942) pointed out that the protection of the innovator's monopoly against imitation is a necessary condition for innovative activity. Also, endogenous growth theory typically predicts that imitation lowers the economy's growth rate as the investment in research is reduced due to lowered expected monopoly profits (Romer, 1990; Grossman and Helpman, 1991a; Aghion and Howitt, 1992; Davis and Şener, 2012).

The work of Boldrin and Levine (2008), who argue against the necessity of IPR protection, has challenged this view recently. Also empirical research has shown that increased competition within industries or the entry of foreign competitors can lead to more innovative activity, measured by R&D expenses and patents, and to higher productivity growth (Geroski, 1990; Blundell et al., 1999; Nickell, 1996; Bloom et al., 2011; Correa and Ornaghi, 2011; Buccirossi et al., 2009).

In this paper, I develop a model in which the threat of competition by an imitator induces the incumbent quality leader to increase his innovative activity. This escape-competition-innovation increases the economy's growth rate. Nevertheless, the probability of being challenged by an imitator reduces the expected profit of an innovator since his advantage over the imitator is only strong enough to charge a limited monopoly price. This lowers the incentives to enter the research sector and consequently reduces the rate of technological progress. The aim of this paper is to examine which of the two effects dominates and which parameters control the trade-off between both effects.

The basic structure of the model is similar to Acemoglu and Cao (2010) where radical innovations are made by outsiders and incremental quality improvements are undertaken by incumbents. This model adds the possibility that an incumbent is challenged by an imitator and evaluates the incumbent's reaction towards this threat. In the model, the decision to enter the research sector and how much secondary development to conduct as a monopolist are determined endogenously, depending on the threat of imitation and replacement. The model also features a rich market structure with intermediate goods sectors that switch between states of monopoly, limited monopoly, or competition. This allows to evaluate the effect of IPR protection on market distortions and to discuss welfare changes.

The results show that a higher probability of imitation can indeed increase the growth rate of the economy. However, in general, the effect is ambiguous and depends primarily on the productivity of secondary development. If increasing secondary development is relatively cheap, the positive effect of imitation induced innovation by the monopolist prevails and lower IPR protection increases the growth rate. Conversely, if increasing secondary development is expensive, the incumbent cannot gain the necessary advantage over the imitator and the growth rate is reduced. For a certain parameter range, the relationship between imitation and growth becomes inversely U-shaped, so that lowering IPR protection first increases the growth rate and then reduces it.

The model also indicates a strong positive effect of imitation on current welfare, which is caused by the influence on the economy's market structure. A higher probability of imitation increases the share of competitive industries and also the share of industries with limited monopoly relative to full monopoly industries. This reduction of monopoly distortions increases output, the wage rate, and utility in the economy. This is even true for some of the cases where imitation unambiguously lowers the innovation rate. A surprising result is that a higher probability of imitation increases the value of an innovation. This comes from the fact that the reduced number of outside innovators leads to a lower probability of displacement which compensates for the increased probability of imitation.

This paper adds to the literature on the interplay of imitation and innovation, which has been studied by a number of authors since the emergence of endogenous growth theory. Segerstrom (1991) develops a quality-ladder model with a continuum of industries where innovation and imitation races take turns within each sector. When imitated, the innovator and the imitator collude and share the monopoly profit. Along the balanced growth path (BGP), the share of sectors in either state is constant. A subsidy to imitative activity has an ambiguous effect on the growth rate, that is facilitating imitation may increase or decrease the growth rate of the economy. A North-South model of innovation and imitation by Grossman and Helpman (1991b) produces similar results. The difference between the two models is that in the latter, imitators in the South have a lower production cost and thus are able to take over the whole market from the innovator.

The model by Mukoyama (2003) uses a similar mechanism. However, in contrast to the models above, imitation leads to Bertrand competition between the innovator and the imitator which eliminates the markup in these industries. Upon imitation, an innovation race between the original innovator and the imitator starts. This provides the incentive for imitation because leap-frogging is excluded and imitation is a precondition for innovation. The fact that imitation leads to competition allows to study the welfare effects of monopolistic distortions. A subsidy to imitation has an ambiguous effect on the growth rate and increases static welfare as the share of industries in competition increases. These results are very similar to those obtained in this model. Also Horii and Iwaisako (2007) derive comparable results. However, they use a different mechanism that is based on the idea that innovation is easier in competitive sectors.

What all these models have in common is that they do not allow the innovator to react towards the threat of imitation and to protect himself. Therefore, the positive effect of imitation on the growth rate never comes from increased R&D intensity but from the increased share of competitive sectors in which innovative activity takes place. In the model by Davis and Şener (2012), the innovator is able to undertake costly rent-protection activities to repel imitation and innovation. It turns out that rent-protection activities can increase the growth rate and welfare when IPR protection is low.¹ However, the effect of imitation on the economy is always negative as it does not lead to increased innovative activity.

¹This is in contrast to Dinopoulos and Syropoulos (2006) who show that without the threat of imitation, rent-protection activities that prolong the expected monopoly duration of an innovator always lower the growth rate and welfare.

Another way for the incumbent quality leader to defend himself against imitation and competition is to undertake own research to escape the outside pressure. This mechanism is introduced and used in a series of papers (Aghion et al., 1997, 2001, 2011, 2012; Czarnitzki et al., 2014) in which either two firms are in an innovation race against each other or an industry leader fights against potential entrants. They show that a higher rate of imitation can increase the innovation rate as the quality leader tries to stay ahead of competition. Since a higher rate of imitation also lowers expected monopoly profits, the relationship between ease of imitation and the growth rate has typically an inverted U-shape, similar to the results in Mukoyama (2003) and in this paper. However, in these models, the competitive structure within industries is exogenously given. So they lack the decision to enter into research in any industry and constitute only partial models of growth. This paper fills this gap by endogenizing the decision to enter the research sector and allowing an industry leader to innovate further to escape potential imitation.

The organization of the paper is as follows. The next section introduces the model and derives prices and output as well as the optimal amount of secondary development by the incumbent. Section 3 solves for the stationary distribution of industries and the number of researchers along the balanced growth path and derives the equilibrium condition for entry into the research sector. In section 4, I discuss the potential effects of a change in IPR protection and present numerical simulations to show the possible outcomes. Section 5 concludes and gives an outlook for future work.

2 The Model

General Setup

The economy comprises three sectors: final goods production, a continuum of industries indexed by $\nu \in [0, 1]$ that produce intermediate goods, and a research sector that develops new designs for the intermediate goods industries. The economy is populated by overlapping generations of uniform agents of mass H who live for three periods. Newborn workers decide to work in final goods production or to enter the research sector. Research is stochastic and may either produce a new innovation that can be patented or an imitation of the latest patented technology of an intermediate goods sector. The research sector produces innovations and imitations for all intermediate goods sectors with equal probability. Research success is revealed at the end of the period. If a researcher creates an innovation for one of the intermediate goods sectors, he takes the monopoly position in this sector and produces intermediate goods with the new technology in his second life period. The monopolist is also able to conduct secondary research to further improve his technology. The unsuccessful researchers who did not obtain a patent for a new technology become workers in their remaining life.

At the end of that period, the research outcome of the subsequent cohort is revealed. For the actual monopolist of an intermediate goods sector, this yields three possible scenarios for the third period. First, if the research of the subsequent cohort produced neither an innovation nor an imitation for his sector, the monopolist remains the full-fledged monopolist in the last period

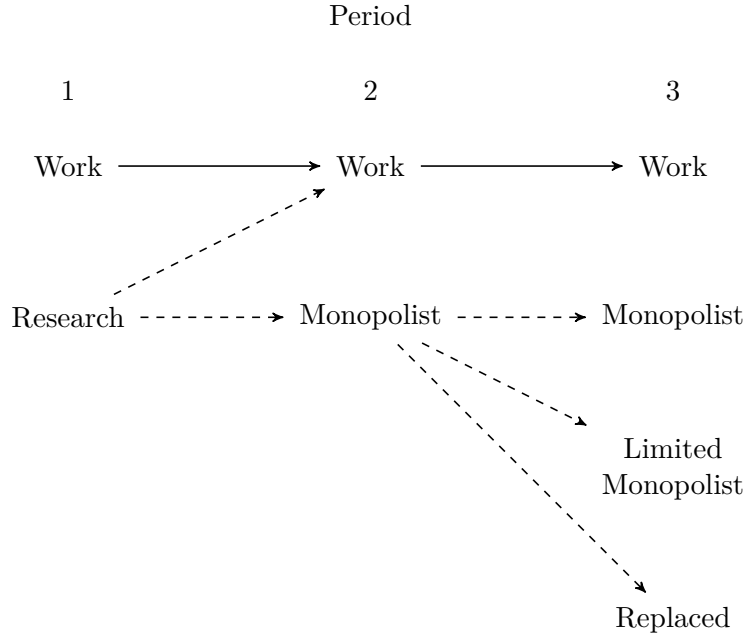


Figure 1: Lifecycle of individuals

of his life. Due to the secondary research he has undertaken in the second period, his profit is higher than in the previous period. Second, if the subsequent cohort has been partially successful and created an imitation of the monopolist's technology, the monopolist faces competition in his last period. However, since his technology has already undergone further improvement during the second period which is not included in the imitation, the current monopolist still has a technological advantage that allows him to make a positive profit in the last period. Nevertheless, he is now forced to lower the price due to the competition of the imitator and becomes a limited monopolist. The imitator himself does not take an active role in intermediate goods production since he cannot compete against the incumbent monopolist and only poses the threat point. So he becomes a worker in his subsequent life. Third, if the research of the next cohort created a new innovation for this intermediate goods sector, the actual monopolist is replaced. The positions, in which individuals can find themselves during their lifetime are depicted in Figure 1.

If the monopolist is not replaced by a new monopolist before he exits the economy, his patent expires and the technology becomes public knowledge. That means that independent firms produce intermediate goods of the latest technology in this sector. With regard to the market structure, intermediate goods sectors can be in four different states: competition (CO), monopolistic with a monopolist in his second lifetime period (M2), monopolistic with a monopolist in this third period (M3), and in a limited monopoly in which the monopolist is challenged by an imitator (LM). The possible transitions from state to state are depicted in Figure 2.² The difference between the states M2 and M3 is that no secondary research takes place in M3 since

² Ω^I , Ω^C denote the probability of an innovation or an imitation in an intermediate goods sector respectively. They are endogenously determined in the equations below.

the monopolist will not invest in his last period, and also that M3 is followed by CO if no new innovation is made in this period.

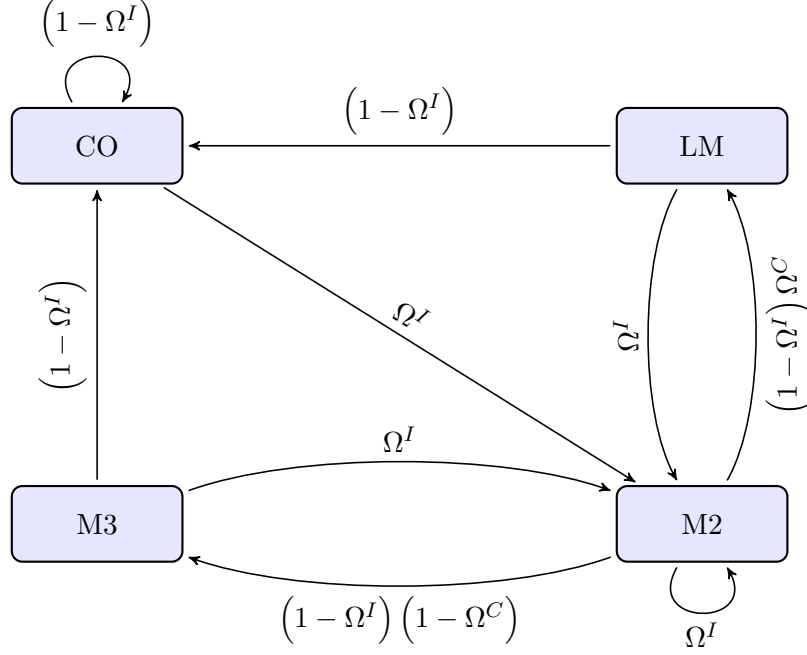


Figure 2: States of the intermediate goods sectors

Consumer Preferences

Individual agents are endowed with one unit of labor per period which they can use for working in final goods production, conducting research, or operating a business as a monopolist in an intermediate goods sector. There is no disutility from supplying labor and workers are risk neutral with no discounting.³ Utility is therefore a linear function of consumption during the three life periods,

$$U_t = c_t + c_{t+1} + c_{t+2}. \quad (1)$$

Final Goods Production

The final good is produced under perfect competition from intermediate goods and labor, following the production function

$$y_t = \frac{1}{1 - \beta} \left[\int_0^1 q_{\nu,t}^\beta x_{\nu,t}^{1-\beta} d\nu \right] L_t^\beta, \quad (2)$$

where x_ν denotes the amount of intermediate goods of type ν with their respective quality q_ν and L_t denotes the measure of agents employed in final goods production. Throughout, the price of the final good in each period is normalized to 1.

³The omission of a discount factor serves to simplify the model but does not affect the results qualitatively.

Research

Primary Research

Agents engaged in the research sector try to discover new designs for intermediate goods that increase the productivity of the existing intermediate good by the factor λ .⁴

Throughout the paper I assume that $\lambda \geq (1 - \beta)^{-\frac{1-\beta}{\beta}}$. This assumption assures that a new monopolist always completely replaces the previous monopolist and is able to charge the full monopoly price.

Every worker in the research sector has the individual probability \tilde{p} of discovering a technology for a random intermediate goods sector. However, once the technology is developed, there is a probability \tilde{i} that it does not constitute a technology improvement for this sector but rather an imitation of the latest patent. The probability for discovering a genuine new technology is thus given by

$$p = \tilde{p} \cdot (1 - \tilde{i}). \quad (3)$$

For the case of an imitation, with probability Φ , the imitation is not treated as a patent infringement and thus can compete against the existing technology on the market. So the inverse of Φ can be regarded as a measure of intellectual property rights protection in the economy. The individual probability to create a marketable imitation of the latest patented technology of an intermediate goods sector is given by

$$i = \tilde{p} \cdot \tilde{i} \cdot \Phi. \quad (4)$$

For the remainder of the paper, I will only use the reduced forms of the individual innovation and imitation probabilities p and i .

Let R_t be the total mass of researchers in period t . Since R_t consists of infinitely many elements, the resulting aggregate innovation probability is approximated by a Poisson distribution (Feller, 1950). Technologies are discovered for all intermediate goods sectors with equal probability, so the aggregate probability that at least one true innovation is made in any intermediate goods sector is given by

$$\Omega^I(R_t) = 1 - e^{-pR_t}. \quad (5)$$

If more than one innovation is created for a particular intermediate goods sector, the patent is attributed to one of the innovators by lottery. The individual probability of obtaining the

⁴Notice, that the quality jump takes place at the end of the period. This implies that in the case of an $M2$ - $M2$ transition, where a second-period monopolist has undertaken secondary development and is then replaced by a new innovator, the quality of the intermediate good increases by secondary development and by fundamental development. So for $M2$ - $M2$ transitions, the quality evolves by $q_{\nu,t+1} = \lambda S_{\nu,t} q_{\nu,t}$. This assumption is in line with Acemoglu and Cao (2010).

patent for a new technology for any intermediate goods sector is given by

$$P(R_t) = \frac{1 - e^{-pR_t}}{R_t}. \quad (6)$$

The aggregate probability that at least one marketable imitation is made for any intermediate goods sector is equivalently given by

$$\Omega^C(R_t) = 1 - e^{-iR_t}. \quad (7)$$

The individual probability of obtaining a patent $P(R_t)$ is decreasing in R_t whereas the aggregate probabilities of innovation and imitation in a sector $\Omega^I(R_t), \Omega^C(R_t)$ are increasing in R_t . Also, the individual and aggregate probabilities of innovation or imitation are increasing in p and i respectively. In the remainder of the paper, the shorter notations Ω_t^I and Ω_t^C will be used for the aggregate probabilities.

Secondary Research

In addition to primary research that creates new designs for intermediate goods replacing the previous generation, the quality of an intermediate good can be improved by the current incumbent of an intermediate goods sector. This secondary development is modeled as technology improvement under certainty that takes one period of time. Since secondary development is costly and time-consuming, the incumbent of an intermediate goods sector will undertake secondary development only during his second life period to reap the benefits of it in his third period. The change of quality is given by

$$q_{\nu,t+1} = S_{\nu,t} \cdot q_{\nu,t}, \quad (8)$$

$$s.t. S_{\nu,t} = \alpha \left(\frac{s_{\nu,t}}{q_{\nu,t}} \right)^\sigma + 1, \quad (9)$$

where $s_{\nu,t}$ denotes the cost of secondary development (measured in terms of the final good) and $\alpha \in \mathbb{R}^+$ and $\sigma \in (0, 1)$ are parameters that control the magnitude and curvature of the cost function. Throughout the paper, I assume that the parameters α, σ are such that the optimal amount of secondary development chosen by the monopolist $\hat{S}_{\nu,t}$ is bounded by

$$\hat{S}_{\nu,t} < (1 - \beta)^{-\frac{1-\beta}{\beta}}. \quad (10)$$

This assumption ensures that in the case of imitation, the monopolist is limited in his price setting by the imitator and cannot charge the unconstrained monopoly price.

Intermediate Goods Production

Intermediate goods are produced at constant marginal cost ψ which is normalized to $\psi = 1 - \beta$ without any loss of generality. Demand for intermediate goods is given by

$$x_{\nu,t} = q_{\nu,t} p_{\nu,t}^{-\frac{1}{\beta}} L_t. \quad (11)$$

The price of intermediate goods depends on the actual market structure in the particular intermediate goods sector:

Monopoly

If the technology leader of an intermediate goods sector is an unchallenged monopolist ($M2, M3$), the price of the intermediate good and the quantity demanded are given by

$$p^M = \frac{\psi}{1 - \beta} = 1, \quad (12)$$

$$x_{\nu,t}^M = q_{\nu,t} L_t. \quad (13)$$

Limited Monopoly

If the monopolist is challenged by an imitator in his third life period, the technological advantage of the monopolist is reduced to the amount of secondary development that he undertook in the previous period, $S_{(t-1)}$. In this case, the monopolist can only charge the limited monopoly price, which makes final good producers just indifferent between buying from the monopolist or the imitator. The resulting price and quantity demanded are given by

$$p_{\nu,t}^{LM} = \psi \cdot S_{\nu,(t-1)}^{\frac{\beta}{1-\beta}} = (1 - \beta) \cdot S_{\nu,(t-1)}^{\frac{\beta}{1-\beta}} \leq 1, \quad (14)$$

$$x_{\nu,t}^{LM} = (1 - \beta)^{-\frac{1}{\beta}} q_{\nu,t} S_{\nu,(t-1)}^{-\frac{1}{1-\beta}} L_t, \quad (15)$$

where the amount of secondary development $S_{\nu,(t-1)}$ is already included in $q_{\nu,t}$.

Competition

If the monopolist of an intermediate goods sector exits the economy, his patent expires and the technology becomes publicly available. As long as no researcher creates a new innovation for this sector, the intermediate good of the latest technology is produced competitively by independent firms. The resulting price and quantity demanded are given by

$$p_{\nu,t}^{CO} = \psi = (1 - \beta), \quad (16)$$

$$x_{\nu,t}^{CO} = (1 - \beta)^{-\frac{1}{\beta}} q_{\nu,t} L_t. \quad (17)$$

Profit of an Innovator

After a researcher has obtained a patent for a new design, he becomes the monopolist of the particular intermediate goods sector in his second life period. His profit for this period is given by

$$\pi_{\nu,t}^{M2}(q_{\nu,t}) = \beta q_{\nu,t} L_t - s_{\nu,t}. \quad (18)$$

With regard to his third life period, there are three possibilities. With probability $(1 - \Omega_t^I)(1 - \Omega_t^C)$ neither an innovation nor an imitation is made for this sector, so he remains the unchallenged monopolist in his third period. With probability $(1 - \Omega_t^I)\Omega_t^C$ he is

not replaced by a new innovator but challenged by an imitator. In this case, he will be a limited monopolist in his third period. Finally, with probability Ω_t^I a new innovation is made for this sector and the current monopolist is replaced. The two possible outcomes for a positive profit in the third period depend on the amount of secondary development that the monopolist undertakes in his second life period $S_{\nu,t}$. They are given by

$$\pi_{\nu,t+1}^{M3}(q_{\nu,t}, S_{\nu,t}) = \beta S_{\nu,t} q_{\nu,t} L_{t+1}, \quad (19)$$

$$\pi_{\nu,t+1}^{LM}(q_{\nu,t}, S_{\nu,t}) = (1 - \beta)^{-\frac{1-\beta}{\beta}} \left[1 - S_{\nu,t}^{-\frac{\beta}{1-\beta}} \right] q_{\nu,t} L_{t+1}. \quad (20)$$

The monopolist's profit is smaller in the limited monopoly case than with an unchallenged monopoly. Furthermore, the profit increases in both cases with the amount of secondary development undertaken in the previous period. However, the marginal effect of secondary development is stronger in the limited monopoly case than under a pure monopoly.

The expected total profit over the two periods $\Pi_{\nu,t}$ of an innovator who obtains the monopoly with new technology level $q_{\nu,t}$ is given by

$$\begin{aligned} \mathbb{E}_t(\Pi_{\nu,t}) &= \beta q_{\nu,t} L_t - s_{\nu,t} + (1 - \Omega_t^I) (1 - \Omega_t^C) \beta S_{\nu,t} q_{\nu,t} L_{t+1} \\ &\quad + (1 - \Omega_t^I) \Omega_t^C (1 - \beta)^{-\frac{1-\beta}{\beta}} \left[1 - S_{\nu,t}^{-\frac{\beta}{1-\beta}} \right] q_{\nu,t} L_{t+1}. \end{aligned} \quad (21)$$

Optimal Secondary Development

In his second life period, the monopolist chooses the amount of secondary development which maximizes his expected profit

$$\hat{S}_{\nu,t} = \arg \max_{S_{\nu,t}} \mathbb{E}_t(\Pi_{\nu,t}), \quad (22)$$

$$s.t. \quad s_{\nu,t} = \left(\frac{S_{\nu,t} - 1}{\alpha} \right)^{\frac{1}{\sigma}} q_{\nu,t}. \quad (23)$$

Notice that the monopolist does not take into account the possible effect of $S_{\nu,t}$ on the aggregate economy, that is on the number of active researchers and on future wages. Optimal secondary development is then implicitly defined by

$$(1 - \Omega_t^I) \left[1 + \Omega_t^C \left((1 - \beta)^{-\frac{1}{\beta}} \hat{S}_{\nu,t}^{-\frac{1}{1-\beta}} - 1 \right) \right] \beta L_{t+1} = \frac{(\hat{S}_{\nu,t} - 1)^{\frac{1-\sigma}{\sigma}}}{\sigma \alpha^{\frac{1}{\sigma}}}. \quad (24)$$

Proposition 1. *A unique optimal value of secondary development $\hat{S}_{\nu,t} \geq 1$ exists, which is independent of the technology level of the monopolist, so $\hat{S}_{\nu,t} = \hat{S}_t$*

Proof. The LHS of equation(24) is strictly decreasing in \hat{S}_t and bounded between $(1 - \Omega_t^I) \left[1 + \Omega_t^C \left((1 - \beta)^{-\frac{1}{\beta}} - 1 \right) \right] \beta L_{t+1}$ for $\hat{S}_t = 1$ and

$(1 - \Omega_t^I) [1 - \Omega_t^C] \beta L_{t+1}$ for $\hat{S}_t \rightarrow \infty$. The RHS of the equation is strictly increasing in \hat{S}_t and is zero for $\hat{S}_t \rightarrow 1$ and goes to infinity for $\hat{S}_t \rightarrow \infty$. This establishes the existence of a unique intersection. The independence of the monopolist's level of technology $q_{\nu,t}$ can be inferred directly from equation (24). \square

Proposition 2. *An increase of the aggregate imitation probability Ω_t^C ceteris paribus increases secondary development \hat{S}_t while an increase of the aggregate innovation probability Ω_t^I lowers secondary development \hat{S}_t . Furthermore, an increase of the aggregate imitation probability Ω_t^C or an increase of the aggregate innovation probability Ω_t^I reduces the expected monopoly profit of an innovator $\mathbb{E}_t(\Pi_{\nu,t})$.*

Proof. To prove the first part, writing equation (24) as implicit function of aggregate innovation and imitation probability and secondary development $F(\Omega_t^I, \Omega_t^C, \hat{S}_t(\Omega_t^I, \Omega_t^C)) = 0$ allows for implicit differentiation to obtain

$$\frac{d\hat{S}_t}{d\Omega_t^C} = -\frac{\frac{\partial F(\cdot)}{\partial \Omega_t^C}}{\frac{\partial F(\cdot)}{\partial \hat{S}_t}} = -\frac{(1 - \Omega_t^I) \left((1 - \beta)^{-\frac{1}{\beta}} \hat{S}_t^{-\frac{1}{1-\beta}} - 1 \right) \beta L_{t+1}}{-\frac{1}{1-\beta} (1 - \Omega_t^I) \Omega_t^C (1 - \beta)^{-\frac{1}{\beta}} \hat{S}_t^{-\frac{2+\beta}{1-\beta}} \beta L_{t+1} - \frac{1-\sigma}{\sigma} \frac{(\hat{S}_t-1)^{\frac{1-2\sigma}{\sigma}}}{\sigma \alpha^{\frac{1}{\sigma}}}} > 0,$$

$$\frac{d\hat{S}_t}{d\Omega_t^I} = -\frac{\frac{\partial F(\cdot)}{\partial \Omega_t^I}}{\frac{\partial F(\cdot)}{\partial \hat{S}_t}} = -\frac{-\Omega_t^I \left[1 + \Omega_t^C \left((1 - \beta)^{-\frac{1}{\beta}} \hat{S}_t^{-\frac{1}{1-\beta}} - 1 \right) \right] \beta L_{t+1}}{-\frac{1}{1-\beta} (1 - \Omega_t^I) \Omega_t^C (1 - \beta)^{-\frac{1}{\beta}} \hat{S}_t^{-\frac{2+\beta}{1-\beta}} \beta L_{t+1} - \frac{1-\sigma}{\sigma} \frac{(\hat{S}_t-1)^{\frac{1-2\sigma}{\sigma}}}{\sigma \alpha^{\frac{1}{\sigma}}}} < 0.$$

For the second part, differentiating the expected profit $\mathbb{E}_t(\Pi_{\nu,t})$ with respect to the aggregate imitation probability Ω_t^C or the aggregate innovation probability Ω_t^I respectively directly yields the result.

$$\frac{\partial \mathbb{E}_t(\Pi_{\nu,t})}{\partial \Omega_t^C} = - (1 - \Omega_t^I) q_{\nu,t} L_t \left[\beta \hat{S}_t - (1 - \beta)^{-\frac{1-\beta}{\beta}} \left(1 - \hat{S}_t^{-\frac{\beta}{1-\beta}} \right) \right] < 0, \quad (25)$$

$$\frac{\partial \mathbb{E}_t(\Pi_{\nu,t})}{\partial \Omega_t^I} = - \left((1 - \Omega_t^C) \beta S_{\nu,t} + \Omega_t^C (1 - \beta)^{-\frac{1-\beta}{\beta}} \left[1 - S_{\nu,t}^{-\frac{\beta}{1-\beta}} \right] \right) q_{\nu,t} L_{t+1} < 0. \quad (26)$$

\square

An increase in the imitation probability raises secondary development because the marginal profit of secondary development is greater in the limited monopoly situation than for an unchallenged monopoly. Without secondary development, the monopolist cannot make any profit when being imitated. Increasing secondary development reduces the negative effect of imitation as the monopolist expands his quality advantage over the imitator which allows him to raise the limited monopoly price. Therefore, secondary development can be regarded as “escape innovation”, similar to the results in Aghion et al. (2011, 2012). An exogenous increase of the innovation probability of outsiders has the opposite effect on secondary development. This is

due to the fact, that the monopolist cannot compete against an innovator that replaces him but only fight against competition of an imitator. If an innovation takes place in the sector, the monopolist is completely replaced in his third period and all investment in secondary development is lost from his point of view.

The second part of Proposition 2 indicates that even though the monopolist can react towards a higher probability of imitation by increasing secondary development, the expected monopoly profit ultimately declines. This implies, that entering the research sector becomes less attractive, when the probability of imitation increases.

Final goods sector

The amount of goods demanded from each intermediate goods sector depends on the quality of the particular good and on the price. The latter depends on the current market structure of the particular intermediate goods sector. In order to derive the final goods output, the intermediate goods sectors are grouped together according to their current state. Let N_t^{CO} be the set of intermediate goods sectors with competitive market structure at time t and μ_t^{CO} the Lebesgue measure of this set. $N_t^{M2}, N_t^{M3}, N_t^{LM}$ with $\mu_t^{M2}, \mu_t^{M3}, \mu_t^{LM}$ are defined equivalently, so that

$$N_t^{CO} \cup N_t^{M2} \cup N_t^{M3} \cup N_t^{LM} = [0, 1],$$

and

$$\mu_t^{CO} + \mu_t^{M2} + \mu_t^{M3} + \mu_t^{LM} = 1.$$

With this, final goods production can be rewritten as

$$y_t = \left[\int_{N_t^{CO}} q_{\nu,t}^\beta \left[(1-\beta)^{-\frac{1}{\beta}} q_{\nu,t} L_t \right]^{1-\beta} d\nu + \int_{N_t^{M2}} q_{\nu,t}^\beta [q_{\nu,t} L_t]^{1-\beta} d\nu + \int_{N_t^{M3}} q_{\nu,t}^\beta [q_{\nu,t} L_t]^{1-\beta} d\nu + \int_{N_t^{LM}} q_{\nu,t}^\beta \left[(1-\beta)^{-\frac{1}{\beta}} q_{\nu,t} \hat{S}_t^{-\frac{1}{1-\beta}} L_t \right]^{1-\beta} d\nu \right] \frac{1}{1-\beta} L_t^\beta, \quad (27)$$

which simplifies to

$$y_t = \frac{(1-\beta)^{-\frac{1-\beta}{\beta}} \int_{N_t^{CO}} q_{\nu,t} d\nu + \int_{N_t^{M2}} q_{\nu,t} d\nu + \int_{N_t^{M3}} q_{\nu,t} d\nu + (1-\beta)^{-\frac{1-\beta}{\beta}} \hat{S}_t^{-1} \int_{N_t^{LM}} q_{\nu,t} d\nu}{1-\beta} L_t. \quad (28)$$

The average quality of intermediate goods in the CO -type sectors at time t is given by

$$Q_t^{CO} = \frac{\int_{N_t^{CO}} q_{\nu,t} d\nu}{\mu_t^{CO}},$$

and $Q_t^{M2}, Q_t^{M3}, Q_t^{LM}$ are defined equivalently. This allows to write final goods output in terms of the average quality of each type of intermediate goods sectors.

$$y_t = \frac{(1 - \beta)^{-\frac{1-\beta}{\beta}} \mu_t^{CO} Q_t^{CO} + \mu_t^{M2} Q_t^{M2} + \mu_t^{M3} Q_t^{M3} + (1 - \beta)^{-\frac{1-\beta}{\beta}} \hat{S}_t^{-1} \mu_t^{LM} Q_t^{LM}}{1 - \beta} L_t. \quad (29)$$

3 Balanced Growth Path

Definition of BGP Equilibrium

On the balanced growth path, the number of total researchers R , the optimal amount of secondary development \hat{S} , and the measures of the four types of intermediate goods sectors $\mu^{CO}, \mu^{M2}, \mu^{M3}, \mu^{LM}$ are constant over time. The average quality of each type of intermediate good sectors $Q^{CO}, Q^{M2}, Q^{M3}, Q^{LM}$, output y , the wage for workers in the final goods sector w , and the expected profit of researchers $\mathbb{E}(\Pi)$ grow at a constant growth rate g .

Stationary Distribution of Intermediate Goods Sectors

The transition of the intermediate goods sectors between states as pictured in Figure 2 is a Markov chain. On the balanced growth path, where innovation and imitation probabilities are constant, the Markov chain is time-homogeneous and the stationary distribution can be derived.

Along the BGP, the transition matrix for every intermediate goods sector is given by

$$\mathbb{P} = \begin{matrix} & \begin{matrix} CO & M2 & M3 & LM \end{matrix} \\ \begin{matrix} CO \\ M2 \\ M3 \\ LM \end{matrix} & \begin{pmatrix} (1 - \Omega^I) & \Omega^I & 0 & 0 \\ 0 & \Omega^I & (1 - \Omega^I)(1 - \Omega^C) & (1 - \Omega^I)\Omega^C \\ (1 - \Omega^I) & \Omega^I & 0 & 0 \\ (1 - \Omega^I) & \Omega^I & 0 & 0 \end{pmatrix} \end{matrix},$$

and the stationary measures of the sets of intermediate sector types are given by

$$\begin{pmatrix} \mu^{CO} \\ \mu^{M2} \\ \mu^{M3} \\ \mu^{LM} \end{pmatrix} = \begin{pmatrix} (1 - \Omega^I)^2 \\ \Omega^I \\ (1 - \Omega^I)(1 - \Omega^C)\Omega^I \\ (1 - \Omega^I)\Omega^C\Omega^I \end{pmatrix}. \quad (30)$$

The stationary distribution specifies the time-invariant measures of the sets of intermediate goods sectors in a certain stage. Another possible interpretation is, that it denotes the average time share that each intermediate sector spends in a certain stage.

Growth Rate and Average Qualities

The stable distribution allows to calculate the growth rate of the economy. All sectors have

the same probability Ω^I for a new innovation which increases the quality by λ . Additionally, in $M2$ sectors secondary development increases the quality by \hat{S} . For $M2$ to $M2$ transitions, the quality increment from fundamental research λ comes on top of the quality improvement from secondary development. With this, the steady-state growth rate of the economy is given by

$$\begin{aligned} g &= \left(\mu^{CO} + \mu^{M3} + \mu^{LM} \right) \cdot \Omega^I (\lambda - 1) + \mu^{M2} \cdot \left[\Omega^I (\hat{S} \lambda - 1) + (1 - \Omega^I) (\hat{S} - 1) \right] \\ &= \Omega^I \left[\hat{S} + \lambda - 2 + \Omega^I (\lambda - 1) (\hat{S} - 1) \right]. \end{aligned} \quad (31)$$

Proposition 3. *An increase of the aggregate innovation probability Ω^I or an increase of secondary development \hat{S} ceteris paribus increases the economy's growth rate on the balanced growth path.*

Proof. Differentiating (31) with respect to Ω^I or with respect to \hat{S} directly leads to the result

$$\frac{\partial g}{\partial \Omega^I} = (\hat{S} + \lambda - 2) + 2\Omega^I (\lambda - 1) (\hat{S} - 1) > 0, \quad (32)$$

$$\frac{\partial g}{\partial \hat{S}} = \Omega^I \left[1 - \Omega^I + \Omega^I \lambda \right] > 0. \quad (33)$$

□

Proposition 3 together with Proposition 2 capture the trade-off that motivates this paper. The growth rate rises if innovation by outsiders increases as well as when secondary development by monopolists is augmented. A higher aggregate imitation probability lowers expected monopoly profits and so reduces the amount of fundamental research, resulting in a lower Ω^I . But imitation also raises optimal secondary development by monopolists. Hence the expected result on the growth rate is ambiguous.

With the time-invariant measures of intermediate sector types, the development of the average quality level of the different intermediate sector types can be traced. For the CO -type, the average quality level evolves according to

$$\begin{aligned} Q_{t+1}^{CO} &= \frac{\left(1 - \Omega^I\right) \mu^{CO} Q_t^{CO} + \left(1 - \Omega^I\right) \mu^{M3} Q_t^{M3} + \left(1 - \Omega^I\right) \mu^{LM} Q_t^{LM}}{\left(1 - \Omega^I\right) \left(\mu^{CO} + \mu^{M3} + \mu^{LM}\right)} \\ &= \frac{\mu^{CO} Q_t^{CO} + \mu^{M3} Q_t^{M3} + \mu^{LM} Q_t^{LM}}{1 - \mu^{M2}}. \end{aligned} \quad (34)$$

Doing this for all types of intermediate goods sectors and using the fact that the average quality of each type of intermediate goods sector grows with rate g on the BGP, the development of the mean quality in the four intermediate sector types can be expressed by the system of linear

equations

$$\begin{pmatrix} \frac{\mu^{CO}}{1-\mu^{M2}} & 0 & \frac{\mu^{M3}}{1-\mu^{M2}} & \frac{\mu^{LM}}{1-\mu^{M2}} \\ \lambda\mu^{CO} & \lambda\hat{S}\mu^{CO} & \lambda\mu^{M3} & \lambda\mu^{LM} \\ 0 & \hat{S} & 0 & 0 \\ 0 & \hat{S} & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} Q_t^{CO} \\ Q_t^{M2} \\ Q_t^{M3} \\ Q_t^{LM} \end{pmatrix} = (1+g) \begin{pmatrix} Q_t^{CO} \\ Q_t^{M2} \\ Q_t^{M3} \\ Q_t^{LM} \end{pmatrix}. \quad (35)$$

The solution to this system of equations yields the time-invariant average quality of each type of intermediate sector relative to the mean quality level of the economy. It is given by

$$\begin{pmatrix} Q_t^{CO} \\ Q_t^{M2} \\ Q_t^{M3} \\ Q_t^{LM} \end{pmatrix} = \begin{pmatrix} \frac{\hat{S}}{(1+g)(g+\Omega^I+\hat{S}(1-\Omega^I))} \\ \frac{(g+\Omega^I)}{\Omega^I(g+\Omega^I+\hat{S}(1-\Omega^I))} \\ \frac{\hat{S}(g+\Omega^I)}{(1+g)(g+\Omega^I+\hat{S}(1-\Omega^I))\Omega^I} \\ \frac{\hat{S}(g+\Omega^I)}{(1+g)(g+\Omega^I+\hat{S}(1-\Omega^I))\Omega^I} \end{pmatrix} \cdot Q_t, \quad (36)$$

where Q_t is the average quality of all intermediate goods in the economy,

$$Q_t = \int_0^1 q_{\nu,t} d\nu = \mu^{CO} Q_t^{CO} + \mu^{M2} Q_t^{M2} + \mu^{M3} Q_t^{M3} + \mu^{LM} Q_t^{LM}. \quad (37)$$

Notice that $Q_t^{M3} = Q_t^{LM}$ which is obvious since all intermediate goods sectors that are included in either N^{M3} or N^{LM} are directly coming from N^{M2} with added secondary development during the $M2$ state and no further changes. It can be easily verified that Q_t^{CO} is smaller than any of the other average qualities. However it is indeterminate whether Q_t^{M2} is greater or lower than Q_t^{M3} or Q_t^{LM} respectively.

Final goods output and wage

Let $q^{CO} = \frac{Q^{CO}}{Q}$ and q^{M2}, q^{M3}, q^{LM} be defined similarly. Then final goods output is given by

$$y_t = \frac{(1-\beta)^{-\frac{1-\beta}{\beta}} \mu^{CO} q^{CO} + \mu^{M2} q^{M2} + \mu^{M3} q^{M3} + (1-\beta)^{-\frac{1-\beta}{\beta}} \hat{S}^{-1} \mu^{LM} q^{LM}}{1-\beta} L Q_t, \quad (38)$$

where the mass of workers is given by the total population net of the mass of researchers, monopolists in the intermediate goods sectors, and the monopolists from last period that have been displaced by new monopolists,

$$L = 3H - R - 2\Omega^I. \quad (39)$$

Having derived the economy's final goods output, the wage for workers in the final goods sector is given by

$$\begin{aligned} w_t &= \frac{\partial y_t}{\partial L} = \beta \frac{(1-\beta)^{-\frac{1-\beta}{\beta}} \mu^{CO} q^{CO} + \mu^{M2} q^{M2} + \mu^{M3} q^{M3} + (1-\beta)^{-\frac{1-\beta}{\beta}} \hat{S}^{-1} \mu^{LM} q^{LM}}{1-\beta} Q_t \\ &= Q_t \cdot \bar{w} , \end{aligned} \quad (40)$$

where \bar{w} is the technology-adjusted wage.

The fact that $q^{M3} = q^{LM}$ implies that if a higher share of intermediate goods industries changes from $M2$ to LM instead of switching to $M3$, caused by a higher aggregate imitation probability Ω^I , final goods output and the wage rate increase. This effect comes from reduced monopoly distortions due to the lower market power of the limited monopolist and yields another positive effect of imitation. On the other hand, as the wage rate increases, becoming a worker in the final goods sector becomes more attractive which implies a negative effect on the amount of primary research.

Lifetime Income of a Worker

A newborn agent who decides to work in the final goods sector earns the wage during his three life periods. The wage increases every period by the economy's growth rate g . Hence life-time income W_Q is given by

$$W_t = Q_t \sum_{\tau=0}^2 (1+g)^\tau \bar{w} = Q_t \cdot \bar{W} , \quad (41)$$

where \bar{W} denotes the worker's technology-adjusted life-time income.

The lifetime income of a worker depends on two factors: the wage rate and the growth rate of the economy. As the probability of imitation goes up, the wage increases due to the reduced market power in the economy. If the growth rate also rises, the impact on the worker's lifetime income is clearly positive. However, if the growth rate is negatively affected, the resulting effect on the worker's lifetime income is ambiguous.

Gains from an Innovation

A newborn agent who decides to enter the research sector and observes an average level of technology Q , expects the quality level of his innovation to be

$$\mathbb{E}_t(Q_{t+1}^V) = (1+g)q^{M2}Q_t.$$

The expected value of an innovation for a researcher is then given by

$$\begin{aligned}
V_t &= Q_t \cdot (1+g)q^{M2} \left[\beta L - \left(\frac{\hat{S} - 1}{\alpha} \right)^{\frac{1}{\sigma}} \right. \\
&\quad \left. + (1 - \Omega^I) (1 - \Omega^C) \beta \hat{S} L + (1 - \Omega^I) \Omega^C (1 - \beta)^{-\frac{1-\beta}{\beta}} \left[1 - S^{-\frac{\beta}{1-\beta}} \right] L \right] \\
&= Q_t \cdot \bar{V},
\end{aligned} \tag{42}$$

where \bar{V} denotes the technology-adjusted value of an innovation.

Arbitrage Equation

Having derived the expected value of an innovation for a researcher and the life-time income of a worker, the arbitrage equation that determines the equilibrium number of researchers along the balanced growth path can be written as

$$\bar{W} = P(R) \cdot \bar{V} + (1 - P(R)) [\bar{W} - \bar{w}], \tag{43}$$

given that the number of researchers is positive and not all young agents enter the research sector,

$$0 < R < H. \tag{44}$$

If the arbitrage condition cannot be fulfilled because no newborn agent finds it attractive to enter the research sector, the economy features zero growth, constant wages, and all intermediate goods sectors are in the competitive state *CO*. Conversely, it could be possible that entering the research sector becomes so attractive, that the RHS of (43) is greater than the LHS for $R = H$ and all young agents enter the research sector. At this point, there is a kink in the decision to enter the research sector. In principle, agents could also enter the research sector in their second life period. However, they would then only have the chance of a one-period monopoly instead of a potential two-period monopoly as young researchers have. In the following, I rule out these two possibilities and focus on the interior solution where a part of newborn agents enters the research sector and the remainder works in final goods production.

The arbitrage equation is independent of the current technology level. Hence the number of researchers does not change over time, which establishes the balanced growth path property. The BGP equilibrium of the economy is determined by the solution to the system of implicit functions (24) and (43) which define the amount of researchers and optimal secondary development from which all other endogenous variable can be derived directly. Unfortunately, an analytic proof for the uniqueness of the equilibrium could not be established. Nevertheless, numerical computation of the equilibrium over a wide range of parameters suggests that uniqueness is fulfilled in practice.

The arbitrage equation can be rearranged to provide further insight how the equilibrium number of researchers is determined

$$\frac{P(R)}{1 - P(R)} (\bar{V} - \bar{W}) = \bar{w}. \quad (45)$$

A higher value of an innovation increases the benefits of research and hence raises the number of researchers in equilibrium. The number of researchers decreases if the life-time income of a worker \bar{W} , which is the alternative to research, or the opportunity cost of research, namely the wage lost during the period of research, \bar{w} increase. The life-time income \bar{W} is closely connected to the wage rate \bar{w} but also positively affected by the growth rate, which in turn positively depends on the number of researchers.

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Welfare

As the arbitrage equation states that the expected utility of an agent that enters the research sector is equal to the life-time income of a worker in final goods production, the latter becomes a perfect measure for the expected life-time utility of any newborn agent in the model.⁵ This can be regarded as a measure of welfare. However, it should be pointed out that it concerns only the welfare of the current newborn generation, not that of future generations which would profit more strongly from an increased rate of economic growth. It can be easily extended into a utilitarian welfare measure where the utility of future generations is weighted with the inverse of the growth rate.

4 Effects of a Change of the Imitation Probability

A change in the individual probability of (a marketable) imitation i affects the economy's equilibrium in a number of ways. First, a higher i increases the aggregate imitation probability and thus reduces the expected profit of an innovator and the number of researchers in equilibrium. In return, the aggregate innovation probability Ω^I drops while the individual success probability of a researcher rises, which dampens the negative effect on the amount of researchers. The higher aggregate imitation probability and the lower aggregate innovation probability together raise the amount of optimal secondary development \hat{S} in equilibrium. The resulting effect on the growth rate is ambiguous.

The higher aggregate imitation probability also reduces monopolistic distortions by increasing the measure of industries in limited monopoly relative to that in third-period monopoly, which

⁵This holds also for the zero-growth equilibrium without research.

raises final goods output and the wage rate. The latter effect further lowers the equilibrium number of researchers as the opportunity cost of research increases. The impact on the life-time income of the worker depends on the growth rate as well and is therefore ambiguous.

Due to the complexity of equations (24) and (43), it is not possible to derive comparative static results for changes of the imitation probability. Therefore I use numerical examples to gain further insight about the effects of an increase in the individual imitation probability. In the remainder of the paper, I focus solely on a change in the individual probability of making a marketable imitation i while the individual probability of successful innovation p is held constant. This implies, that the change of i comes from a change in the parameter Φ , that is from a change in the protection of intellectual property rights.

For the simulation, the period length is set to 15 years. The mass of agents is $H = 5$ and the innovation probability is set to $p = 0.0615$ to yield an annual growth rate of 2% when the imitation probability is set to zero. I set $\beta = 2/3$ to capture the labor share of income. Following Acemoglu and Cao (2010), the quality improvement of a fundamental innovation is set to $\lambda = 3$ and the cost of secondary development is calibrated to yield $S = 1.5$ at zero imitation probability.⁶ For the first figure, the chosen values are $\alpha = 0.374$ and $\sigma = 0.5$. All figures are quality adjusted, that is they are divided by the average level of technology.

Figure 3 illustrates how the economy reacts to a change in the individual imitation probability i which increases from zero to one on the horizontal axis. Looking at the two topmost plots, it can be seen that secondary development grows constantly as the imitation probability increases whereas the number of researchers falls. The combined result on the growth rate is mixed in this example and represents an inverted U-shape, similar to the results in Aghion et al. (2001, 2002) and Mukoyama (2003). For small values of i , the positive effect of stronger secondary development is dominant, so that the growth rate increases. The highest growth rate is achieved when the aggregate imitation probability in a sector reaches 28%. As i increases further, the negative effect of having less fundamental research becomes more important and the growth rate decreases even though it remains above the value for zero-imitation probability. Overall, the effect on the growth rate is quite small in this example.

The next plots reveal how the determinants of the arbitrage equation are affected by changes in the individual imitation probability. The wage in the final goods sector increases with higher imitation probability as the measure of sectors with competition or limited monopoly increases relative to those with pure monopoly. The higher wage rate, which can be regarded as the cost of fundamental research, adds an indirect negative effect of increased imitation probability on fundamental research. A similar result can be found in Horii and Iwaisako (2007). The life-time income of a worker also grows with the imitation probability. In the area where the growth rate increases, this result is clear, since both, the wage and the growth rate positively affect the life-time income of a worker. However, even in the area where the growth rate starts to decline, the life-time income of workers rises further. The wage effect dominates because the changes in

⁶See also Freeman and Soete (1997) and Scherer (1986) for accounts of the innovation process.

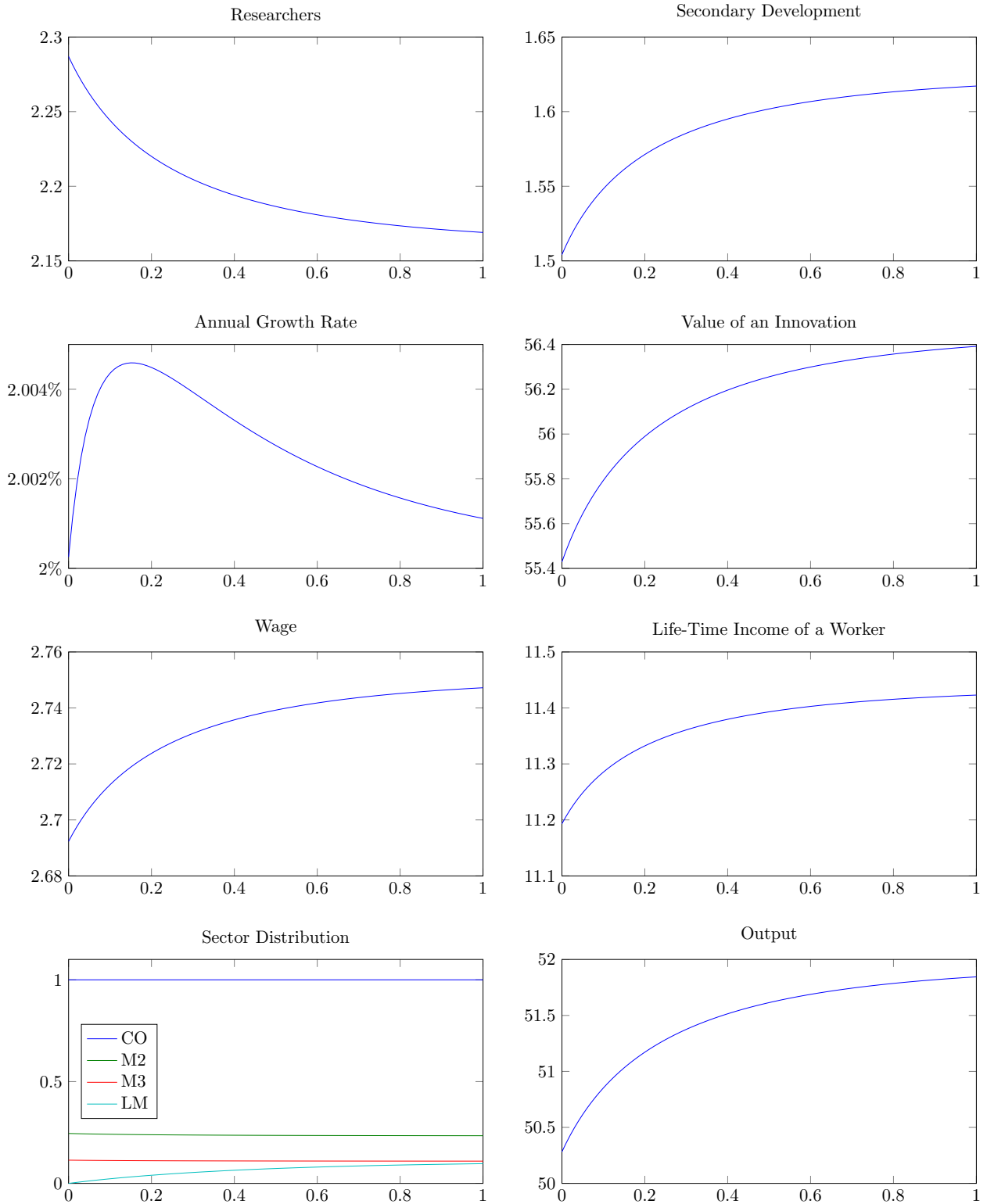


Figure 3: Effect of changes in the individual imitation probability (Imitation probability i given on horizontal axis)

the growth rate are very small. This adds to the reduction of researchers, as the outside option of research increases.

Interestingly, the expected value of an innovation does not decrease but rather increases as the imitation probability rises. This comes as a surprise as the threat of imitation should lower the expected monopoly profit. However, as the number of researchers declines, the threat of being replaced by another innovator drops. Also, fewer researchers imply a higher number of production workers which increases demand for intermediate goods and hence raise the monopoly profit.

The life-time income of a worker also measures the expected utility of all newborn agents in the economy. Here it turns out, that a higher rate of imitation always increases utility, even though the growth rate starts to decline at some point. This implies, that the positive effect caused by reduced market power is stronger, than the loss due to less growth. The life-time income of final good workers rises because monopolistic distortions are reduced and thus wages increase. The expected utility of researchers goes up because the individual probability to obtain a patent increases with fewer researchers while the probability of being displaced in the third period falls. In addition, the monopoly profit increases as the number of production workers rises.

The last two plots provide some more insight about how the aggregate economy reacts to a change in the individual imitation probability. The left plot shows the equilibrium distribution of the states of intermediate goods sectors. As the imitation probability rises, the measure of sectors in limited monopoly increases at the expense of the sectors in third-period monopoly until eventually, all monopolists are imitated and $M3$ vanishes. In addition, the measure of sectors in a second-period monopoly declines whereas the measure of sectors in competition increases as the number of researchers falls. Since both effects imply a reduction of monopolistic distortions in the economy, the output increases. A second factor, that raises output, is the increase in the number of workers in final goods production.

Productivity of Secondary Development

The results derived above depend on how strong secondary development reacts towards an increase in the imitation probability. Figure 4 illustrates how the economy is affected by a higher imitation rate with different parameters for the cost of secondary development.

For this comparison, I use different combinations of the parameters α and σ that control the scale and curvature of the productivity of secondary development. The focus is on the effect of different values for σ , since this parameter controls the convexity of the cost of secondary development and thus strongly affects the decision how much to increase secondary development in reaction towards an increase in the imitation probability. Therefore, I compare the results for $\sigma = \{0.1, 0.25, 0.4, 0.5, 0.6\}$. To be able to compare the results, I hold the level of secondary development at zero imitation probability constant at $\hat{S} = 1.5$ and chose α accordingly. All other parameters of the model have been left constant, only the individual innovation probability has been adapted slightly to give the same growth rate at zero imitation probability for all parameter setups.⁷

⁷The adjustment of the individual innovation probability amounts to only 6% at most.

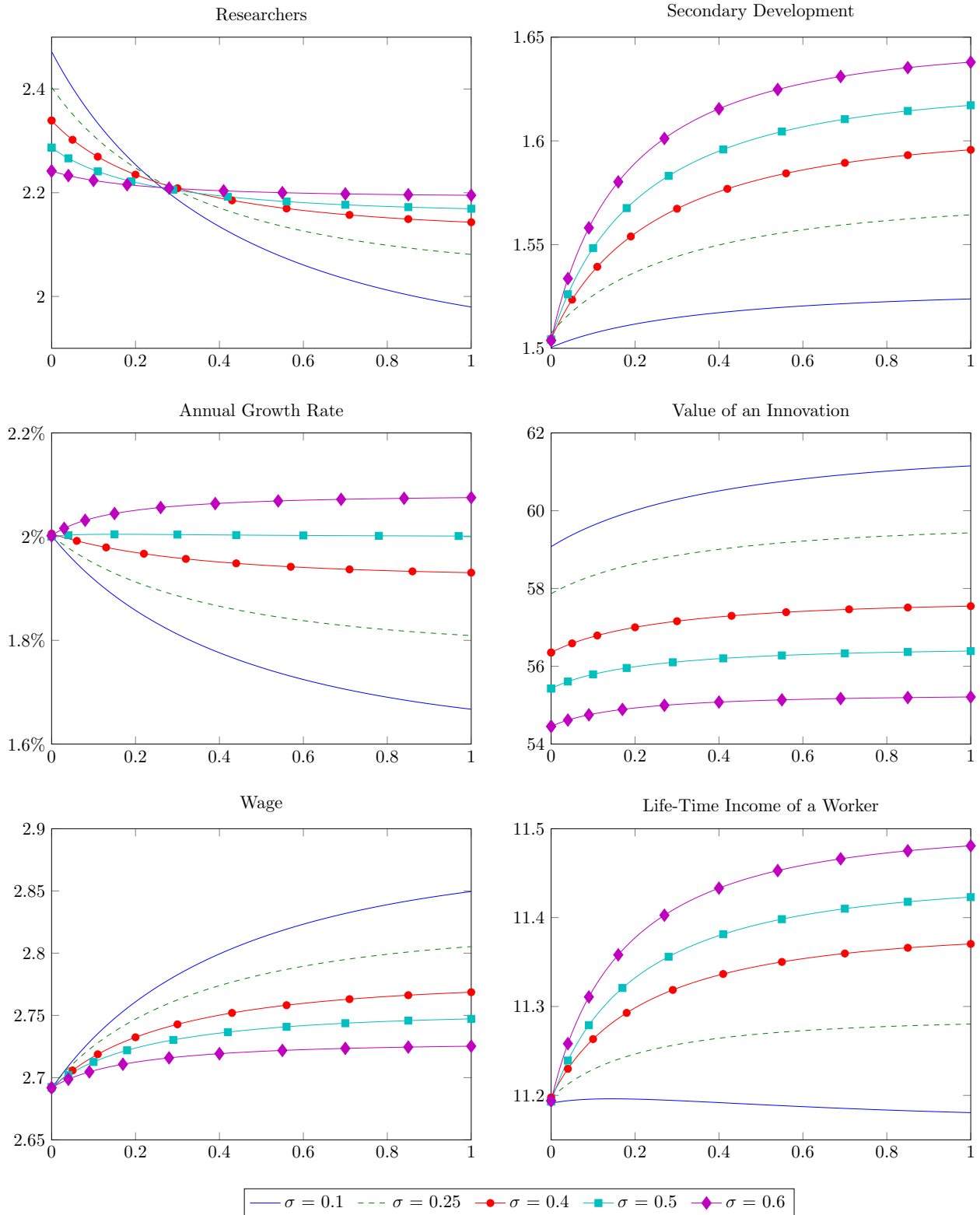


Figure 4: Impact of the productivity of secondary development (Imitation probability i given on horizontal axis)

It can be seen, that the steeper the cost increase of secondary development is (lower σ), the smaller is the rise of secondary development in reaction to the increased individual imitation probability. As this reduces the innovators profit in the limited monopoly case and thus the expected value of an innovation, the number of researchers decreases stronger in the case of higher marginal costs of secondary development. Since secondary development rises to a lesser extent and the number of researchers decreases stronger, the growth rate always falls with the individual imitation probability when σ is small.

On the other hand, if the marginal cost of secondary development is low, the growth rate always increases with the probability of imitation because secondary development increases sharply to escape the competition. This is the case for $\sigma = 0.6$ and higher. The special case where an increase of the individual imitation probability first increases the growth rate and then reduces it occurs only for a small interval of σ .

The wage rate in final goods production increases with the imitation probability for all σ as the market power is reduced. The effect is stronger the higher the marginal cost of secondary development is. This comes from the fact that for a high marginal cost of secondary development, the number of researchers declines stronger, leading to a higher share of sectors in competition and also because the lower amount of secondary development leads to reduced monopoly distortions in the limited monopoly sectors as the advantage of the innovator over the imitator shrinks. The level of output behaves similarly as wages. In addition to the reduced monopoly distortions, a lower number of researchers implies a higher number of workers in the final goods sector. This effect increases output even further.

The life-time income of a worker, which also represents expected utility for all agents in the economy, typically increases with the imitation probability. This is even true for cases where the growth rate is reduced by imitation. Only for very high marginal costs of secondary development, the strong decline of the growth rate outbalances the positive effect of the reduced market power and welfare is negatively affected by imitation. This is an important result, as it shows that the probability of imitation may have opposing effects on growth and on welfare. This implies that the discussion whether imitation is harmful or not should shift from a sole focus on the growth rate towards potential welfare gains.

The most unexpected result is the fact the the value of an innovation always increases with the individual imitation probability which is contrary to the canonical result of endogenous growth theory that imitation lowers the expected monopoly profit. Interestingly, the effect is strongest for high marginal cost of secondary development, when monopolists are less able to protect themselves from imitators. However, the number of researchers declines very strongly in this case, caused by the strong increase in the wage rate. This reduces the aggregate innovation probability and thus lowers the probability of displacement by another innovator. So the expected value of an innovation increases. Furthermore, the higher number of production workers increases the demand for intermediate goods and thus the expected monopoly profit.

5 Conclusions

In this paper, I have developed a model to explore whether imperfect IPR protection can stimulate technological progress by inducing technology leaders to increase their research activities in order to escape the competition of imitators. An increased probability of imitation lowers research by outsiders but increases secondary development by incumbents. It turns out that the combined effect on the growth rate is ambiguous, depending primarily on the research productivity of incumbents. If secondary development by incumbents is highly productive, the increased threat of imitation increases the growth rate and vice versa. For certain parameters, the relationship between imitation probability and economic growth resembles an inverted U-shape.

The model also shows a strong market effect that increases output, the wage rate, and static welfare due to a higher degree of competition in the economy. These positive effects can be found also for cases where the effect on the growth rate is negative. The results imply that imitation should be seen more positively than it is typically the case. Policy makers who decide on the degree of property rights protection should focus not solely on the effects on the growth rate but also on potential welfare gains from reduced market power.

For future work it would be desirable to completely endogenize the imitation decision and decouple it from outsider innovation. To achieve this, imitators must have the opportunity to gain something from imitation, which is not the case in the actual model. The literature offers three ways of achieving this goal: lower production cost of the intermediate good for the imitator as it is assumed in the North-South model by Grossman and Helpman (1991b), a profit sharing approach as in Segerstrom (1991), or an increased chance to become the future innovator as in Mukoyama (2003). With regard to the model presented here, the profit sharing approach appears to be the most promising. However, the implementation is not straightforward as the number of successful imitators will be important while currently the focus is only on the fact whether at least one imitation takes place in a sector.

A further step would be to extend the model's three period OLG setup into a framework with infinitely-lived households. This would not only help the model to fit into the literature but also would allow for a better calibration to real world moments, especially to increase the role of secondary development. As argued in Acemoglu and Cao (2010), incumbent quality leaders make up for about two thirds of TFP growth. In the current structure of the model, incumbents have only one period for further improvements, so the influence of secondary development on the growth rate is rather limited. In a multiple period setup, incumbents could undertake quality improvements over a longer time while constantly being in danger of imitation. With this increased role of secondary development, the positive effect of imitation on the growth rate could be even greater.

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