Essays on Social Capital and Economic Growth

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Abstract

In this thesis we present three models to analyze the dynamic relationship between social capital and economic growth. Throughout it is assumed that social capital increases with socialization while it decreases with labor migration. We consider two channels through which social capital affects the economy. First, social capital affects the innovation process (Chapter 2 and 3) and second, it affects the output (Chapter 3). It has also been assumed that the same objective can also be achieved by improving appropriate formal institutions but doing so is costly. Chapter 1 introduces the topic and discusses related literature. Chapter 2 presents a simple model and shows that in the absence of formal institutions, a higher rate of innovation lowers R&D investment as it weakens the existing informal institutions. Social capital declines due to a decline in socialization time and also because of an increase in the labor migration rate. As a result, rise in the rate of growth rate is lower that what would be predicted by a standard growth model (benchmark case). We show that formal institutions need to be developed in response to new technological breakthrough because of its detrimental impact on social capital. Chapter 3 extends the model by adding physical capital into the model and analyzes alternative ways to finance a chosen level of expenditure on formal institutions. We find that financing through lump sum tax is growth maximizing, however, tax on consumption results in highest improvement in welfare. In the case where social capital affects output directly (Chapter 4), we analyze the impact of increase in the rate of innovation and an exogenous improvement in formal institutions financed by lump-sum tax. We find that while both shocks increase the rate at which the economy grows and decrease the stock of social capital; productivity adjusted physical capital and R&D investment declines when innovation rate goes up while they increase when the formal institutions are improved. They both result in long-run welfare gain. More effective formal institutions result in even higher economic growth and long-run welfare gain.

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DEDICATION

To my late mother

Chapter 1

Introduction

After the pioneering work by Coleman (1988, 90) and Putnam (1993, 2000), research on social capital has received enormous attention from economists. Social capital has been recognized as an important determinant of economic performance of a country.[1] While a country with a high stock of social capital tends to grow faster than a country with a low stock of social capital, higher growth may itself be detrimental to social capital which, in turn, may hamper the growth performance. Putnam et al (1993) argued that a large part of the differences in per capita income between Northern and Southern Italy can be explained by the differences in their level of social capital, measured by membership in formal and informal groups and clubs. Routledge and von Amsberg (2003), and Miguel (2003) argued that a higher growth rate erodes social capital by increasing the labor migration rate.[2]

Additionally, Putnam (2000) documents that social capital in the US declined monotonically since 1960s, but there was no apparent adverse impact on the US economy. Particularly, during the 1990s US experienced rapid economic growth, a period when there was a sharp decline in social capital. He identifies some possible determinants of this decline as rising female participation in the labor market, increase in geographical mobility, replacement of small stores by supermarkets, and individualization of leisure time. He, further, argued that during this period alternative (formal) sectors increased rapidly in response to decline in the strength of the

[1] See Knack and Keefer (1997), Temple and Johnson (1998), Zak and Knack (2001), Beugelsdijk et al (2004),Guiso et al (2004), Akcomak and Well (2009) for details.
[2] Social capital is person and place specific. See Glaeser and Redlick (2009)

informal sector (social capital). Putnam (2000) writes, "... during the 1980s both public and private spending on security rose rapidly as a share of GNP ... By 1995 America had 40% more police and guards and 150% more lawyers and judges than would have been projected in 1970, even given the growth of population and economy".

What is `social capital'? According to Putnam et al (1993), "social capital... refers to features of social organizations, such as *trust*, *norms*, and [social] *networks* that can improve the efficiency of society ...". Durlauf and Fafchamps (2004) identify three main underlying ideas behind social capital; first, it generates positive externalities in the society, second, these externalities are achieved through shared trust, and norms, and third, shared trust and norms arise from informal forms of organizations. In a nutshell, any form of social organization or informal institution that facilitates cooperation and coordination, reduces transaction costs or improves market efficiency can be regarded as social capital. For example, since it is extremely difficult and prohibitively expensive to write complete and enforceable contracts in most cases, contracting parties, therefore, can lower these costs by writing a weaker incentive intensive contract.[3] Social connections or social networks may also reduce the impact of the moral hazard problem.[4] Granovetter (1995) argued that social networks play a useful role in channeling information about jobs and job applicants in the labor market. In many cases, social capital is necessary in resolving conflicts among competing interests, reducing the free riders problem and internalizing the externality in the provision of public good.[5] Guiso et al (2004) have shown that social capital plays an important role in the degree of financial development across different

[3] Rob and Zemsky (2002) show that weaker incentive intensive contracts are desired when output strongly depends on partially observed cooperative efforts of workers.
[4] Jackson and Schneider (2011) have shown that social connections significantly reduced the effects of moral hazard in New York City taxi industry.
[5] See Coleman (1988) for details.

parts of Italy. Recently, Akcomak and Weel (2009) investigated 102 European regions and concluded that social capital increases growth by fostering innovation.

To capture the dynamics of social capital, we assume that the stock of social capital increases when people socialize and decreases with labor migration.[6] We, further, assume that social capital is a by-product of an individual's rational decision where the reason for socialization is the pleasure derived from social interaction and labor migration is the result of technological shocks to the economy. The assumption that social capital is an externality is in line with the observations made by Arrow (2000). He writes, "*There is considerable consensus ... that much of the reward for social interactions is intrinsic - that is, the interaction is the reward - or at least that the motives for interaction are not economic ... The relations between the market and social interactions appear to be two-sided. On the one hand ... the market needs supplementation (for efficiency) by nonmarket relations* [social capital]. *On the other hand, labor or supplier turnover in response to price* [changes] *may destroy the willingness to offer trust or, more generally, to invest in the future of the relation*".

In related literature, Zak and Knack (2001), analyze the impact of trust on growth in a heterogeneous agent growth model. Consumers are randomly matched with investment brokers every period and decide how much time to spend in monitoring. Trust varies inversely with the level of monitoring. Routledge and von Amsberg (2003) analyze the impact of growth on social capital. They argue that technological innovation results in reallocation of labor which reduces social capital. Other approaches that incorporate social capital into growth models use human capital (Sequeira and Ferreira-Lopes (2011)), degree of marketization (Bartolini and Bonatti (2009)), and participation in social networks as determinants of social capital (Beugelsdijk and Smulder (2009)).

[6] Similar to time investment in Glaeser et al (2002).

This dissertation presents three models that analyze the dynamic relationship between social capital and economic growth where not only the positive impact of social capital on economic growth but also the detrimental impact of growth on social capital has been considered. This relationship has been analyzed in a variant of Aghion-Howitt (1992) Schumpeterian growth model where a representative consumer makes labor-socialization and consumption-saving decisions.

Chapter 2 introduces a simple model that captures the dynamics of social capital and economic growth. Following Zak and Knack (2001) and Guiso et al (2004), we assume that consumers can invest their savings only through investment brokers. These brokers are opportunists in the sense that given the opportunity they would cheat and run away with the money. However, their ability to cheat (or the frequency of getting caught and money recovered) depends upon the strength of informal (social capital) and formal institutions. Therefore, a higher level of social capital increases investment and growth by reducing the broker's ability to cheat.[7]

We consider three different institutional environments in this chapter. The benchmark case corresponds to the standard Schumpeterian growth model with a labor-socialization tradeoff where institutions are perfect and costless to maintain. The other two cases consider imperfect institutional environments. The second case includes only informal institutions (social capital) and the third incorporates both formal and informal institutions.

Using plausible parameter values, we show that in the absence of formal institutions, a higher rate of innovation lowers R&D investment as it weakens the existing informal institutions. Social capital declines through two sources, first, due to a decline in socialization time and

[7] Alternatively, it can be argued that social capital raises the return from investment by reducing the cost of finding an honest broker or by reducing the cost of contracting because it may allow for writing a weaker contract.

second, because of an increase in the labor migration rate. As a result, rise in the rate of growth rate is lower that what would be predicted by a standard growth model (benchmark case).

It has been argued that the reason for the failure of poor countries to catch up is the lack of institutions.[8] That is, in the absence of functional institutions, economic performance of poor countries may not improve significantly even if the technologies of the developed countries, which have been proven useful, are used.[9] We show that formal institutions need to be developed in response to new technological breakthrough because of its detrimental impact on social capital. Although improvement in formal institutions increases growth, it reduces social capital even further.[10] Therefore, improvement in formal institutions should not only take into account the initial decline in social capital but also consider its own negative impact on social capital. A poor country, therefore, lacking in either resources or will to improve its institutions will be caught in a poverty trap.

In Chapter 3, we extend the analysis of the previous chapter by adding physical capital into the model. As we observed in Chapter 2 that in order to have sustained economic growth a country must develop its formal institutions in response to declining social capital. Earlier, we used only non-distortionary lump-sum tax to finance the expenditure on formal institutions. Here, we consider more realistic forms of tax structure and their impact on the economy. The tax rates are set so as to finance the chosen level of expenditure on formal institutions in a decentralized economy framework. We consider taxes on wage income, interest income, consumption, total income and on research activities in addition to lump sum tax. Only one type of tax has been considered at any time.

[8] See Keefer and Knack (1997), Hall and Jones (1999) and Acemoglu et al (2005).
[9] See Francois and Zabojnik (2005).
[10] A higher expenditure on formal institution increases investment income and growth by reducing cheating, however, because of crowding out and the resulting decline in socialization time together with an increase in labor migration rate reduces social capital which, in turn, hampers growth.

The idea of the impact of tax-financed increase in government expenditure in an endogenous growth framework is not new; see, for example, Barro (1990), Jones et al (1993), Glomm and Ravikumar (1994, 1997), and Turnovsky (1996, 2000, 2005). Barro (1990) considers the impact of productive government expenditure where income tax is set to finance the chosen level of expenditure. Turnovsky (2000) shows that the growth effect of an increase in government expenditure is highest when it is financed by lump-sum tax, followed by consumption tax, wage income tax and tax on capital income. This paper distinguishes it from the literature by considering that these expenditures are made to improve formal institutions which have only distributional consequences. That is, it reduces the transaction cost by fostering generalized trust in the economy. We find that improvement in formal institutions results in largest increase in growth rate when it is financed by lump-sum tax; followed by consumption, wage income, interest income, income and the tax on research activities. We also find that both consumption tax and the tax on wage income performs better in terms of long-run welfare changes when compared to lump-sum tax with consumption tax resulting in largest gain in welfare. This is because of the presence of externalities (business stealing, intertemporal spillover, social capital) in the decentralized economy where distortionary taxes (consumption and wage) acts to partly correct them.

In Chapter 4, we analyze the relationship between social capital and economic growth where social capital raises output directly by reducing the frictions inside the production process. Once again, the same objective can be achieved by improving formal institutions but doing so is costly. In contrast to the chapter 1 and 2, where we assumed that institutions affect the return from investment and therefore affect the supply of funds for R&D investment, in this chapter we assume that institutions affect the output and therefore profit of firms which, in turn, affect the demand for fund in R&D sector. The strength of institutions in the economy is determined by the flow of services provided by the level of social capital and the strength of formal institutions. Formal institutions may be thought of as spending on infrastructure, strengthening the rules of the law or firm's spending on screening and monitoring to reduce the impact of adverse selection and moral hazard problem within the firm. In this case, we analyze the impact of increase in the rate of innovation and an exogenous improvement in formal institutions financed by lump-sum tax.

We find that while both shocks increase the rate at which the economy grows and decrease the stock of social capital; productivity adjusted physical capital and R&D investment declines when innovation rate goes up while they increase when the formal institutions are improved. They both result in long-run welfare gain. Also, more effective formal institutions result in even higher economic growth and long-run welfare gain.

In related literature, Sequeira and Ferreira-Lopes (2011, 2012) include social capital as a productive factor; however, there is no role of formal institutions in their paper. Bartolini and Bonatti (2009), also include both social capital and formal institutions in the production function in an endogenous growth model, but do not consider the transitional dynamics. Also, we consider social capital as a function of socialization and labor migration rate whereas they consider that social capital declines if ratio of social capital to output falls below a threshold level.

Chapter 2

Social Capital and Economic Growth

This chapter introduces a simple model that captures the dynamic relationship between social capital and economic growth where not only the positive impact of social capital on economic growth but also the detrimental impact of growth on social capital has been considered. This relationship has been analyzed in a variant of Aghion-Howitt (1992) Schumpeterian growth model where a representative consumer makes labor-socialization and consumption-saving decisions. Following Zak and Knack (2001) and Guiso et al (2004), we assume that consumers can invest their savings only through investment brokers. These brokers are opportunists in the sense that given the opportunity they would cheat and run away with the money. However, their ability to cheat (or the frequency of getting caught and money recovered) depends upon the strength of informal (social capital) and formal institutions. Therefore, a higher level of social capital increases investment and growth by reducing the broker's ability to cheat.[11]

We consider three different institutional environments in this paper. The benchmark case corresponds to the standard Schumpeterian growth model with a labor-socialization tradeoff where institutions are perfect and costless to maintain. The other two cases consider imperfect institutional environments. The second case includes only informal institutions (social capital) and the third incorporates both formal and informal institutions.

Given the complexity of the model, most of the analysis is conducted numerically. Using plausible parameter values, we show that in the absence of formal institutions, a higher rate of

[11] Alternatively, it can be argued that social capital raises the return from investment by reducing the cost of finding an honest broker or by reducing the cost of contracting because it may allow for writing a weaker contract.

innovation lowers R&D investment as it weakens existing informal institutions. Social capital declines through two sources, first, due to a decline in socialization time and second, because of an increase in the labor migration rate. As a result, our model predicts lower rate of growth when compared to standard growth models.

The rest of the chapter is organized as follows. Section 2.1 presents the model, Section 2.2 characterizes the equilibrium in a decentralized economy, Section 2.3 solves for the social planner's problem, Section 2.4 calibrates the model and discusses short- and long-run effects of technological shocks, and Section 2.5 discusses the results and presents some possible extensions of the model.

2.1 The Model

In order to analyze the dynamic relationship between social capital and growth, we use a variant of the quality-ladder growth model of Aghion and Howitt (1992). We extend the model by incorporating the labor-socialization trade off and by incorporating institutional factors that can affect the return from investment.

2.1.1 Production

In this economy, there is a final consumption good produced by competitive firms. It can be produced using an intermediate good and the best available technology in that intermediate good sector. There is a continuous mass one of intermediate good sectors.[12] Intermediate goods are produced using only labor.[13] Each unit of labor hour produces exactly one unit of intermediate good irrespective of the sector in which a worker works in. Therefore, we denote l_{it} as the output of intermediate good sector i at time t, which employs l_{it} units of labor hour. Each

[12] We assume that each intermediate good sector is located at different locations. This is to ensure that once a worker switches job he moves to a different location which, in turn, reduces the strength of social capital.
[13] We abstract away from physical capital for simplicity.

sector produces only one type of intermediate good in which they have complete monopoly power. The contribution of intermediate good sector, i, towards the final good, Y_{it}, at time t is given by

$$Y_{it} = A_{it}\, l_{it}^{\alpha} \tag{2.1}$$

where A_{it} is the state of the art technology in intermediate good sector i. Aggregate final good is the sum of the contributions of all intermediate good sectors towards the final good.

$$Y_t = \int_0^1 Y_{it}\ di \quad = \quad \int_0^1 A_{it}\, l_{it}^{\alpha}\ di \tag{2.2}$$

2.1.2 Technology (R&D)

We assume that there is a different R&D sector for each intermediate good.[14] Each R&D sector is competitive. The Poisson arrival rate of innovation in each sector is given by $\lambda\, n_{it}$, where λ is an innovation parameter, $n_{it}\ \left(\frac{N_{it}}{A_t}\right)$ is the productivity adjusted investment in the R&D sector i, N_{it} is the investment into R&D sector and A_t is the state of the art technology in the economy at time t. We assume that innovation is increasingly difficult, that is, the probability of innovation decreases when we go up in the ladder in the technological innovation for the same level of investment, N_{it}. Each innovation at time t in any sector i permits the innovator to start producing in sector i using the leading edge technology, A_t. Each innovation raises the technology parameter, A, by a constant factor, γ. Once an innovation occurs in sector i, either the existing firm purchases the patent from the innovator or only the ownership of the firm

[14] Having R&D sector is more relevant for the developed countries. For other economies (emerging or poor) we can interpret R&D expenditure as the expenditure on buying technologies from developed countries.

changes.[15] After the innovation, the technology in that sector jumps discontinuously from A_{it} to the state of the art technology, A_t.

Although, technology grows discontinuously at the individual sector level, economy wide technology, A_t, evolves gradually. We assume that this leading technology grows at a rate proportional to the aggregate flow of innovation, n_t, per unit of time. The economy-wide growth rate of technology is given by

$$\frac{\dot{A}_t}{A_t} = \lambda\, n_t \ln\gamma \;, \qquad \gamma > 1 \tag{2.3}$$

where $n_t = \int_0^1 n_{it}\, di$ is the aggregate productivity adjusted investment into R&D sector. We define $a_{it} = \frac{A_{it}}{A_t}$, as the relative productivity of intermediate good sector i with respect to the state of the art technology in the economy. We assume that the relative productivities are distributed across different intermediate good sector according to:

$$F(a) = a^{\frac{1}{\ln\gamma}} \qquad , \qquad 0 \le a \le 1 \tag{2.4}$$

where $F(a)$ is the cumulative distribution function of the relative productivities, a. The probability distribution function of the relative productivity, a, therefore, is $f(a) = \frac{1}{\ln\gamma}\ a^{\frac{1}{\ln\gamma}-1}$. At any time, the distribution of relative productivities stays the same but the relative position of firms change.

2.1.3 Consumers

We consider an economy populated with a continuous mass one of representative consumers. Each consumer is endowed with one unit flow of time which is allocated between working l and socializing $(1 - l)$. At each time, a consumer makes the following decisions: first,

[15] This is to ensure that after the innovation the same (previously employed) workers along with some new workers are working in that firm and there is not a complete restructuring inside that firm.

how much to consume and how much to save and, second, how to allocate its time between working and socializing. A representative consumer's preference is given by the following intertemporal isoelastic utility function: [16]

$$U = \int_0^\infty u(C_t, 1 - l_t)\, e^{-\beta t}\, dt = \int_0^\infty \frac{1}{\rho}\, [C_t(1 - l_t)^\eta]^\rho\, e^{-\beta t}\, dt \qquad (2.5)$$

$$-\infty < \rho \leq 1; \quad \eta > 0$$

where C_t is the consumption in period *t*, β is the discount factor, and η captures the impact of socialization on the welfare of consumers.

As in Zak and Knack (2001) and Guiso et al (2004), we assume that consumers can invest their savings only through investment brokers. There is a continuum of risk-neutral investment brokers. These brokers invest consumer's savings into R&D firms and receive the return after the realization period. However, they are opportunists and can abscond with the money with probability, $(1 - \phi)$, where ϕ captures the strength of existing institutions in the economy which protects the consumers from fraudulent behavior of these brokers. The strength of institutions, ϕ, in turn, depends on the strength of *informal institutions*, which we call *social capital,* and the *formal institutions*.[17] A higher stock of social capital and a better formal institutional environment, by reducing the probability of cheating, increases the expected return from R&D investment. The representative consumer's budget constraint, therefore, is given by:

$$\dot{V}_t = W_t\, l_t + \phi_t\, r_t\, V_t - C_t - T_t \qquad ; \qquad 0 \leq \phi_t \leq 1 \qquad (2.6)$$

where V_t is the value of the all assets held by consumers, W_t is the current wage rate, and r_t is the market interest rate. The strength of institutions, ϕ_t, depends on the services provided by the

[16] This is a standard labor-leisure tradeoff utility function where we treat leisure as socialization.
[17] The strength of formal institution is captured by productivity-adjusted expenditure. It may either be financed by the government or by private organizations.

stock of social capital, s_t, and productivity-adjusted expenditure, $g_t = \frac{G_t}{A_t}$, on formal institutions finance by lump-sum tax (or contributions) T_t, where G_t is the current expenditure on formal institutions at time *t*. Alternatively, s_t and g_t can also be interpreted as a measure of personalized and generalized trust, respectively, in the economy. We consider the following functional form for ϕ:

$$\phi_t = 1 - e^{-\theta_s s_t - \theta_g g_t} \quad ; \quad \theta_s, \theta_g > 0 \tag{2.7}$$

where, θ_s and θ_g capture the impact of social capital and formal institutions on the effectiveness of the institutions.

Assuming that the brokers do not save, their per period consumption is given by $C_t^b = (1-\phi_t)r_t V_t$, where $(1-\phi_t)$ is the probability with which the brokers can cheat. Alternatively, $(1-\phi_t)$ can also be interpreted as the transaction cost of searching an honest broker or the cost of writing a complete and enforceable contract with the new broker. Assuming that expenditure (G_t) on formal institutions is fully financed by total contributions (T_t) every period, the economy-wide budget constraint can be given by:

$$\dot{V}_t = W_t\, l_t + \phi\left(s_t, \frac{G_t}{A_t}\right) r_t\, V_t - C_t - G_t \tag{2.8}$$

2.1.4 Social Capital

As argued earlier, since social capital increases with socialization and decreases with labor migration, we consider the following equation for the evolution of the stock of social capital:

$$\dot{s}_t = (1 - l_t) - m_t\, s_t \ , \quad 0 \le m_t \le 1\, ; \ 0 \le s_t < \infty \tag{2.9}$$

where, m_t is the rate of labor migration across different sectors in the economy. If a proportion m_t of workers switch jobs then the social capital is destroyed by a measure of $m_t s_t$.

Since the motive of socialization is not economic, the consumers do not consider the impact of their socializing decision on the social capital. This creates an additional source of externality into the model (*social capital externality*) where the formation of social capital is the side product of the individual rational decision of socialization.

We consider three different institutional environments in this paper. The first case is associated with perfect institutions ($\phi = 1$). The second case includes only informal institutions (social capital) and the third incorporates both formal and informal institutions where the strength of institutions is endogenously determined.

2.2 Decentralized Economy

We start our analysis with the last case which includes both social capital, s, and formal institutions, g, as determinants of institutions, ϕ, where social capital is determined endogenously within the model while the expenditure on formal institutions, G, is optimally chosen. The other two cases are treated as special cases.

2.2.1 Equilibrium

An allocation in this economy consists of the time paths of consumption, and aggregate output, $[C_t, Y_t]_{t=0}^{\infty}$, time paths of R&D expenditure, state of the art technology, and net present value of the assets, $[N_t, A_t, V_t]_{t=0}^{\infty}$, time paths of interest rate, and wage rate, $[r_t, W_t]_{t=0}^{\infty}$ and time paths of labor supply, migration rate, social capital, government expenditure, and the strength of institutions $[l_t, m_t, s_t, G_t, \phi_t]_{t=0}^{\infty}$. An equilibrium is an allocation where the representative consumers maximize utility, intermediate good producers maximize profit, innovators maximize their net present discounted value and the labor market clears.

We start with the production sector. We assume that the final good sector is competitive while each of the intermediate good sectors is monopolized.[18,19] For simplicity, we also assume that the monopolists use first-degree price discrimination to extract all surpluses from the final good sector. It implies that the monopolist can charge $A_{it} l_{it}^{\alpha}$ from the firms in the final good sector. The objective of a monopolist intermediate good firm is choose the optimal level of l_{it} to maximize its profit, $\Pi_{it} = A_{it}\, l_{it}^{\alpha} - W_t l_{it}$. The demand for labor, output and profit of an intermediate good firm *i* is given by,

$$l_{it} = \alpha^{\frac{1}{1-\alpha}} \left(\frac{1}{\frac{W_t}{A_{it}}} \right)^{\frac{1}{1-\alpha}} = \alpha^{\frac{1}{1-\alpha}} \left(\frac{1}{w_t} \right)^{\frac{1}{1-\alpha}} a_{it}^{\frac{1}{1-\alpha}} \quad \text{or} \quad \alpha\, Y_{it} = W_t\, l_{it} \tag{2.10a}$$

$$Y_{it} = \alpha^{\frac{\alpha}{1-\alpha}}\, A_{it} \left(\frac{1}{\frac{W_t}{A_{it}}} \right)^{\frac{\alpha}{1-\alpha}} = \alpha^{\frac{\alpha}{1-\alpha}} \frac{A_t}{w_t^{\frac{1}{1-\alpha}}}\, a_{it}^{\frac{1}{1-\alpha}} \tag{2.10b}$$

$$\Pi_{it} = (1-\alpha) Y_{it} = (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}} \frac{A_t}{w_t^{\frac{1}{1-\alpha}}}\, a_{it}^{\frac{1}{1-\alpha}} \tag{2.10c}$$

where $w_t = W_t / A_t$ is the productivity adjusted wage rate. The demand for labor increases when the technology in that sector improves and decreases if they fail to innovate because of the rise in wage in response to innovation in other sectors. The output and the profit, therefore, would also increase with innovation and would fall otherwise. The aggregate flow of demand for labor, l_t, can be found by summing equation (2.10a) over *i*.

$$l_t = \frac{\alpha^{\frac{1}{1-\alpha}}}{1 + \frac{1}{1-\alpha} \ln \gamma} \; \frac{1}{w_t^{\frac{1}{1-\alpha}}} \tag{2.11a}$$

[18] Price of the final good is normalized to one.
[19] Quality gap is assumed to be sufficiently large between any two consecutive innovations in order to rule out limit pricing.

We, then, get the following expressions for the productivity-adjusted aggregate output, $y_t = \frac{Y_t}{A_t}$, and profit, $\pi_t = \frac{\Pi_t}{A_t}$, in the economy by summing equation (2.10b) and (2.10c) respectively over i, by using (2.11a), and then diving through by A_t as

$$y_t = \frac{\alpha^{\frac{\alpha}{1-\alpha}}}{1 + \frac{1}{1-\alpha}\ln\gamma} \quad \frac{1}{w_t^{\frac{\alpha}{1-\alpha}}} \quad = \frac{1}{\left(1 + \frac{1}{1-\alpha}\ln\gamma\right)^{1-\alpha}} \quad l_t^{\alpha} \tag{2.11b}$$

$$\pi_t = (1-\alpha) y_t = \frac{1-\alpha}{1 + \frac{1}{1-\alpha}\ln\gamma} \quad l_t^{\alpha} \tag{2.11c}$$

In order to find the labor reallocation (migration) rate, we, first, use the expression of w_t from (2.11a) into (2.10a) and then differentiate it with respect to time. Noting that A_{it} is constant for non-innovating firms, rate of change of demand for labor for these firms can be expressed as:

$$\frac{\dot{l}_{it}}{l_{it}} = -\frac{1}{1-\alpha} \frac{\dot{A}_t}{A_t} + \frac{\dot{l}_t}{l_t} \tag{2.12a}$$

The first part captures the decline in demand as the workers move from non-innovating to innovating firms and the second is the change in labor hour each worker puts in when the economy experiences a technological shock. As our interest lie in the fraction of workers who change jobs, we consider only the first component. Since the number of non-innovating firms is $(1 - \lambda n_t)$ at any time t, by using equation (2.3), we get the following expression for the labor migration rate in the economy:

$$m_t = \frac{1}{1-\alpha} \lambda \, n_t \ln\gamma \; (1 - \lambda \, n_t) \tag{2.12b}$$

We next turn to the equilibrium in R&D sector. Because the expected payoff to an innovation is the same in every sector, the same equilibrium flow of investment, N_t , will be used in each R&D sector. The value of an innovation, V_{it}, (or the value of a firm that innovates at time *t*) in sector *i* at time *t* is given by the net present value of all future profits.[20]

$$V_{it}(A_t) \; = \int_{\tau=t}^{\infty} e^{-\int_t^{\tau} r_u \, du} \; e^{-\int_t^{\tau} \lambda \, n_u \, du} \, \Pi_{i\tau}(A_t) \, d\tau \tag{2.13a}$$

where $\Pi_{it}(A_t)$ is the profit of a firm at time τ in which innovation occurred at time t and $e^{-\int_t^{\tau} \lambda \, n_u \, du}$ is the probability that this firm is still producing using technology A_t at time $\tau \geq t$. By using (2.3) and after some algebraic manipulations, we get the productivity-adjusted value of an innovation, $v_{it} = V_{it}/A_t$, as:

$$v_{it}(A_t) \; = (1-\alpha)\left(1 + \frac{1}{1-\alpha}\ln\gamma\right)^{\alpha} \int_{\tau=t}^{\infty} l_{\tau}^{\alpha} \, e^{-\int_t^{\tau}\left(r_u + \lambda n_u + \frac{\alpha}{1-\alpha}\,\lambda\, n_u \ln\gamma\right)du} \, d\tau \tag{2.13b}$$

The amount of resources devoted to research is determined by the research arbitrage condition which equates expected marginal benefit to marginal cost. That is,

$$\lambda \, n_t \, V_{it}(A_t) = N_t \qquad \text{or} \qquad v_{it}(A_t) \; = \frac{1}{\lambda} \tag{2.14a}$$

Differentiating (2.13b) and (2.14a) with respect to time and by equating them to each other, we get v_{it} as:

$$v_{it}(A_t) \; = \; (1-\alpha) \; \left(1 + \frac{1}{1-\alpha}\ln\gamma\right)^{\alpha} \; \frac{l_t^{\alpha}}{r_t + \lambda \, n_t + \dfrac{\alpha}{1-\alpha} \; \lambda \, n_t \ln\gamma} \tag{2.14b}$$

Using (2.14a) and (2.14b), we get the familiar research-arbitrage condition:

$$\frac{\lambda \, (1-\alpha) \; \left(1 + \frac{1}{1-\alpha}\ln\gamma\right)^{\alpha} \; l_t^{\alpha}}{r_t + \lambda \, n_t + \dfrac{\alpha}{1-\alpha} \; \lambda \, n_t \ln\gamma} = 1 \tag{2.15}$$

[20] Recall that once the innovation occurs in sector *i* at time *t*, the technology in that sector jumps from A_{it} to the state of the art technology, A_t.

Finally, the productivity adjusted value of all firms is given by:[21]

$$v_t = \frac{1}{\lambda} \frac{1}{1 + \frac{1}{1-\alpha} \ln \gamma} \tag{2.16}$$

A representative consumer chooses consumption and labor to maximize utility (Eq. 2.5) subject to the budget constraint (Eq. 2.8). The first order conditions at the optimum are

$$u_C = C^{\rho-1} (1-l)^{\eta\rho} = \mu \tag{2.17a}$$

$$-u_l = \eta C^{\rho} (1-l)^{\eta\rho-1} = \mu W \tag{2.17b}$$

$$\phi r = \beta - \frac{\dot{\mu}}{\mu} \tag{2.17c}$$

where μ is the private shadow value of wealth, together with the transversality condition $\lim_{t\to\infty} \mu V_t e^{-\beta t} = 0$. The interpretation of these equations are standard; (2.17a) equates the private marginal utility of consumption to the shadow value of wealth; (2.17b) equates the private marginal utility of socialization to its opportunity cost, the real wage valued at the shadow value of wealth, while (2.17c) equates the return on assets to the rate of return of consumption.

By solving equations (2.17a) and (2.17b), we get the familiar relationship between labor and consumption,

$$1 - l_t = \frac{\eta C_t}{W_t} = \frac{\eta c_t}{w_t} \tag{2.18a}$$

where $c_t = C_t/A_t$ is the productivity adjusted consumption. The Euler equation is given by using equation (2.3) and time derivatives of (2.17a) and (2.18a) into equation (2.17c),

$$\frac{\dot{C}_t}{C_t} = \Omega(l_t)\,[\phi_t r_t - \beta + \Psi(l_t)\lambda\, n_t \ln \gamma] \tag{2.18b}$$

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[21] $v_t = \int_i v_{it} di$,where $v_{it}(A_{it}) = a_{it}^{\frac{1}{1-\alpha}} v_{it}(A_t)$, is the value of a firm with technology A_{it} at time t and $v_{it}(A_t) = \frac{1}{\lambda}$.

where, $\Omega(l_t) = -\frac{1-\alpha(1-l_t)}{\eta\rho l_t+(\rho-1)\left(1-\alpha(1-l_t)\right)} > 0$ and $\Psi(l_t) = -\frac{\eta\rho l_t}{1-\alpha(1-l_t)} > 0$.

Finally, the expenditure, *G*, on formal institution equates the additional return from investment due to strengthening of institutions to its cost.

$$\theta_G\, r_t \frac{V_t}{A_t} = b\, r_t\, v_t\, (1-\phi_t) = 1 \tag{1.19}$$

We summarize the equilibrium conditions as follows:

Definition *An equilibrium in this economy is given by the time paths of consumption, and aggregate output,* $[C_t, Y_t]_{t=0}^{\infty}$ *that satisfies (2.8), and (2.11b), time paths of R&D expenditure, state of the art technology, and net present value of the assets,* $[N_t, A_t, V_t]_{t=0}^{\infty}$ *given by (2.15), (2.3) and (2.16), time paths of interest rate, and wage rate,* $[r_t, w_t]_{t=0}^{\infty}$ *consistent with (2.18b) and (2.11a) and time paths of labor supply, migration rate, social capital, and formal institutions* $[l_t, m_t, s_t, G_t, \phi_t]_{t=0}^{\infty}$ *given by (2.18a), (2.12b), (2.9), (2.19) and (2.7).*

Case I (Benchmark): Perfect Institution ($\boldsymbol{\phi = 1}$)

In this case, the evolution of social capital is no longer relevant. The production and R&D sectors will have the same optimality conditions. Since the institutions are perfect and costless, the relevant budget constraint now is:

$$\dot{V} = Wl + rV - C \tag{2.20a}$$

Consumer's optimization gives us the same labor supply function as earlier (2.18a). However, the Euler condition is given by:

$$\frac{\dot{C}_t}{C_t} = \Omega(l_t)\,[r_t - \beta + \Psi(l_t)\lambda\, n_t \ln \gamma] \tag{2.20b}$$

Additionally, optimality conditions with respect to government expenditure on formal institutions, G, is now no longer relevant.

Case II: Social Capital is the only determinant of Institutions ($\boldsymbol{\phi_t = 1 - e^{\theta_s s_t}}$)

The optimality conditions in production and R&D sectors are again the same as earlier. The agent's optimality condition and the Euler equation are again given by (2.18a) and (2.18b). Again, as in case I, there is no optimality condition for G.

We define a balanced growth path as an equilibrium path in which all variables grow at a constant rate except for labor allocation, interest rate, migration rate, social capital and the strength of institutions, which are constant. Following our definition of balanced growth path, it is convenient to write the system in terms of stationary productivity adjusted variables. It is straightforward to express the dynamics of the decentralized economy in terms of $c,\ l,\ \phi\ ,\ m$ and n as

$$\dot{c_t} = c\,\Omega(l_t)\,[\phi_t r_t - \beta + (\rho - 1)\lambda\, n_t \ln\gamma] \tag{2.21a}$$

$$\dot{s_t} = (1 - l_t) - m_t s_t \tag{2.21b}$$

along with labor market clearing conditions,

$$l_t + \frac{\eta}{\alpha}\left(1 + \frac{1}{1-\alpha}\ln\gamma\right)^{1-\alpha} c_t\, l_t^{1-\alpha} = 1 \tag{2.22a}$$

$$\frac{\alpha^{\frac{1}{1-\alpha}}}{1 + \frac{1}{1-\alpha}\ln\gamma}\ \frac{1}{w_t^{\frac{1}{1-\alpha}}} + \eta\frac{c_t}{w_t} = 1 \tag{2.22b}$$

research arbitrage condition (2.15), labor migration rate (2.12b), expenditure on formal institutions (2.19), strength of institutions (2.7), and the economy-wide budget constraint[22]

$$w_t l_t + (\phi_t\, r_t - \lambda\, n_t \ln\gamma)\, v_t - c_t - g_t = 0 \tag{2.22c}$$

Imposing the steady-state conditions $\dot{c} = \dot{s} = 0$, we can solve for the steady-state values of productivity-adjusted variables, consumption ($\tilde{c}$), R&D investment ($\tilde{n}$), expenditure on formal institutions ($\tilde{g}$), and wage rate ($\widetilde{w}$), and the other variables, interest rate ($\tilde{r}$), labor ($\tilde{l}$), migration

[22] We, first, write (2.8) in terms of $\dot{v}$, and then use $\dot{v} = 0$ from (2.16).

rate ($\tilde{m}$), social capital ($\tilde{s}$), and the strength of institutions ($\tilde{\phi}$). Finally, productivity-adjusted output ($\tilde{y}$), profit ($\tilde{\pi}$) and value of assets ($\tilde{v}$) can be found by using (2.11b), (2.11c) and (2.16) respectively.

Linearizing (2.21a) and (2.21b) around the steady-state yields an approximation to the underlying dynamic system. This system forms the basis for our dynamic simulations. For all plausible parameter values, the system has one positive (unstable) and one negative (stable) eigenvalues, leading us to conclude that it is saddle point stable.

2.3 Social Planner

Now we briefly discuss the Pareto optimal allocation. Decentralized equilibrium is Pareto suboptimal because of two sources of externalities. The first is the externality in the R&D sector where the monopolists do not internalize the loss to the earlier monopolist caused by new innovation (*business stealing effect*) resulting in too much innovation and they ignore the impact of their innovation on the next innovation (*intertemporal spillover effect*) leading to too little innovation in the decentralized economy. The second source of externality is the *social capital externality* where consumers do not take into account the impact of socialization on social capital as they take the stock of social capital as given at any point of time. Since the full benefit of socialization is not taken into account, consumers spend less time socializing in decentralized economy.

2.3.1 Equilibrium

Since there is no inefficiency in the production side, the equilibrium conditions are again given by equations (2.9), (2.10) and (2.11). The resource constraint can now be written as: [23]

$$N_t = \left(\alpha + \phi_t\,(1-\alpha)\right)Y_t - C_t - G_t \tag{2.23}$$

[23] See Appendix A for derivation of resource constraint for the Social Planner.

The social planner chooses consumption, labor, R&D investment and the expenditure on formal institutions to maximize utility (2.5) subject to the technology growth (2.3), evolution of social capital (2.9), resource constraint (2.23) and labor migration rate (2.12b). The optimality conditions are:

$$\frac{1}{\lambda \ln \gamma}\left(C^{\rho-1}\,(1-l)^{\eta\rho} + \mu_2 m_N s\right) = \mu_1 \tag{2.24a}$$

$$\frac{1}{\lambda \ln \gamma}\left(\eta C^{\rho}\,(1-l)^{\eta\rho-1} + \mu_2(1+m_N N_l s)\right) = \mu_1 N_l \tag{2.24b}$$

$$\left(\lambda \ln \gamma - \frac{\mu_2}{\mu_1} m_N s\right) N_A - \frac{\mu_2}{\mu_1}\, m_A s = \beta - \frac{\dot{\mu_1}}{\mu_1} \tag{2.24c}$$

$$\left(\frac{\mu_1}{\mu_2}\lambda \ln \gamma - m_N s\right) N_s - m = \beta - \frac{\dot{\mu_2}}{\mu_2} \tag{2.24d}$$

$$(1-\alpha)\frac{Y}{A}\ \phi_G = 1 \tag{2.24e}$$

where μ_1 and μ_2 denote the shadow value of technology and social capital respectively, together with the transversality conditions

$$\lim_{t\to\infty} \mu_1 A e^{-\beta t} = \lim_{t\to\infty} \mu_2 s e^{-\beta t} = 0 \tag{2.24e}$$

There are some key differences from the corresponding conditions for the decentralized economy. First, (2.24a) equates the utility of an additional unit of consumption, adjusted by its impact on social capital multiplied by the shadow value of social capital, to the shadow value of technology. Since additional consumption reduces the funds available for R&D investment and thereby increases social capital by reducing labor migration rate (2.12b), people would, therefore, consume less compared to decentralized economy. Second, (2.24b) equates the *social* marginal benefit of socialization (which includes its positive impact on social capital as well) to the real wage valued at the shadow value of technology. Third, (2.24c) and (2.24d) are the intertemporal efficiency conditions, where (2.24c) equates the rate of return of technology to the social return of consumption and (2.24d) equates the return of social capital to the rate of return of consumption evaluated in terms of the shadow value of social capital. Finally, Eq. (2.24e) determines the optimal expenditure on formal institutions.

We can express the macrodynamic equilibrium of the centrally planned economy in terms of productivity adjusted variables as:[24]

$$\dot{c_t} = c[\Theta_1(c, l, n, s, g, m, \phi) - \lambda\, n_t \ln \gamma] \quad (2.25a)$$

$$\dot{l_t} = \Theta_2(c, l, n, s, g, m, \phi) \quad (2.25b)$$

$$\dot{s_t} = (1 - l_t) - m_t s_t \quad (2.25c)$$

2.4 Numerical Results

Due to the complexity of the model, we calibrate it in order to obtain further insight. The baseline parameter values are given as follows: $\alpha = 0.7$; $\beta = 0.02$; $\gamma = 2$; $\lambda = 0.3,\ 0.4$; $\eta = 0.1$; $\theta_s = 1$; $\theta_g = 100$. Our choice of the preference parameters, α and β are standard. The parameter η describes the degree of substitution between socialization/leisure and consumption. We chose η as 0.1 in order to ensure that people socialize 10-20% of the total available time out of working and socializing, however, the results are qualitatively similar for other values of η. This is in contrast with the previous literature where the estimated work time is approximately 1/3 of the total available time. The reason for this difference is that we are not considering any other leisure activities and therefore our total time is approximately 10 hours a day, not 24 hours. The choice of γ, the size of innovation, and λ, innovation probability parameter, are such that the growth rate in the decentralized economy in the most general framework ranges between 2 and 4%. However, we can easily change these parameters to reflect varying growth experience of different countries. In this regard, it can be argued that the countries experiencing higher growth are able to either innovate more frequently or acquire the necessary resources (for example, foreign investment) in order to sustain higher growth. Once again, the qualitative results of the

[24] see Appendix B.2.

model are unchanged for other reasonable parameter values as well. As social capital is accumulated over time whereas expenditure on formal institutions is a flow variable, the effectiveness of formal institutions, which is captured by θ_g, should be sufficiently high for it to have any significant impact on the economy. One may also argue that formal institutions should have larger impact as they affect the whole economy in general, as compared to social capital which is more local in nature. It is because of these reasons, we have chosen a significantly high value for θ_g. Equation (2.19) also provides an idea about the magnitude of θ_g. We know that, for g to be positive, b must be greater than $\frac{1}{r\,v\,(1-\phi)}$. Using the values of r, v and ϕ from case II of Table 1A, we get $\theta_g > 36.28$.[25] Although some of the parameters are difficult to pin down, the calibration exercise still provides useful insights into the dynamics of social capital and economic growth.

First, we will compare the steady-state results in the decentralized economy (Table 2.1A) and the central planner's (Table 2.1B) case under the abovementioned three institutional environments. Thereafter, we analyze the comparative static results and finally, we examine the dynamic effect of an increase in the innovation parameter, λ, on the economy.

2.4.1 Steady-State

In the benchmark model (Case I), the steady state growth rate in a decentralized economy (Table 2.1A) is given by 2.75%, when we consider the innovation parameter, λ, to be 0.3. Consumption is 0.515, that is, people consume 79.53 percent of total output produced, spend 10.21 percent of the time socializing, and 8.8 percent of them change job. However, once we allow for endogenous institutions (Case II and Case III), growth performance deteriorates. In case II, in the absence of any formal institution, growth rate falls by 0.43 percent points. In this

[25] $r = 0.1054$, $v = 1.0069$, and $\phi = 0.7403$.

less than perfect institutional environment, $\phi = 0.74$, a lower effective rate of return shifts the supply of R&D investment left, thereby reducing R&D investment from 0.1325 to 0.1116 (that is, from 20.46 to 17.22 percent of total output) and increasing the market interest rate from 8.9 to 10.5 percent. As investment income falls from 0.09 (rv) to 0.08 (ϕrv), consumption declines, inducing people to work more from 0.898 to 0.899 and reducing wage rate from 0.5048 to 0.5046. Overall, wage income rises from 0.4433 to 0.4437 which, in turn, raises consumption. As overall income falls, consumption falls from 0.515 to 0.509. Once we include formal institutions into the model (Case III), growth rate rises by 0.3 percent point (to 2.6 percent) compared to case II and is closer to the benchmark case. An increase in expenditure on formal institutions crowds out current consumption. As argued earlier, decline in consumption raises labor hour and reduces wage rate. The resulting increasing in wage income raises consumption, however, the overall impact is negative. Improving formal institution raises the health of the institutions in the economy which increases the supply of R&D investment by raising the return from investment. In addition, increase in labor hour increases the demand for R&D investment because of its impact on profit and on value of an innovation. Overall supply side dominates resulting in an increase in R&D investment and a fall in interest rate. Increase in *n* raises economic growth directly but at the same time increases labor migration as well. Reduction in socialization time together with increased migration rate reduces social capital which adversely affects the economy. However as the direct impact of g dominates, while consumption and social capital declines, R&D investment and growth rate rises.[26] In this case, 1.6 percent of the total output is spent on formal institutions.[27]

[26] If, however, indirect effect dominates then it is optimal to set g =0.
[27] In the United States, on an average approximately 1.9 percent of GDP was used on public order and safety in the last 15 years before the current recession during which the average growth rate was approximately 3%. Data source: Bureau of Economic Analysis.

The results in the case of social planner (Table 2.1B) are qualitatively similar except that socialization increases from 9 to 16 percent of total time when social capital is included in the model. This is because the social planner internalizes social capital externality and therefore considers the additional benefit of socialization on growth through an improvement in social capital.

2.4.2 A Permanent Increase in the Innovation Parameter (λ): Long Run Effects

We now introduce a permanent increase in the innovation parameter, λ, from 0.3 to 0.4. In the benchmark case, we observe that the growth performance improves by 1 percent point. Output, R&D investment and interest rate increases while consumption, socialization and wage rate declines. As the rate of innovation increases, causing an increase in the demand for R&D investment, investment rises along with the market interest rate. As mentioned earlier, as consumption is crowded out, it raises wage income which, in turn, raises consumption and leads to a further rise in R&D investment through increase in labor hour. Growth rate in the economy rises, therefore, not only due to the initial rise in λ, but also due to the resulting increase in R&D investment which, in turn, increases labor migration rate. Overall, consumption falls from 0.515 to 0.511 (from 79.54 to 78.95% of total output), and investment rises from 0.132 to 0.136.

Once social capital is included into the model, not only the rise in growth rate is lower (0.66 percent points), but, in fact, investment into R&D sector falls from 0.112 to 0.107 (from 17.22 to 16.55% of output) declines. The intuition is as follows: increase in λ increases the demand for R&D investment, raising investment and market interest rate. Consequently, consumption falls while work hour rises. As social capital declines with a fall in socialization time and a rise in labor migration rate (because of higher growth rate), effective return from investment falls. R&D investment falls and market interest rate rises further as the supply of funds in R&D sector declines hampering growth rate. Overall R&D expenditure falls as institutional factors dominate its initial rise.

Therefore, the countries which are trying to grow faster in the absence of effective formal institutions may not be able to reap the full benefit of new technologies because of its detrimental impact on the existing informal institutions. In fact, contrary to the popular belief that new technologies brings in more investment, we observe that investment falls in the absence of any formal institution. However, if a country chooses the strength of formal institutions optimally, in response to declining social capital, growth performance is far better (increase in growth rate is 0.98 percent point, only marginally lower than the benchmark case). In this case, growth rate (at 3.6 percent) itself is very close to the benchmark case (3.8 percent). Expenditure on formal institutions increases from 0.0106 to 0.0135, which is an increase from 1.64 to 2.08 percent of total output. Therefore, if a country would like to improve its growth performance, it should change its formal institution in response to declining social capital in order to experience sustained higher economic growth.

The last column of the tables report the long run welfare change measured by the optimized utility of the representative agent where C and l are evaluated along the equilibrium path. These welfare changes are measures of equivalent variations, calculated as the percentage change in the flow of income necessary to maintain the level of welfare unchanged following the shock. As anticipated, the welfare gain is highest in case I (15.23%) and is lowest in case II (12.31%). Again, we get very similar qualitative results for the social planner's problem. Our simulation exercise shows that the optimal expenditure on formal institution should rise from 3.5% to 3.8% of total GDP, as the economy experiences technological breakthrough (as λ goes up from 0.3 to 0.4). For an economy growing at 2.55%, 2.66% of GDP should be devoted to formal institutions. [28]

2.4.3 Transitional Dynamics

The transitional adjustment paths for case III following an increase in the probability of innovation are illustrated in Fig. 2.1. Fig. 2.1.1 illustrates the stable adjustment locus in c-s space, indicating how c and s both generally decrease together during the transition.

The short-run responses are reported in Table 2.2. As argued earlier, an increase in the innovation parameter immediately increases the demand for investment into R&D sector leading to an increase in the market interest rate, r, and overshooting R&D investment, n, while crowding out current consumption, c and expenditure on formal institutions, g. This decline in c, in turn, induces people to work more and thereby increasing equilibrium labor hour and reducing the wage rate. The strength of institutions, ϕ, deteriorates as g falls. As institutions weakens, rate of return on investment falls which, in turn, reduces the supply of R&D funds. Through this channel, market interest rate rises while R&D investment falls. Also, increase in labor hour raises the demand for R&D investment, raising investment and interest rate. Overall, on impact, R&D investment rises from 0.125 to 0.130 which along with an increase in λ, raises economic growth from 2.6 to 3.6% and labor migration rate from 8.35 to 11.4%. Consumption falls from 0.503 to 0.499, labor hour jumps from 0.9004 to 0.901, and market interest rate rises from 9.5 to 12.19%. As a result of decline in g from 0.0106 to 0.0103, the strength of institutions decline from 0.896 to 0.891.

Over time, social capital starts declining as a result of a reduction in socialization time and an increase in labor migration rate. Since the marginal benefit of improving formal

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[28] This is the case when λ is 0.2. This result is not reported in the table.

institutions exceeds its cost, g rises over time. Increase in g however crowds out current consumption, consumption continues to declines, labor hour rises and wage rate declines during the transition period. Although, the strength of institutions improves during the transition period after its initial fall as improvement in formal institutions dominates declining social capital, it remains below its steady state level. Also, it is not enough to fully compensate initial decline in ϕ and therefore, the strength of institutions declines in the long run. As a result, R&D investment falls after during the transition while interest rate rises. Growth rate and labor migration rate, therefore, also decline during the transitional path.

The reduction in initial consumption and leisure results in short-run welfare loss of 0.86% but as the consumption grows overtime, welfare rises (Fig 2.1.12) and the overall intertemporal welfare gain is 14.71%.

2.5 Conclusions

We have developed a new framework to analyze the endogenous relationship between social capital and economic growth. Our model is based on the argument that a higher social capital is beneficial for economic performance of a country but higher growth itself destroys it. We show that a higher growth prospect reduces social capital by reducing socialization time and by increasing labor reallocation rate. In the absence of any formal institutions, an increase in the rate of innovation reduces the investment into R&D sector. The reason behind this decline in R&D expenditure is the erosion of the strength of existing informal institutions. It is generally argued that technological advancements require the strengthening of existing formal institutions and in some cases new institutions need to be set up. This paper argues that in addition to that, formal institutions needs to be improved further to fill the void created by the erosion of existing informal institution, a result of technological advancements.

This model also provides an alternative explanation to the growth convergence conundrum. Even if a poor country may acquire better technologies of rich countries, catch up rate might still be low if the decline in social capital is not compensated by improving formal institutions. Therefore, a poor country lacking in resources or lacking in will to develop formal institutions may, therefore, will remain poor.

Although we have abstained from capital accumulation for simplicity, it is straightforward to include it in the model. Also, a more complete model should incorporate some form of heterogeneity among the economic agents. Improvements in communication technology such as telephone, internet, or online social networks by lowering the cost of maintaining contacts with friends and family increases the size and strength of social networks and therefore the impact of labor reallocation on social capital may not be too strong. Incorporating these features into a model of social capital and economic growth will help in better understanding of this inter-relationship and hence have strong policy implications. In this model, we have assumed that the formal institution is financed by lump-sum contributions. It would be interesting to characterize the optimal tax policy for these institutions. As very little is known about the absolute and relative effectiveness of various types of institutions, new research, both at theoretical as well as at empirical level is desired. Lastly, social capital has many dimensions such as trust, norms, social network to name a few. We need to look into the dynamics of each of them separately and their relationship with growth in order to have more precise predictions.

Table 2.1: Long-Run Effects of increase in λ

Case I: Benchmark Case ($\phi = 1$)

Case II: Social Capital is the only determinant of institutions

Case III: Both social capital and formal institutions determine the strength of institutions

Baseline Parameters: $\alpha = 0.7,\ \beta = 0.02,\ \gamma = 2,\ \eta = 0.1,\ a = 1,\ b = 100$

Table 2.1A: Decentralized Economy

$\lambda = 0.3$

	c	***l***	***w***	***r* %**	***n***	***y***	***m* %**	***s***	***g***	***ϕ***	***G* %**	***ΔW***
Case I	0.5151	0.8979	0.5048	8.89	0.1325	0.6476	8.82	1.1567	-	1	2.75	-
Case II	0.5089	0.8991	0.5046	10.54	0.1116	0.6482	7.48	1.3481	-	0.7403	2.32	-
Case III	0.5030	0.9003	0.5044	9.50	0.1252	0.6487	8.35	1.1939	0.0106	0.8955	2.60	-

$\lambda = 0.4$

	c	***l***	***w***	***r* %**	***n***	***y***	***m* %**	***s***	***g***	***ϕ***	***G* %**	***ΔW***
Case I	0.5115	0.8987	0.5047	11.46	0.1364	0.6479	11.92	0.8502	-	1	3.78	15.23
Case II	0.5029	0.9003	0.5044	14.53	0.1074	0.6488	9.49	1.0497	-	0.6499	2.98	12.31
Case III	0.4967	0.9015	0.5042	12.28	0.1291	0.6494	11.32	0.8702	0.0135	0.8921	3.58	14.71

Table 2.1B: Social Planner

$\lambda = 0.3$

	c	***l***	***w***	***r* %**	***n***	***y***	***m* %**	***s***	***g***	***ϕ***	***G* %**	***ΔW***
Case I	0.4319	0.9140	0.5022	13.63	0.2238	0.6557	14.47	0.5943	-	1.0000	4.65	-
Case II	0.4135	0.8372	0.5156	16.15	0.1625	0.6166	10.72	1.5190	-	0.7811	3.38	-
Case III	0.4139	0.9086	0.5030	13.99	0.2061	0.6529	13.40	0.6818	0.0229	0.9489	4.28	-

$\lambda = 0.4$

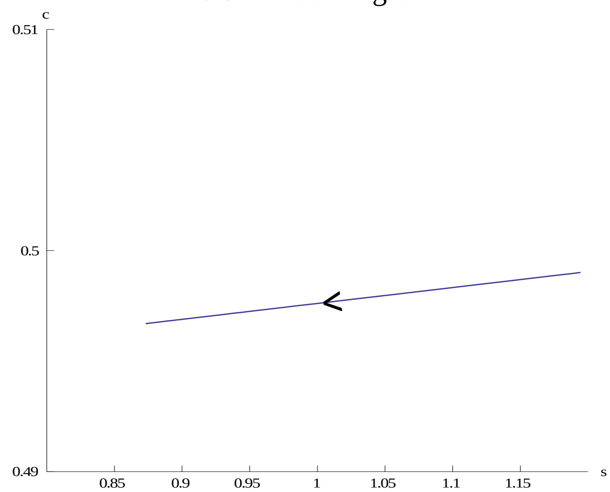
	c	***l***	***w***	***r* %**	***n***	***y***	***m* %**	***s***	***g***	***ϕ***	***G* %**	***ΔW***
Case I	0.4228	0.9157	0.5019	18.20	0.2338	0.6566	19.58	0.4301	-	1	6.48	16.67
Case II	0.3927	0.8295	0.5170	24.38	0.1646	0.6126	14.21	1.2005	-	0.6989	4.56	12.64
Case III	0.4033	0.9132	0.5023	18.68	0.2169	0.6552	18.31	0.4744	0.0250	0.9491	6.01	16.14

Table 2.2: Short-Run Effects of increase in λ (Case III)

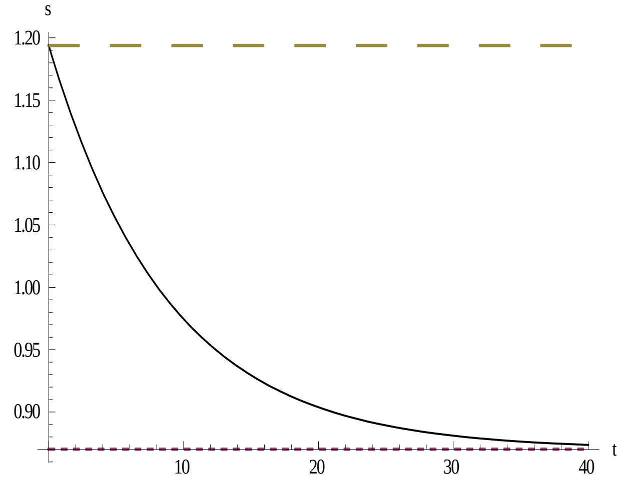
	c(0)	*l(0)*	*w(0)*	*r(0)* %	*n(0)*	*y(0)*	*m(0)* %	*g(0)*	*ϕ(0)*	*G(0)* %	*ΔW(0)* %
Case III	0.4990	0.9010	0.5043	12.19	0.1299	0.6492	11.38	0.0102	0.8913	3.60	-0.86

Figure 2.1: Dynamic Responses to Innovation Shock

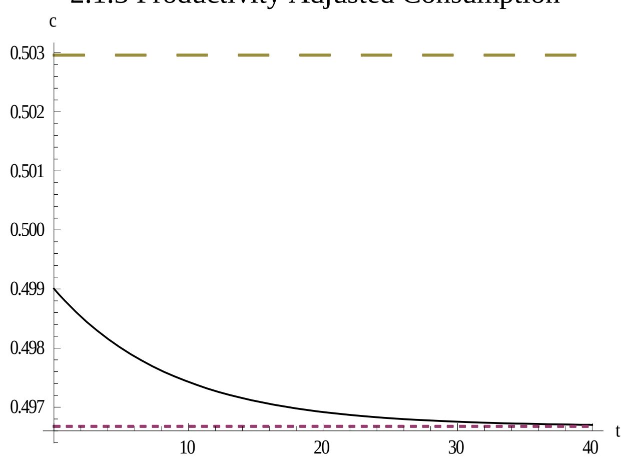
2.1.1 Phase Diagram



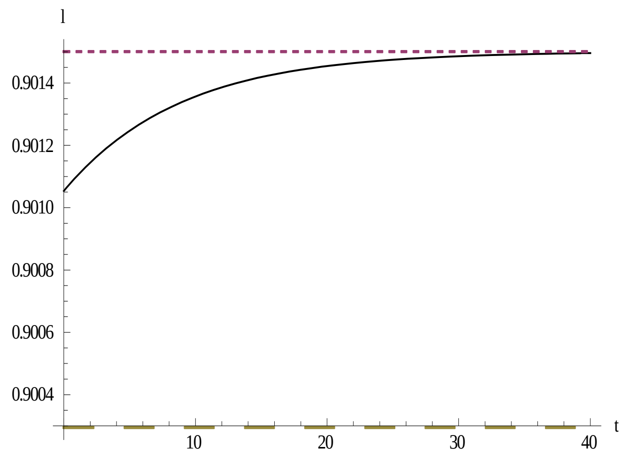
2.1.2 Social Capital



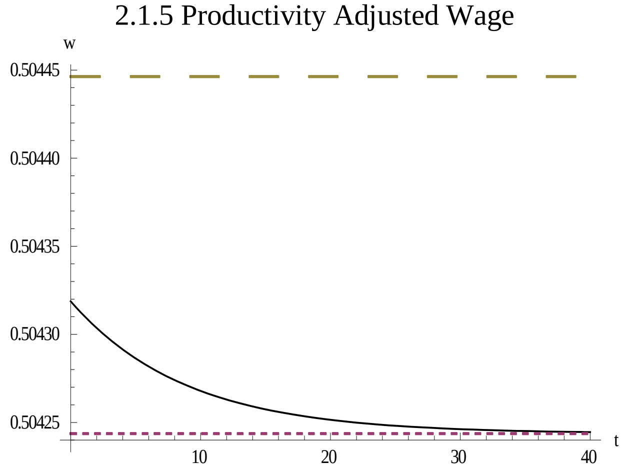
2.1.3 Productivity Adjusted Consumption



2.1.4 Labor



2.1.5 Productivity Adjusted Wage



2.1.6 Productivity Adjusted R&D Investment

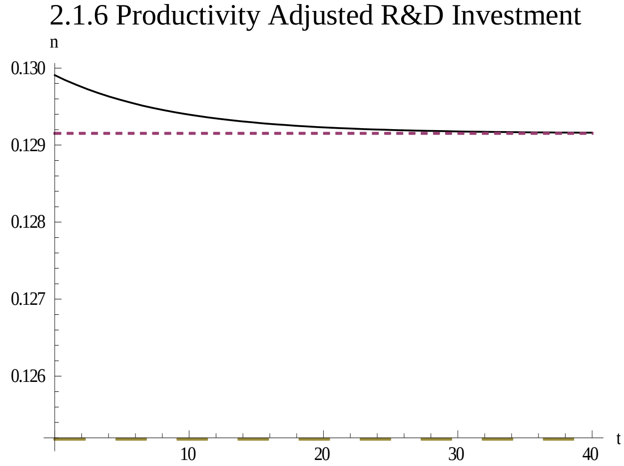
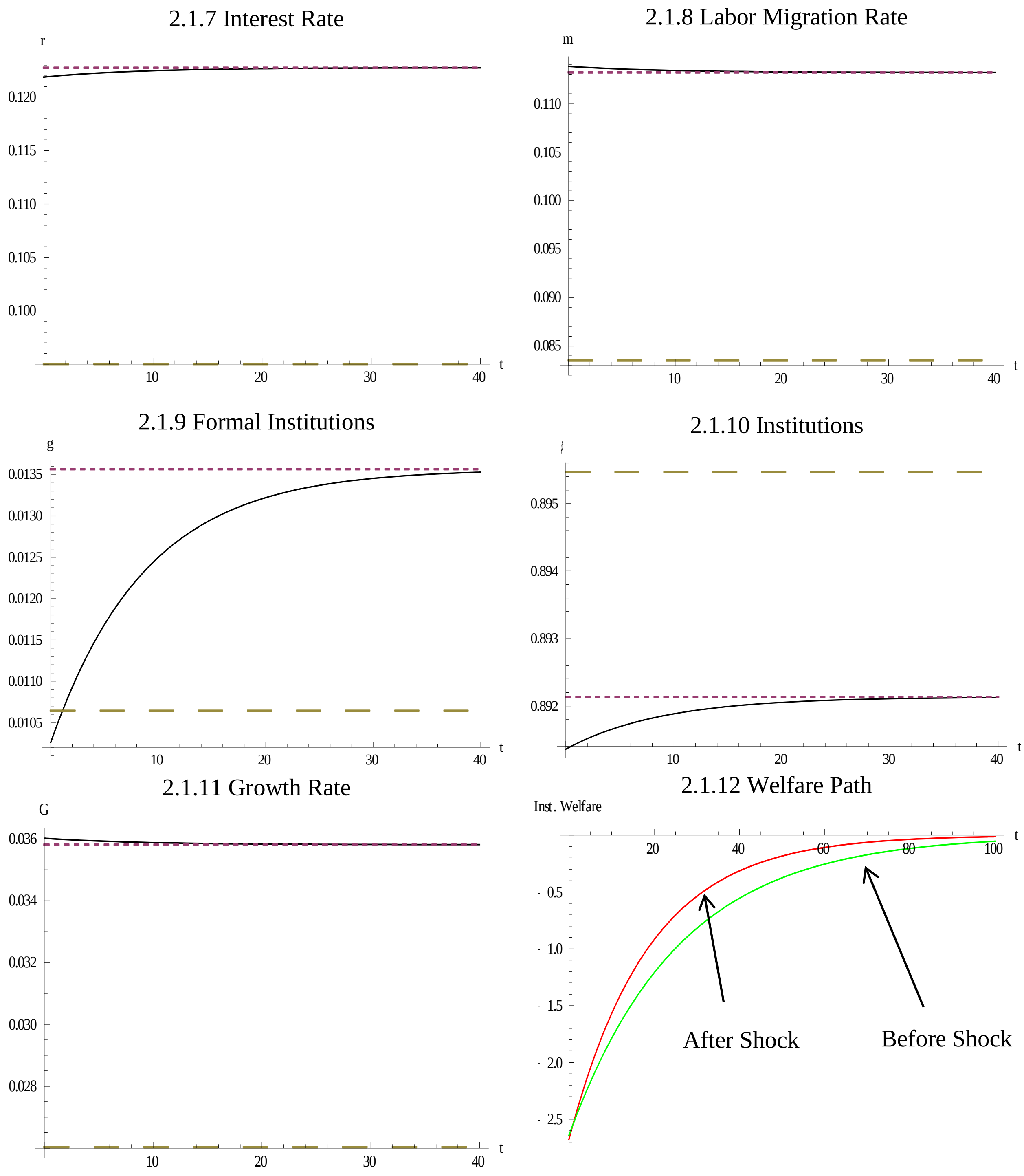


Figure 2.1 Continued



Chapter 3

Second-Best Optimal Taxation to Finance Formal Institutions

In this chapter, we extend the analysis of the previous chapter by adding physical capital into the model. As we observed that in order to have sustained economic growth a country must develop its formal institutions in response to declining social capital. Earlier, we used only non-distortionary lump-sum tax to finance the expenditure on formal institutions. In this chapter, we analyze the alternative and more realistic forms of tax structure and their impact on the economy. The (dynamic) tax rates are set so as to finance the chosen level of expenditure on formal institutions in a decentralized economy framework. We consider tax on wage income, interest income, consumption, total income and on research activities in addition to lump sum taxation. We consider only one type of tax at a time. The idea is to identify the best possible way to raise funds to finance the formal institutions.

The idea of the impact of tax-financed increase in government expenditure in an endogenous growth framework is not new; see, for example, Barro (1990), Jones et al (1993), Glomm and Ravikumar (1994, 1997), and Turnovsky (1996, 2000, 2005). Barro (1990) considers the impact of productive government expenditure where income tax is set to finance the chosen level of expenditure. Turnovsky (2000) shows that the growth effect of an increase in government expenditure is highest when it is financed by lump-sum tax, followed by consumption tax, wage income tax and capital income tax. This paper distinguishes it from the literature by considering that these expenditures are made to improve formal institutions which have only distributional consequences. That is, it reduces the transaction cost by fostering generalized trust in the economy. We find that improvement in formal institutions results in largest increase in growth rate when it is financed by lump-sum tax; followed by consumption, wage income, interest income, income and the tax on research activities. We also find that both consumption tax and the tax on wage income performs better in terms of long-run welfare changes when compared to lump-sum tax with consumption tax resulting in largest gain in welfare. This is because of the presence of externalities (business stealing, intertemporal spillover, social capital) in the decentralized economy where distortionary taxes (consumption and wage) acts to partly correct them.

The rest of the chapter is organized as follows. Section 3.1 presents the model, Section 3.2 characterizes the equilibrium, Section 3.3 calibrates the model and discusses short- and long-run effects of various taxes, and Section 3.4 concludes this chapter.

3.1 The Model

We extend the model in the previous chapter by including physical capital into the production function. There are three sectors in this economy: production (intermediate and final), R&D and household.

3.1.1 Production

In this economy, there is a final consumption good produced by competitive firms. It can be produced using an intermediate good and the best available technology in that intermediate good sector. There is a continuous mass one of intermediate good sectors.[29] Each sector produces only one type of intermediate good in which they have complete monopoly power. Intermediate goods are produced using physical capital and labor according to:

[29] We assume that each intermediate good sector is located at different locations. This is to ensure that once a worker switches job he moves to a different location.

$$x_{it} = \left(\frac{K_{it}}{A_{it}}\right)^{\theta} \; l_{it}^{1-\theta} \qquad ; \qquad 0 < \theta < 1 \tag{3.1}$$

The contribution of intermediate good sector, i, towards the final good, Y_{it}, at time t is given by

$$Y_{it} = A_{it}\, x_{it}^{\alpha} = A_{it}\left(\frac{K_{it}}{A_{it}}\right)^{\alpha\theta} l_{it}^{\alpha(1-\theta)} \qquad ; \qquad 0 < \alpha \leq 1 \tag{3.2}$$

where A_{it} is the state of the art technology in intermediate good sector i. Aggregate final good is the sum of the contributions of all intermediate good sectors towards the final good.

$$Y_t = \int_0^1 Y_{it}\; di \quad = \quad \int_0^1 A_{it}\left(\frac{K_{it}}{A_{it}}\right)^{\alpha\,\theta} l_{it}^{\alpha(1-\theta)}\; di \tag{3.3}$$

3.1.2 Technology (R&D)

We assume that there is a different R&D sector for each intermediate good.[30] Each R&D sector is competitive. The Poisson arrival rate of innovation in each sector is given by $\lambda\, n_{it}$, where λ is an innovation parameter, n_{it} $\left(\frac{N_{it}}{A_t}\right)$ is the productivity adjusted investment in the R&D sector *i*, N_{it} is the investment into R&D sector and A_t is the state of the art technology in the economy at time *t*. We assume that innovation is increasingly difficult, that is, the probability of innovation decreases when we go up in the ladder in the technological innovation for the same level of investment, N_{it}. Each innovation at time t in any sector *i* permits the innovator to start producing in sector i using the leading edge technology, A_t. Each innovation raises the technology parameter, A, by a constant factor, γ. Once an innovation occurs in sector i, either the existing firm purchases the patent from the innovator or only the ownership of the firm

[30] Having R&D sector is more relevant for the developed countries. For other economies (emerging or poor) we can interpret R&D expenditure as the expenditure on buying technologies from the developed countries.

changes.[31] After the innovation, the technology in that sector jumps discontinuously from A_{it} to the state of the art technology, A_t.

Although, technology grows discontinuously at the individual sector level, economy wide technology, A_t, evolves gradually. We assume that this leading technology grows at a rate proportional to the aggregate flow of innovation, n_t, per unit of time. The economy-wide growth rate of technology is given by

$$\frac{\dot{A}_t}{A_t} = \lambda\, n_t \ln\gamma \qquad ; \qquad \gamma > 1 \tag{3.4}$$

where $n_t = \int_0^1 n_{it}\, di$ is the aggregate productivity adjusted investment into R&D sector. We define $a_{it} = \frac{A_{it}}{A_t}$, as the relative productivity of intermediate good sector i with respect to the state of the art technology in the economy. We assume that the relative productivities are distributed across different intermediate good sector according to:

$$F(a) = a^{\frac{1}{\ln\gamma}} \qquad ; \qquad 0 \leq a \leq 1 \tag{3.5}$$

where $F(a)$ is the cumulative distribution function of the relative productivities, a. The probability distribution function of the relative productivity, a, therefore, is $f(a) = \frac{1}{\ln\gamma}\ a^{\frac{1}{\ln\gamma}-1}$. At any time, the distribution of relative productivities stays the same but the relative position of firms change.

3.1.3 Consumers

We consider an economy populated with a continuous mass one of representative consumers. Each consumer is endowed with one unit flow of time which is allocated between working l and socializing $(1 - l)$. At each time, a consumer makes the following decisions: first,

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[31] This is to ensure that after the innovation the same (previously employed) workers along with some new workers are working in that firm and there is not a complete restructuring inside that firm.

how much to consume and how much to save and, second, how to allocate its time between working and socializing. A representative consumer's preference is given by the following intertemporal isoelastic utility function[32]:

$$U = \int_0^{\infty} \frac{1}{\rho} \left[C\,(1-l)^{\eta}\right]^{\rho} e^{-\beta t}\, dt \tag{3.6}$$

$$-\infty < \rho \leq 1; \quad \eta > 0$$

where C_t is the consumption in period *t*, β is the discount factor, and η captures the impact of socialization on the welfare of consumers. As in Zak and Knack (2001) and Guiso et al (2004), we assume that consumers can invest their savings only through investment brokers. There is a continuum of risk-neutral investment brokers. These brokers invest consumer's savings and receive the return after the realization period. However, they are opportunists and can abscond with the money with probability, $(1-\phi)$, where $\phi \in [0,1]$ captures the strength of existing institutions in the economy which protects the consumers from fraudulent behavior of these brokers.[33] The strength of institutions, ϕ, in turn, depends on the strength of *informal institutions*, which we call *social capital*, and the *formal institutions*.[34] A higher stock of social capital and a better formal institutional environment, by reducing the probability of cheating (or reducing the transaction cost), increases the expected return from investment made in either physical capital or R&D sector. We also assume that resources are perfectly mobile between the two sectors and therefore the return from investing in either asset would be the same. The representative consumer's budget constraint, therefore, is given by:

[32] This is a standard labor-leisure tradeoff utility function where we treat leisure as socialization.

[33] Alternatively, $(1-\phi_t)$ can be considered as the expenditure made in searching an honest broker, the transaction cost of gathering information about making informed investment choices or the cost of writing complete and enforceable contract.

[34] The strength of formal institution is captured by productivity-adjusted expenditure. It may either be financed by the government or by private organizations.

$$\dot{K} + \dot{V} = (1 - \tau_y)\big((1 - \tau_w)W\, l + (1 - \tau_r)\phi_t\, r\, (V + K)\big) - (1 + \tau_c)C - T \tag{3.7}$$

where V_t is the value of the all assets held by consumers, K_t is the stock of physical capital, W_t is the current wage rate, and r_t is the market interest rate. The strength of institutions, ϕ_t, depends on the services provided by the stock of social capital, s_t, and productivity-adjusted expenditure, $g_t = \frac{G_t}{A_t}$, on formal institutions finance by either a lump-sum tax T_t, a tax on wage income τ_w, a tax on interest income τ_r, a tax on consumption τ_c or a tax on income τ_y. G_t is the current expenditure on formal institutions at time *t*. Alternatively, s_t and g_t can also be interpreted as a measure of personalized and generalized trust, respectively, in the economy. We consider the following functional form for ϕ:

$$\phi_t = 1 - e^{-\psi_s s_t - \psi_g g_t} \quad ; \quad \psi_s, \psi_g > 0 \tag{3.8}$$

where, ψ_s and ψ_g capture the impact of social capital and formal institutions on the effectiveness of the institutions.

Assuming that the brokers do not save, their per period consumption is given by $C_t^b = (1 - \phi_t)r_t V_t$, where $(1 - \phi_t)$ is the probability with which the brokers can cheat. We further assume that the government's budget is balanced at each time:

$$G_t = \tau_y\left(\tau_w\, W\, l + \tau_r\, \phi\, r\, (K + V)\right) + \tau_c\, C + \tau_n N + T \tag{3.9}$$

where, τ_n is the rate at which every dollar spent on research activity taxed. The economy-wide, therefore, budget constraint can be given by:

$$\dot{K} + \dot{V} = W\, l + \phi_t(s_t, g_t) r\, (V + K) - C - G + \tau_n N \tag{3.10}$$

3.1.4 Social Capital

As earlier, we consider the following equation for the evolution of the stock of social capital:

$$\dot{s_t} = (1 - l_t) - m_t\, s_t \ , \qquad 0 \leq m_t \leq 1\ ; \ \ 0 \leq s_t < \infty \tag{3.11}$$

where, m_t is the rate of labor migration across different sectors in the economy. If a proportion m_t of workers switch jobs then the social capital is destroyed by a measure of $m_t s_t$.

Since the motive of socialization is not economic, the consumers do not consider the impact of their socializing decision on the social capital. This creates an additional source of externality into the model (*social capital externality*) where the formation of social capital is the side product of the individual rational decision of socialization.

3.2 Equilibrium

An allocation in this economy consists of the time paths of consumption, and aggregate output, $[C_t, Y_t]_{t=0}^{\infty}$, time paths of R&D expenditure, state of the art technology, stock of physical capital and net present value of the assets, $[N_t, A_t, K_t, V_t]_{t=0}^{\infty}$, time paths of interest rate, and wage rate, $[r_t, W_t]_{t=0}^{\infty}$ and time paths of labor supply, migration rate, social capital, tax rate and the strength of institutions $[l_t, m_t, s_t, \tau, \phi_t]_{t=0}^{\infty}$. An equilibrium is an allocation where the representative consumers maximize utility, intermediate good producers maximize profit, innovators maximize their net present discounted value and the labor market clears.

We start with the production sector. We assume that the final good sector is competitive while each of the intermediate good sectors is monopolized.[35,36] For simplicity, we also assume that the monopolists use first-degree price discrimination to extract all surpluses from the final good sector. It implies that the monopolist can charge $A_{it}x_{it}^{\alpha}$ from the firms in the final good sector. The objective of a monopolist intermediate good firm is choose the optimal level of l_{it} to

[35] Price of the final good is normalized to one.
[36] Quality gap is assumed to be sufficiently large between any two consecutive innovations in order to rule out limit pricing.

maximize its profit, $\Pi_{it} = A_{it}x_{it}^{\alpha} - W_t l_{it} - r_t K_{it}$. The demand for labor and capital, and the profit of an intermediate good firm *i* is given by,

$$l_{it} = \left(\frac{\alpha\,\theta^{\alpha\theta}(1-\theta)^{1-\alpha\theta}}{w_t^{1-\alpha\theta}\,r_t^{\alpha\theta}}\right)^{\frac{1}{1-\alpha}} a_{it}^{\frac{1-\alpha\theta}{1-\alpha}} \tag{3.12a}$$

$$k_{it} = \left(\frac{\alpha\,\theta^{1-\alpha(1-\theta)}(1-\theta)^{\alpha(1-\theta)}}{w_t^{\alpha(1-\theta)}\,r_t^{1-\alpha(1-\theta)}}\right)^{\frac{1}{1-\alpha}} a_{it}^{\frac{1-\alpha\theta}{1-\alpha}} \tag{3.12b}$$

$$y_{it} = k_{it}^{\alpha\theta}\,l_{it}^{\alpha(1-\theta)}\,a_{it}^{1-\alpha\theta} \tag{3.12c}$$

and,

$$\pi_{it} = (1-\alpha)\,k_{it}^{\alpha\theta}\,l_{it}^{\alpha(1-\theta)}\,a_{it}^{1-\alpha\theta} \tag{3.12d}$$

where $w_t = \frac{W_t}{A_t}$, $k_{it} = \frac{K_{it}}{A_t}$, $y_{it} = \frac{Y_{it}}{A_t}$ and $\pi_{it} = \frac{\Pi_{it}}{A_t}$ are the productivity adjusted wage rate, the level of capital stock, output and the profit of the intermediate good firm i respectively. We can clearly see that both the demand for labor and capital increases when the technology in that sector improves and falls if it fails to innovate since innovations occur somewhere in the economy which puts upward pressure on wage. The profit of the intermediate good firm *i*, therefore, would also increase with innovation and would fall otherwise. The aggregate flow of demand for labor, l_t, and productivity adjusted demand for capital, k_t, can be found by summing equation (3.12a) and (3.12b) over *i*.

$$l_t = \left(\frac{\alpha\,\theta^{\alpha\theta}(1-\theta)^{1-\alpha\theta}}{w_t^{1-\alpha\theta}\,r_t^{\alpha\theta}}\right)^{\frac{1}{1-\alpha}} \frac{1}{1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma} \tag{3.13a}$$

$$k_t = \left(\frac{\alpha\,\theta^{1-\alpha(1-\theta)}(1-\theta)^{\alpha(1-\theta)}}{w_t^{\alpha(1-\theta)}\,r_t^{1-\alpha(1-\theta)}}\right)^{\frac{1}{1-\alpha}} \frac{1}{1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma} \tag{3.13b}$$

To get the expression for the productivity-adjusted aggregate output, $y_t = \frac{Y_t}{A_t}$, we first get the expressions of w_t and r_t from (3.13a) and (3.13b) into (3.12a) and (3.12b). We then use the expressions of k_{it} and l_{it} into Eq. (3.12c) and then sum it over i to get:

$$y_t = \frac{1}{\left(1 + \frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{1-\alpha}} k_t^{\alpha\theta} l_t^{\alpha(1-\theta)} \tag{3.13c}$$

In order to find the labor reallocation (migration) rate, we, first, use (3.13a) and (3.13b) into (3.12a) to get:

$$l_{it} = \left(1 + \frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right) l_t\, a_{it}^{\frac{1-\alpha\theta}{1-\alpha}} \tag{3.14a}$$

We, then, differentiate Eq. (3.14a) with respect to time. Noting that A_{it} is constant for non-innovating firms, rate of change of demand for labor for these firms can be expressed as:

$$\frac{\dot{l}_{it}}{l_{it}} = -\frac{1-\alpha\theta}{1-\alpha}\frac{\dot{A}_t}{A_t} + \frac{\dot{l}_t}{l_t} \tag{3.14b}$$

The first part captures the decline in demand as the workers move from non-innovating to innovating firms and the second is the change in labor hour each worker puts in when the economy experiences a technological shock. As our interest lie in the fraction of workers who change jobs, we consider only the first component. Since the number of non-innovating firms is $(1-\lambda n_t)$ at any time *t*, by using equation (3.4), we get the following expression for the labor migration rate in the economy:

$$m_t = \frac{1-\alpha\theta}{1-\alpha}\lambda\, n_t \ln\gamma\ (1-\lambda\, n_t) \tag{3.14c}$$

We next turn to the equilibrium in R&D sector. Because the expected payoff to an innovation is the same in every sector, the same equilibrium flow of investment, N_t , will be used in each R&D sector. The value of an innovation, V_{it}, (or the value of a firm that innovates) in sector *i* at time *t* is given by the net present value of all future profits.[37]

$$V_{it}(A_t) \ = \int_{\tau=t}^{\infty} e^{-\int_t^{\tau} r_u \, du} \ e^{-\int_t^{\tau} \lambda \, n_u \, du} \, \Pi_{i\tau}(A_t) \, d\tau \tag{3.15a}$$

where $\Pi_{it}(A_t)$ is the profit of a firm at time τ in which innovation occurred at time t and $e^{-\int_t^{\tau} \lambda \, n_u \, du}$ is the probability that this firm is still producing using technology A_t at time $\tau \geq t$. By using (3.4) and (3.12d) and after some algebraic manipulations, we get the productivity-adjusted value of an innovation, $v_{it} = \frac{V_{it}}{A_t}$, as:

$$v_{it}(A_t) \ = (1-\alpha)\left(1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha} \int_{\tau=t}^{\infty} k_{\tau}^{\alpha\theta}\, l_{\tau}^{\alpha(1-\theta)} \ e^{-\int_t^{\tau}\left(r_u+\lambda n_u+\frac{\alpha(1-\theta)}{1-\alpha}\,\lambda\, n_u \ln\gamma\right)du} \, d\tau \tag{3.15b}$$

The amount of resources devoted to research is determined by the research arbitrage condition which equates expected marginal benefit to marginal cost. That is,

$$\lambda \, n_t \, V_{it}(A_t) = (1+\tau_n) \, N_t \qquad \text{or} \qquad v_{it}(A_t) \ = \frac{1+\tau_n}{\lambda} \tag{3.16a}$$

Differentiating (3.15b) and (3.16a) with respect to time and by equating them to each other, we get v_{it} as:

$$v_{it}(A_t) \ = \ \frac{(1-\alpha)\ \left(1+\dfrac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha} \ k_t^{\alpha\theta} \ l_t^{\alpha(1-\theta)}}{r_t+\lambda\, n_t + \ \dfrac{\alpha}{1-\alpha} \ \ \lambda \, n_t \ln\gamma} \tag{3.16b}$$

Using (3.16a) and (3.16b), we get the familiar research-arbitrage condition:

$$\frac{\lambda\,(1-\alpha)\ \left(1+\dfrac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha} \ k_t^{\alpha\theta} \ l_t^{\alpha(1-\theta)}}{(1+\tau_n)\left(r_t+\lambda\, n_t + \ \dfrac{\alpha(1-\theta)}{1-\alpha} \ \ \lambda \, n_t \ln\gamma\right)} = 1 \tag{3.17a}$$

[37] Recall that once the innovation occurs in sector *i* at time *t*, the technology in that sector jumps from A_{it} to the state of the art technology, A_t.

$$\text{or,}\qquad n_t = \frac{\frac{\lambda}{(1+\tau_n)}\,(1-\alpha)\,\left(1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha}\,k_t^{\alpha\theta}\,l_t^{\alpha(1-\theta)} - r_t}{\lambda\left(1+\frac{\alpha(1-\theta)}{1-\alpha}\ln\gamma\right)} \tag{3.17b}$$

Equation (3.17b) is the demand for fund for R&D activities. Finally, the productivity adjusted value of all firms is given by:[38]

$$v_t = \frac{1}{\lambda}\,\frac{1}{1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma} \tag{3.18}$$

A representative consumer chooses consumption and leisure to maximize utility (Eq. 3.6) subject to the budget constraint (Eq. 3.7). The first order conditions at the optimum are

$$u_C = C^{\rho-1}(1-l)^{\eta\rho} = \mu\,(1+\tau_c) \tag{3.19a}$$

$$-u_l = \eta C^{\rho}(1-l)^{\eta\rho-1} = \mu\,W\left(1-\tau_y\right)(1-\tau_w) \tag{3.19b}$$

$$(1-\tau_y)(1-\tau_r)\phi\,r = \beta - \frac{\dot{\mu}}{\mu} \tag{3.19c}$$

where μ is the private shadow value of wealth, together with the transversality conditions $\lim_{t\to\infty}\mu V_t e^{-\beta t} = 0$ and $\lim_{t\to\infty}\mu K_t e^{-\beta t} = 0$. By solving equations (3.19a) and (3.19b), we get the familiar relationship between labor and consumption,

$$1 - l_t = \frac{\eta C_t}{W_t} = \frac{\eta c_t\,(1+\tau_c)}{w_t\,(1-\tau_y)(1-\tau_w)} \tag{3.20a}$$

where $c_t = \frac{C_t}{A_t}$ is the productivity adjusted consumption. The Euler equation is given by using the time derivatives of (3.19a) and (3.20a) into equation (3.18c),

$$\frac{\dot{C}_t}{C_t} = \Omega(l_t)\left[\left(1-\tau_y\right)(1-\tau_r)\phi_t\,r_t - \beta + \Psi(l_t)\left((1-\alpha\theta)\frac{\dot{A}_t}{A_t} + \alpha\theta\frac{\dot{K}_t}{K_t}\right)\right] \tag{3.20b}$$

where, $\Omega(l_t) = -\frac{1-\alpha(1-\theta)(1-l_t)}{\eta\rho l_t+(\rho-1)\left(1-\alpha(1-\theta)(1-l_t)\right)} > 0$ and $\Psi(l_t) = -\frac{\eta\rho l_t}{1-\alpha(1-\theta)(1-l_t)} > 0$.

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[38] $v_t = \int_i v_{it}\,di$,where $v_{it}(A_{it}) = a_{it}^{\frac{1}{1-\alpha}}\,v_{it}(A_t)$, is the value of a firm with technology A_{it} at time t and $v_{it}(A_t) = \frac{1}{\lambda}$.

We summarize the equilibrium conditions as follows:

Definition *An equilibrium in this economy is given by the time paths of consumption, and aggregate output,* $[C_t, Y_t]_{t=0}^{\infty}$ *that satisfies (3.20b), and (3.13c), time paths of R&D expenditure, state of the art technology, stock of physical capital and net present value of the assets,* $[N_t, A_t, K_t, V_t]_{t=0}^{\infty}$ *given by (3.17b), (3.4), (3.7) and (3.18), time paths of interest rate, and wage rate,* $[r_t, w_t]_{t=0}^{\infty}$ *consistent with (3.13b) and (3.13a) and time paths of labor supply, migration rate, social capital, tax rate and the strength of institutions* $[l_t, m_t, s_t, \tau, \phi_t]_{t=0}^{\infty}$ *given by (3.20a), (3.14c), (3.11),(3.9) and (3.8).*

We define a balanced growth path as an equilibrium path in which all variables grow at a constant rate except for labor allocation, interest rate, migration rate, social capital and the strength of institutions, which are constant. Following our definition of balanced growth path, it is convenient to write the system in terms of stationary productivity adjusted variables. It is straightforward to express the dynamics of the decentralized economy as

$$\dot{k}_t = w\, l + (\phi_t r - \lambda\, n \ln \gamma)\,(v + k) - c - g + \tau_n n \tag{3.21a}$$

$$\dot{s}_t = (1 - l_t) - m_t s_t \tag{3.21b}$$

$$\dot{c}_t = c\,\Omega(l_t)\left[(1 - \tau_y)(1 - \tau_r)\phi_t r_t - \beta + (\rho - 1)\lambda\, n_t \ln \gamma + \Psi(l_t)\,\alpha\theta\,\frac{\dot{k}_t}{k_t}\right] \tag{3.21c}$$

along with labor market clearing conditions (3.13a) and (3.20a), research-arbitrage condition (3.17a), labor migration rate (3.14c) and market interest rate (3.13b). Imposing the steady-state conditions $\dot{k} = \dot{s} = \dot{c} = 0$, we can solve for the steady-state values of productivity-adjusted variables, level of physical capital ($\tilde{k}$), consumption ($\tilde{c}$), R&D investment ($\tilde{n}$), and wage rate ($\tilde{w}$), and the other variables, interest rate ($\tilde{r}$), labor ($\tilde{l}$), migration rate ($\tilde{m}$), social capital ($\tilde{s}$), tax schedule ($\tilde{\tau}$) and the strength of institutions ($\tilde{\phi}$). Finally, productivity-adjusted output ($\tilde{y}$), and value of assets ($\tilde{v}$) can be found by using (3.13c), and (3.18) respectively.

Linearizing equations (3.21a) - (3.21c) around the steady-state yields an approximation to the underlying dynamic system. This system forms the basis for our dynamic simulations. For all plausible parameter values, the system has one positive (unstable) and two negative (stable) eigenvalues, leading us to conclude that it is saddle point stable.

3.3 Numerical Results

Due to the complexity of the model, we calibrate it in order to obtain further insight. The baseline parameter values are given as follows: $\alpha = 0.9$; $\theta = 0.3$; $\beta = 0.02$; $\gamma = 2$; $\rho = -1.5$; $\eta = 0.1$; $\psi_s = 1, \psi_g = 100$. Our choice of the preference parameters, α, β and θ are standard. The parameter η describes the degree of substitution between socialization/leisure and consumption. We chose η as 0.1 in order to ensure that people socialize 10-20% of the total available time out of working and socializing, however, the results are qualitatively similar for other values of η. This is in contrast with the previous literature where the estimated work time is approximately 1/3 of the total available time. The reason for this difference is that we are not considering any other leisure activities and therefore our total time is approximately 10 hours a day, not 24 hours. The choice of γ, the size of innovation, and λ, innovation probability parameter, are such that the growth rate is approximately 2% in the baseline model. However, we can easily change these parameters to reflect varying growth experience of different countries. In this regard, it can be argued that the countries experiencing higher growth are able to either innovate more frequently or acquire the necessary resources (for example, foreign investment) in order to sustain higher growth. Once again, the qualitative results of the model are unchanged for other reasonable parameter values as well. ψ_s and ψ_g capture the effectiveness of social capital and formal institutions respectively in the production process. As mentioned in chapter 2, we have considered a very high value of ψ_g in order to make sure that the marginal benefit of improving formal institutions exceeds the marginal cost. Although some of the parameters are difficult to pin down, the calibration exercise still provides useful insights into the dynamics of social capital and economic growth.

In the baseline model, people consume 87 percent of their income, spend 11 percent of the total available time socializing and 12 percent of them switch jobs at any point of time. The market interest rate is 10.78 percent, the expenditure on research activities are 7.2 percent of total income and the rate of growth is given by 1.8 percent. Since g is set to zero, the strength of institutions ($\phi = 0.586$) are determined solely by the amount of social capital.

The long-run effects of improving formal institutions through alternative tax schedule are reported in Table 3.1A while the short-run effects are reported in Table 3.1B. Transitional paths are shown in Figure 3.1. In addition, the final columns in Table 3.1A and 3.1B summarize the effects on long-run welfare, [ΔW], and short-run welfare, [ΔW(0)] , both measured by the optimized utility of the representative agent where c and l are evaluated along the equilibrium path. These welfare changes are measures of equivalent variation, calculated as the percentage change in the initial stock of physical capital necessary to maintain the level of welfare unchanged following the particular shock.

3.3.1 Unanticipated Permanent increase in g (Improvement in Formal Institutions)

We consider an unanticipated permanent increase in the productivity adjusted expenditure on formal institutions from 0 to 0.02. Improvement in formal institutions raises the overall health of institutions in the economy from 0.586 to 0.944 in the short run. As it raises the effective return from investment, resources move away from consumption into R&D and physical capital sector in the short-run except when tax is imposed on interest income. In this case, since the change in effective interest is positive, it results in rise in both investment and consumption.[39] The fall in consumption, in general, induces people to work more or vice-versa (lump-sum tax, tax on interest income and tax on research activities), but the imposition of tax on wage income, on consumption and income reduce the supply of labor (see Eq. 3.20a) resulting in the movement of equilibrium labor in the same direction as consumption in the short-run. As the risk associated with investment reduces because of better institutional environment, market rate of interest falls while investment rises except when the tax is imposed on the research activities. The increase in investment into R&D sector is the highest when lump-sum tax is imposed as it allows for movement of resources from consumption without any distortions consequently it results in highest rate of growth. Short-run welfare gain is highest when income tax is imposed as both consumption and the rate of socialization increase instantaneously.

Transitional dynamics are shown in Figure 3.1. With investment in physical capital, the stock of physical capital starts rising during the transition in all cases. Although, the rate of socialization increases, the increase in labor migration rate dominates and therefore, social capital declines throughout except the case when tax on research activity is imposed. Tax on R&D sector reduces the resources devoted to R&D activities which, in turn, lowers the labor migration rate and raises the stock of social capital initially. However, the rise in the stock of physical capital reduces its marginal productivity and therefore the market rate of interest. This decline in the rate of interest leads to rise in the investment into R&D sector which, in turn, raises the labor migration rate. After a while, the increase in migration dominates the rise in socialization time resulting in declining social capital. Also, increase in n, raises the rate of growth of the economy during the transition. Overall, in the long-run (see Table 3.1A) the stock of productivity adjusted physical capital, consumption, wage, R&D investment, output, growth

[39] If, however, the change in effective interest was negative, it would be optimal not to improve formal institutions.

rate and labor migration rate increases while social capital, labor and the market rate of interest falls. The rate of growth of the economy is highest when the expenditure on formal institutions are financed by the lump-sum tax whereas the maximum change in long-run welfare occurs when consumption tax is imposed. This result is surprising as the literature shows that non-distortionary tax performs better than a distortionary tax. Even tax on wage income performs better from the welfare point of view. The reason for this result could be the presence of externalities (business stealing, intertemporal spillover, social capital) in the decentralized economy and the distortionary taxes acts to reduce the effects of these externalities.

3.4 Conclusions

In this chapter, we add the stock of physical capital as another factor of production. We analyze the impact of improvement in formal institutions on the dynamics of social capital and economic growth. It considers alternative taxes to finance the expenditure on formal institutions. We find that financing through lump sum tax is growth maximizing, however, tax on consumption results in highest change in welfare.

Table 3.1: Comparative Statics

Baseline Parameters: $\alpha = 0.9;\ \theta = 0.3;\ \beta = 0.02;\ \gamma = 2; \lambda = 0.4;\ \rho = -1.5;\ \eta = 0.1;\ \ \psi_s = 1, \psi_g = 100$

Table 3.1A: Long-Run Effects

	k	s	c	l	w	r %	n	y	m %	ϕ	Tax %	G %	ΔW %
Benchmark $g = 0$	2.494	0.882	0.7598	0.8918	0.7025	10.77	0.0621	0.9945	12.266	0.5859	-	1.723	-
Improvement in Formal Institutions ($g = 0.02$)													
T	3.506	0.696	0.8788	0.8862	0.7720	8.36	0.0837	1.0859	16.365	0.9325	-	2.319	20.55
τ_w	3.508	0.716	0.8773	0.8831	0.7731	8.34	0.0835	1.0837	16.338	0.9338	2.93	2.315	20.63
τ_c	3.507	0.711	0.8777	0.8838	0.7728	8.35	0.0836	1.0842	16.345	0.9335	2.28	2.316	20.71
τ_r	3.331	0.7286	0.8743	0.8852	0.7617	6.59	0.0804	1.0702	15.755	0.9347	6.59	2.230	19.61
τ_y	3.453	0.7192	0.8764	0.8838	0.7696	8.44	0.0826	1.0796	16.163	0.9341	2.03	2.290	20.33
τ_n	4.400	0.8774	0.9572	0.8835	0.8217	7.07	0.0674	1.1524	13.277	0.9437	29.67	1.869	14.62

Table 3.1B: Short-Run Effects

	$c(0)$	$l(0)$	$w(0)$	$r(0)$ %	$n(0)$	$y(0)$	$m(0)$ %	$\phi(0)$	$Tax(0)$ %	$G(0)$ %	$\Delta W(0)$ %
T	0.7514	0.8935	0.7095	10.17	0.0663	0.9956	13.069	0.9440	-	1.839	-1.257
τ_w	0.7506	0.8905	0.7104	10.14	0.06620	0.9936	13.046	0.9440	3.16	1.836	-1.089
τ_c	0.7517	0.8911	0.7102	10.15	0.06623	0.9940	13.050	0.9440	2.66	1.836	-1.000
τ_r	0.7662	0.8913	0.7081	10.30	0.06517	0.9942	12.845	0.9440	7.07	1.181	0.887
τ_y	0.7553	0.8908	0.7097	10.19	0.06588	0.9938	12.983	0.9440	2.19	1.827	-0.490
τ_n	0.7530	0.8942	0.7219	9.36	0.0458	0.9962	9.096	0.9440	43.69	1.271	-1.109

Figure 3.1: Dynamic Responses to Taxes

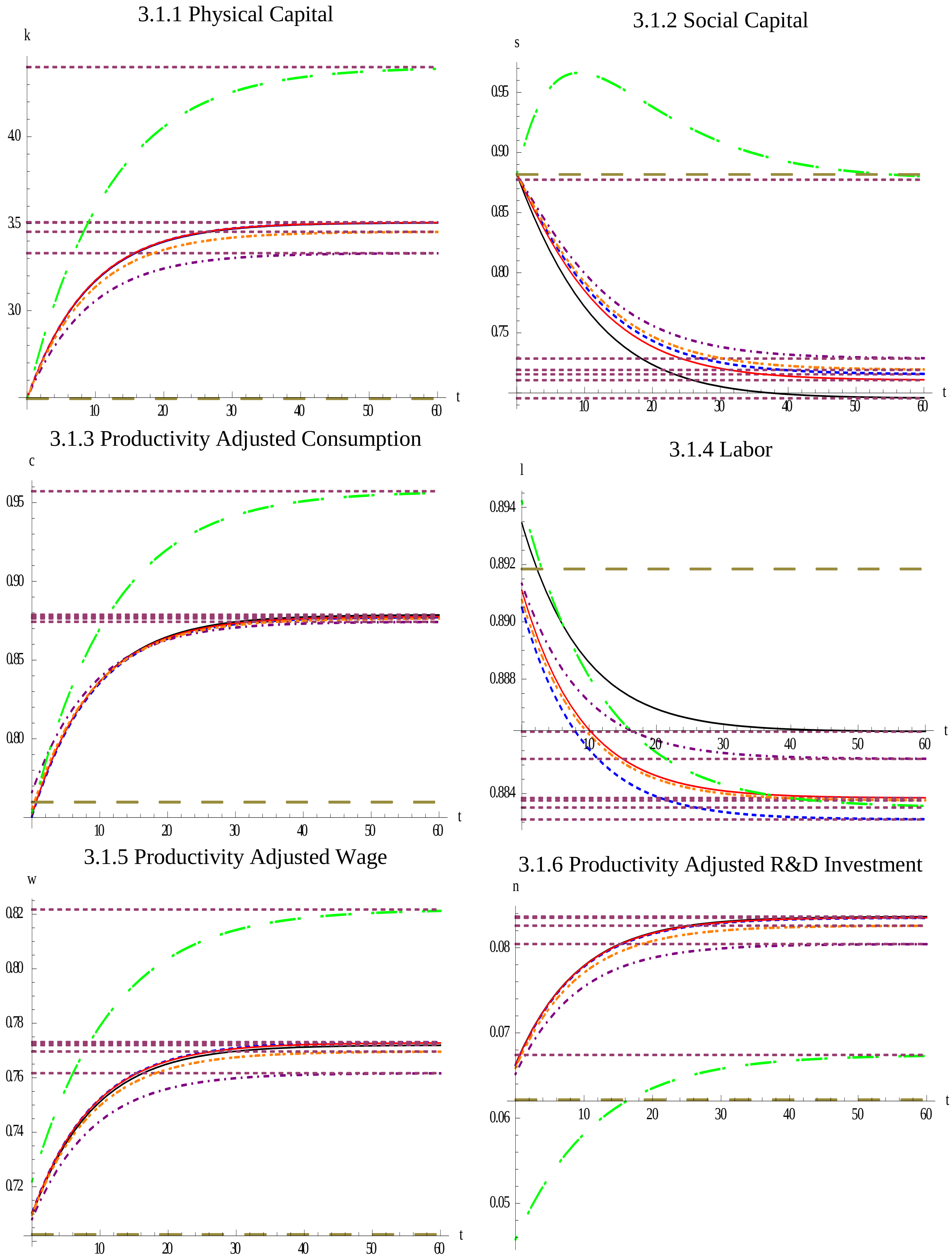
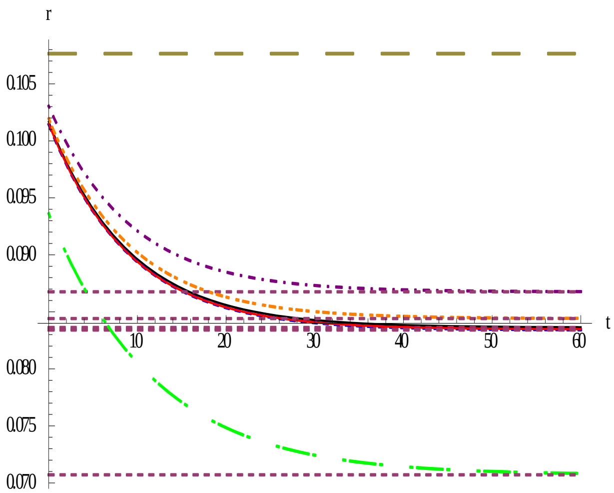
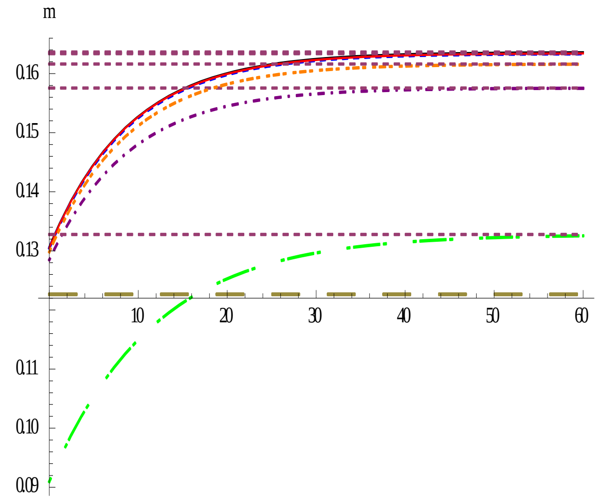


Figure 3.1 Continued

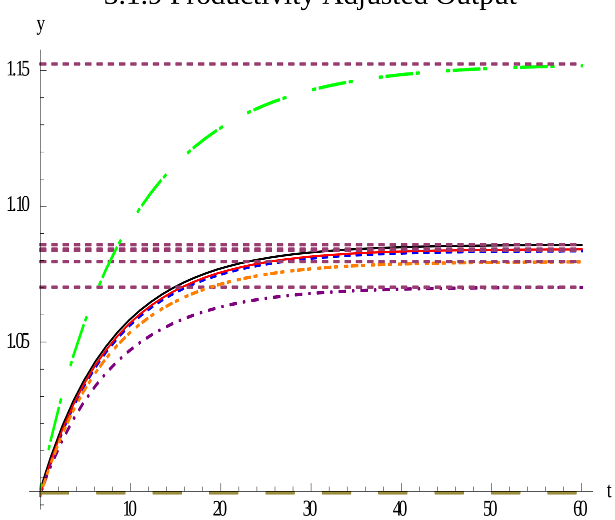
3.1.7 Interest Rate



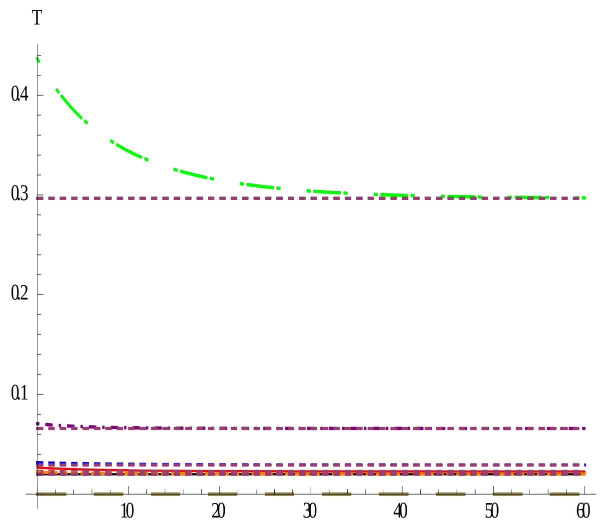
3.1.8 Labor Migration Rate



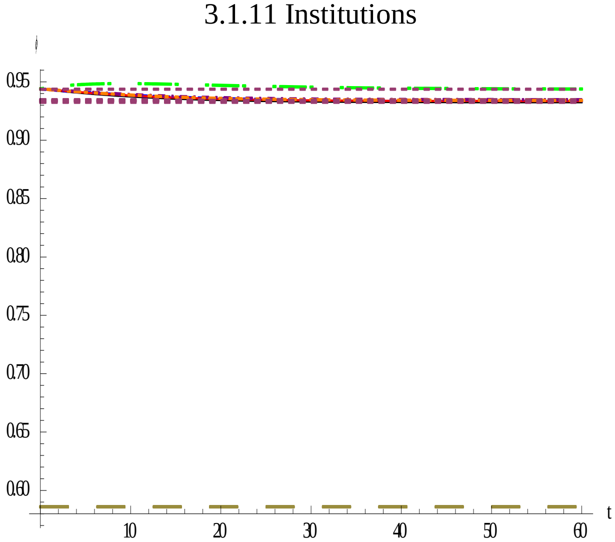
3.1.9 Productivity Adjusted Output



3.1.10 Taxes



3.1.11 Institutions



3.1.12 growth Rate

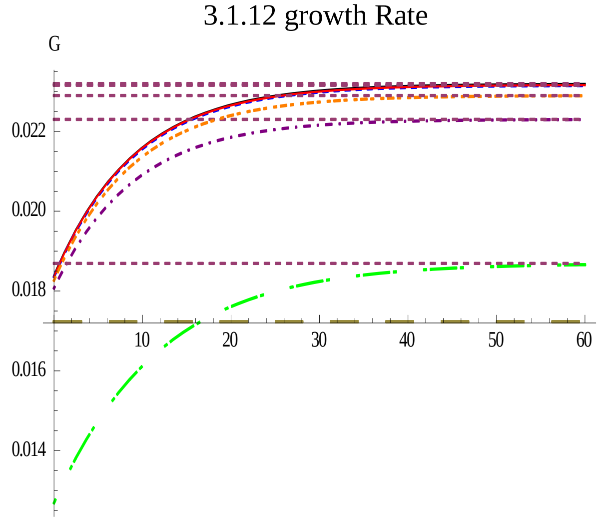
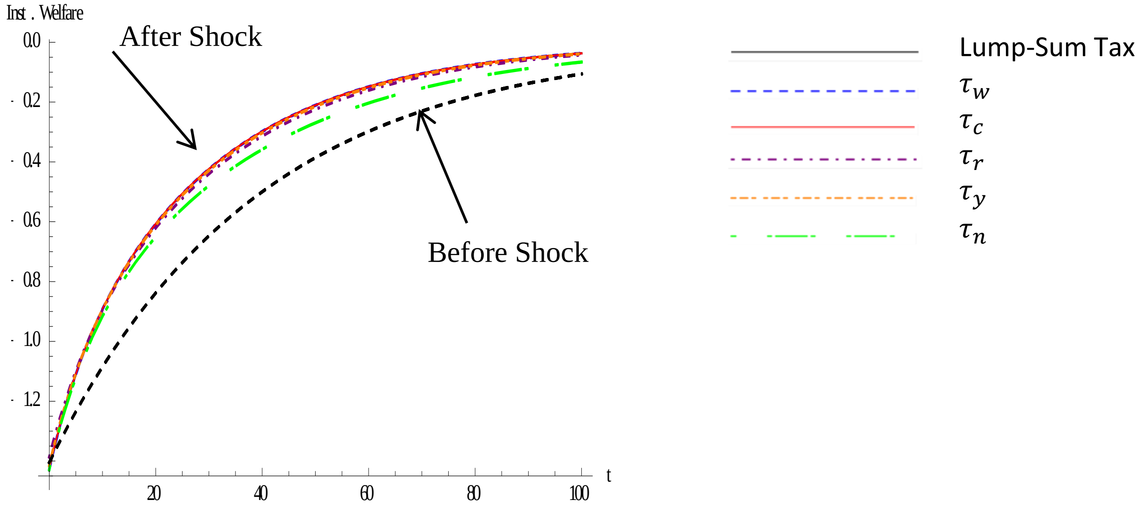


Figure 3.1 Continued

3.1.13 Welfare Path



Chapter 4

Productive Social Capital and Economic Growth

In this chapter, we analyze the relationship between social capital and economic growth where social capital raises output directly by eliminating the frictions inside the production process. Once again, the same objective can be achieved by improving formal institutions but doing so is costly. In contrast to the chapter 1 and 2, where we assumed that institutions affect the return from investment and therefore affect the supply of funds for R&D investment, in this chapter we assume that institutions affect the output and therefore profit of firms which, in turn, affect the demand for fund in R&D sector. The strength of institutions in the economy is determined by the flow of services provided by the level of social capital and the strength of formal institutions. Formal institutions may be thought of as spending on infrastructure, strengthening the rules of the law or firms spending on screening and monitoring to reduce the impact of adverse selection and moral hazard problem within the firm. In this case, we analyze the impact of increase in the rate of innovation and an exogenous improvement in formal institutions financed by lump-sum tax.

We find that while both shocks increase the rate at which the economy grows and decrease the stock of social capital, productivity adjusted physical capital and R&D investment declines when innovation rate goes up while they increase when the formal institutions are improved. They both result in long-run welfare gain. More effective formal institutions result in even higher economic growth and long-run welfare gain.

In related literature, Sequeira and Ferreira-Lopes (2011, 2012) include social capital as a productive factor; however, there is no role of formal institutions. Bartolini and Bonatti (2009), also include both social capital and formal institutions in the production function in an endogenous growth model, but do not consider transitional dynamics. Also, we consider social capital as a function of socialization and labor migration rate whereas they consider that social capital declines if ratio of social capital to output is below a threshold level.

The rest of the chapter is organized as follows. Section 4.1 presents the model, Section 4.2 characterizes the equilibrium, Section 4.3 calibrates the model and discusses short- and long-run effects of technological shock and the impact of institutional shock, and Section 4.4 concludes this chapter.

4.1 The Model

There are three sectors: production (final and intermediate good), technology (R&D) and household.

4.1.1 Production

There is a final consumption good produced by competitive firms. The final food is produced according to the following Cobb-Douglas production function:

$$Y_t = \int_0^1 \phi^{1-\alpha} A_{it} \, x_{it}^{\alpha} \qquad ; \qquad 0 < \alpha < 1 \tag{4.1}$$

Where, ϕ is the level of institutions, x_{it} is the flow of intermediate good i ($i \in [0,1]$). The parameter A_{it} is the productivity parameter of intermediate good i. We consider the following CES type functional form of institutions:

$$\phi = \left(\psi_s \, s^{\sigma} + \psi_g \, g^{\sigma}\right)^{\frac{1}{\sigma}} \qquad ; \quad \psi_s, \psi_g > 0 \ , \qquad 0 \neq \sigma < 1 \tag{4.2}$$

where, ψ_s and ψ_g captures the relative strength of social capital and formal institutions.

There is a continuous mass one of intermediate good sectors. Each sector produces only one type of intermediate good in which they have complete monopoly power. Each intermediate good is produced using physical capital and labor, K_{it} and l_{it}, according to

$$x_{it} = \left(\frac{K_{it}}{A_{it}}\right)^{\theta} \ l_{it}^{1-\theta} \qquad ; \qquad 0 < \theta < 1 \tag{4.3}$$

4.1.2 Technology (R&D)

We assume that there is a different R&D sector for each intermediate good.[40] Each R&D sector is competitive. The Poisson arrival rate of innovation in each sector is given by $\lambda\, n_{it}$, where λ is an innovation parameter, $n_{it}\ \left(\frac{N_{it}}{A_t}\right)$ is the productivity adjusted investment in the R&D sector i, N_{it} is the investment into R&D sector and A_t is the state of the art technology in the economy at time *t*. We assume that innovation is increasingly difficult, that is, the probability of innovation decreases when we go up in the ladder in the technological innovation for the same level of investment, N_{it}. Each innovation at time t in any sector *i* permits the innovator to start producing in sector i using the leading edge technology, A_t. Each innovation raises the technology parameter, A, by a constant factor, γ. Once an innovation occurs in sector i, either the existing firm purchases the patent from the innovator or only the ownership of the firm changes.[41] After the innovation, the technology in that sector jumps discontinuously from A_{it} to the state of the art technology, A_t.

Although, technology grows discontinuously at the individual sector level, economy wide technology, A_t, evolves gradually. We assume that this leading technology grows at a rate

[40] Having R&D sector is more relevant for the developed countries. For other economies (emerging or poor) we can interpret R&D expenditure as the expenditure on buying technologies from the developed countries.
[41] This is to ensure that after the innovation the same (previously employed) workers along with some new workers are working in that firm and there is not a complete restructuring inside that firm.

proportional to the aggregate flow of innovation, n_t, per unit of time. The economy-wide growth rate of technology is given by

$$\frac{\dot{A}_t}{A_t} = \lambda\, n_t \ln\gamma \qquad ; \qquad \gamma > 1 \tag{4.4}$$

where $n_t = \int_0^1 n_{it}\, di$ is the aggregate productivity adjusted investment into R&D sector. We define $a_{it} = \frac{A_{it}}{A_t}$, as the relative productivity of intermediate good sector i with respect to the state of the art technology in the economy. We assume that the relative productivities are distributed across different intermediate good sector according to:

$$F(a) = a^{\frac{1}{\ln\gamma}} \qquad ; \qquad 0 \le a \le 1 \tag{4.5}$$

where $F(a)$ is the cumulative distribution function of the relative productivities, a. The probability distribution function of the relative productivity, a, therefore, is $f(a) = \frac{1}{\ln\gamma}\ a^{\frac{1}{\ln\gamma}-1}$. At any time, the distribution of relative productivities stays the same but the relative position of firms change.

4.1.3 Consumers

We consider an economy populated with a continuous mass one of representative consumers. Each consumer is endowed with one unit flow of time which is allocated between working l and socializing $(1 - l)$. At each time, a consumer makes the following decisions: first, how much to consume and how much to save and, second, how to allocate its time between working and socializing. A representative consumer's preference is given by the following intertemporal isoelastic utility function[42]:

[42] This is a standard labor-leisure tradeoff utility function where we treat leisure as socialization.

$$U = \int_0^\infty \frac{1}{\rho}\,[C\,(1-l)^\eta]^\rho\, e^{-\beta t}\, dt \tag{4.6}$$

$$-\infty < \rho \le 1; \quad \eta > 0$$

where C_t is the consumption in period t, β is the discount factor, and η captures the impact of socialization on the welfare of consumers. The representative consumer's budget constraint, therefore, is given by:

$$\dot{K} + \dot{V} = W\,l + r\,V + r\,K - C - T$$

or (4.7a)

$$\dot{K} = Y - C - N - T$$

where V is the value of the assets held by consumers, W is the current wage rate, r is the market interest rate and T is the lump-sum tax or contributions. Assuming that the budget is always balanced, the economy wide budget constraint is given by

$$\dot{K} + \dot{V} = W\,l + r\,V + r\,K - C - G$$

or (4.7b)

$$\dot{K} = Y - C - N - G$$

4.1.4 Social Capital

As earlier, we consider the following equation for the evolution of the stock of social capital:

$$\dot{s_t} = (1 - l_t) - m_t\, s_t\ , \qquad 0 \le m_t \le 1\,;\ \ 0 \le s_t < \infty \tag{4.8}$$

where, m_t is the rate of labor migration across different sectors in the economy. If a proportion m_t of workers switch jobs then the social capital is destroyed by a measure of $m_t s_t$.

Since the motive of socialization is not economic, the consumers do not consider the impact of their socializing decision on the social capital. This creates an additional source of externality into the model (*social capital externality*) where the formation of social capital is the side product of the individual rational decision of socialization.

4.2 Equilibrium

An allocation in this economy consists of the time paths of consumption, and aggregate output, $[C_t, Y_t]_{t=0}^{\infty}$, time paths of R&D expenditure, state of the art technology, stock of physical capital and net present value of the assets, $[N_t, A_t, K_t, V_t]_{t=0}^{\infty}$, time paths of interest rate, and wage rate, $[r_t, W_t]_{t=0}^{\infty}$ and time paths of labor supply, migration rate, social capital, and the strength of institutions $[l_t, m_t, s_t, \phi_t]_{t=0}^{\infty}$. An equilibrium is an allocation where the representative consumers maximize utility, intermediate good producers maximize profit, innovators maximize their net present discounted value and the labor market clears.

We start with the production sector. We assume that the final good sector is competitive while each of the intermediate good sectors is monopolized.[43,44] For simplicity, we also assume that the monopolists use first-degree price discrimination to extract all surplus from the final good sector. It implies that the monopolist can charge $\phi^{1-\alpha} A_{it} x_{it}^{\alpha}$ from the firms in the final good sector. The objective of a monopolist intermediate good firm is choose the optimal level of l_{it} to maximize its profit, $\Pi_{it} = \phi^{1-\alpha} A_{it} x_{it}^{\alpha} - W_t l_{it} - r_t K_{it}$. The demand for labor and capital, and the profit of an intermediate good firm *i* is given by,

$$l_{it} = \phi_t \left(\frac{\alpha\, \theta^{\alpha\theta} (1-\theta)^{1-\alpha\theta}}{w_t^{1-\alpha\theta}\, r_t^{\alpha\theta}} \right)^{\frac{1}{1-\alpha}} a_{it}^{\frac{1-\alpha\theta}{1-\alpha}} \tag{4.9a}$$

$$k_{it} = \phi_t \left(\frac{\alpha\, \theta^{1-\alpha(1-\theta)} (1-\theta)^{\alpha(1-\theta)}}{w_t^{\alpha(1-\theta)}\, r_t^{1-\alpha(1-\theta)}} \right)^{\frac{1}{1-\alpha}} a_{it}^{\frac{1-\alpha\theta}{1-\alpha}} \tag{4.9b}$$

and,

$$\pi_{it} = \phi_t^{1-\alpha} (1-\alpha) k_{it}^{\alpha\theta}\, l_{it}^{\alpha(1-\theta)}\, a_{it}^{1-\alpha\theta} \tag{4.9c}$$

[43] Price of the final good is normalized to one.
[44] Quality gap is assumed to be sufficiently large between any two consecutive innovations in order to rule out limit pricing.

where $w_t = \frac{W_t}{A_t}$, $k_{it} = \frac{K_{it}}{A_t}$ and $\pi_{it} = \frac{\Pi_{it}}{A_t}$ are the productivity adjusted wage rate, the level of capital stock and the profit of intermediate good firm i respectively. We can clearly see that both the demand for labor and capital increases when the technology in that sector improves and falls if it fails to innovate since innovations occur somewhere in the economy which puts upward pressure on wage. The profit of the intermediate good firm *i*, therefore, would also increase with innovation and would fall otherwise. In addition, profits are higher when an economy possesses better institutions. The aggregate flow of demand for labor, l_t, and the productivity adjusted demand for capital, k_t, can be found by summing equation (4.9a) and (4.9b) over *i*.

$$l_t = \phi_t \left(\frac{\alpha\, \theta^{\alpha\theta} (1-\theta)^{1-\alpha\theta}}{w_t^{1-\alpha\theta}\, r_t^{\alpha\theta}} \right)^{\frac{1}{1-\alpha}} \frac{1}{1 + \frac{1-\alpha\theta}{1-\alpha} \ln \gamma} \tag{4.10a}$$

$$k_t = \phi_t \left(\frac{\alpha\, \theta^{1-\alpha(1-\theta)} (1-\theta)^{\alpha(1-\theta)}}{w_t^{\alpha(1-\theta)}\, r_t^{1-\alpha(1-\theta)}} \right)^{\frac{1}{1-\alpha}} \frac{1}{1 + \frac{1-\alpha\theta}{1-\alpha} \ln \gamma} \tag{4.10b}$$

We, then, get the following expressions for the productivity-adjusted aggregate output, $y_t = \frac{Y_t}{A_t}$, by using (4.9a) and (4.9b) into (4.3) and then by using (4.3) into (4.1) and then diving through by A_t as

$$y_t = \frac{1}{\left(1 + \frac{1-\alpha\theta}{1-\alpha} \ln \gamma\right)^{1-\alpha}} \phi_t^{1-\alpha} k_t^{\alpha\theta}\, l_t^{\alpha(1-\theta)} \tag{4.11a}$$

$$\pi_t = (1-\alpha) y_t = \frac{1-\alpha}{\left(1 + \frac{1-\alpha\theta}{1-\alpha} \ln \gamma\right)^{1-\alpha}} \phi_t^{1-\alpha}\, k_t^{\alpha\theta}\, l_t^{\alpha(1-\theta)} \tag{4.11b}$$

In order to find the labor reallocation (migration) rate, we, first, use expressions of w_t and r_t from (4.10a) into (4.10b) to get:

$$l_{it} = \left(1 + \frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)\, l_t\, a_{it}^{\frac{1-\alpha\theta}{1-\alpha}} \tag{4.12a}$$

We, then, differentiate Eq. (4.12a) with respect to time. Noting that A_{it} is constant for non-innovating firms, rate of change of demand for labor for these firms can be expressed as:

$$\frac{\dot{l}_{it}}{l_{it}} = -\frac{1-\alpha\theta}{1-\alpha}\,\frac{\dot{A}_t}{A_t} + \frac{\dot{l}_t}{l_t} \tag{4.12b}$$

The first part captures the decline in demand as the workers move from non-innovating to innovating firms and the second is the change in labor hour each worker puts in when the economy experiences a technological shock. As our interest lie in the fraction of workers who change jobs, we consider only the first component. Since the number of non-innovating firms is $(1-\lambda n_t)$ at any time *t*, by using equation (4.4), we get the following expression for the labor migration rate in the economy:

$$m_t = \frac{1-\alpha\theta}{1-\alpha}\,\lambda\, n_t \ln\gamma\,\,(1-\lambda\, n_t) \tag{4.12c}$$

We next turn to the equilibrium in R&D sector. Because the expected payoff to an innovation is the same in every sector, the same equilibrium flow of investment, N_t , will be used in each R&D sector. The value of an innovation, V_{it}, (or the value of a firm that innovates) in sector *i* at time *t* is given by the net present value of all future profits.[45]

$$V_{it}(A_t) \;=\int_{\tau=t}^{\infty} e^{-\int_t^\tau r_u\,du}\; e^{-\int_t^\tau \lambda\, n_u\,du}\,\Pi_{i\tau}(A_t)\,d\tau \tag{4.13a}$$

where $\Pi_{it}(A_t)$ is the profit of a firm at time τ in which innovation occurred at time t and $e^{-\int_t^\tau \lambda\, n_u\,du}$ is the probability that this firm is still producing using technology A_t at time $\tau \geq t$.

[45] Recall that once the innovation occurs in sector *i* at time *t*, the technology in that sector jumps from $A_{it}$to the state of the art technology, A_t.

By using (4.4) and (4.9c) and after some algebraic manipulations, we get the productivity-adjusted value of an innovation, $v_{it} = \frac{V_{it}}{A_t}$, as:

$$v_{it}(A_t) = (1-\alpha)\left(1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha}\int_{\tau=t}^{\infty}\phi_{\tau}^{1-\alpha}\,k_{\tau}^{\alpha\theta}\,l_{\tau}^{\alpha(1-\theta)}\,e^{-\int_t^{\tau}\left(r_u+\lambda n_u+\frac{\alpha(1-\theta)}{1-\alpha}\,\lambda\,n_u\ln\gamma\right)du}\,d\tau \qquad (4.13b)$$

The amount of resources devoted to research is determined by the research arbitrage condition which equates expected marginal benefit to marginal cost. That is,

$$\lambda\,n_t\,V_{it}(A_t) = N_t \qquad \text{or} \qquad v_{it}(A_t) = \frac{1}{\lambda} \qquad (4.14a)$$

Differentiating (4.13b) and (4.14a) with respect to time and by equating them to each other, we get v_{it} as:

$$v_{it}(A_t) = \frac{(1-\alpha)\left(1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha}\phi_t^{1-\alpha}\,k_t^{\alpha\theta}\,l_t^{\alpha(1-\theta)}}{r_t+\lambda\,n_t+\frac{\alpha}{1-\alpha}\,\lambda\,n_t\ln\gamma} \qquad (4.14b)$$

Using (4.14a) and (4.14b), we get the familiar research-arbitrage condition:

$$\frac{\lambda(1-\alpha)\left(1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha}\phi_t^{1-\alpha}\,k_t^{\alpha\theta}\,l_t^{\alpha(1-\theta)}}{r_t+\lambda\,n_t+\frac{\alpha(1-\theta)}{1-\alpha}\,\lambda\,n_t\ln\gamma} = 1 \qquad (4.15a)$$

or, $$n_t = \frac{\lambda(1-\alpha)\left(1+\frac{1-\alpha\theta}{1-\alpha}\ln\gamma\right)^{\alpha}\phi_t^{1-\alpha}\,k_t^{\alpha\theta}\,l_t^{\alpha(1-\theta)} - r_t}{\lambda\left(1+\frac{\alpha(1-\theta)}{1-\alpha}\ln\gamma\right)} \qquad (4.15b)$$

Equation (4.15b) gives the demand for fund for R&D activities which rises with the improvement in institutions in the economy. It is in contrast to chapter 1 where the demand for R&D funds were unaffected by the quality of institutions.

Finally, the productivity adjusted value of all firms is given by:[46]

---

[46] $v_t = \int_i v_{it}di$,where $v_{it}(A_{it}) = a_{it}^{\frac{1}{1-\alpha}}\,v_{it}(A_t)$, is the value of a firm with technology A_{it} at time t and $v_{it}(A_t) = \frac{1}{\lambda}$.

$$v_t = \frac{1}{\lambda} \frac{1}{1 + \frac{1-\alpha\theta}{1-\alpha} \ln \gamma} \tag{4.16}$$

A representative consumer chooses consumption and leisure to maximize utility (Eq. 4.6) subject to the budget constraint (Eq. 4.7a). The first order conditions at the optimum are

$$u_C \;=\; C^{\rho-1}(1-l)^{\eta\rho} \;=\; \mu \tag{4.17a}$$

$$-\,u_l \;=\; \eta C^{\rho}(1-l)^{\eta\rho-1} \;=\; \mu W \tag{4.17b}$$

$$r \;=\; \beta - \frac{\dot{\mu}}{\mu} \tag{4.17c}$$

where μ is the private shadow value of wealth, together with the transversality conditions $\lim_{t\to\infty} \mu V_t e^{-\beta t} = 0$ and $\lim_{t\to\infty} \mu K_t e^{-\beta t} = 0$. The interpretation of these equations are standard; (4.17a) equates the private marginal utility of consumption to the shadow value of wealth; (4.17b) equates the private marginal utility of socialization to its opportunity cost, the real wage valued at the shadow value of wealth, while (4.17c) equates the return on assets/capital to the rate of return of consumption.

By solving equations (4.17a) and (4.17b), we get the familiar relationship between labor and consumption,

$$1 - l_t = \frac{\eta C_t}{W_t} = \frac{\eta c_t}{w_t} \tag{4.18a}$$

where $c_t = \frac{C_t}{A_t}$ is the productivity adjusted consumption. The Euler equation is given by using the time derivatives of (4.17a) and (4.18a) into equation (4.17c),

$$\frac{\dot{C}_t}{C_t} = \Omega(l_t)\left[r_t - \beta + \Psi(l_t)\left((1-\alpha\theta)\frac{\dot{A}_t}{A_t} + \alpha\theta\frac{\dot{K}_t}{K_t}\right)\right] \tag{4.18b}$$

where, $\Omega(l_t) = -\frac{1-\alpha(1-\theta)(1-l_t)}{\eta\rho l_t + (\rho-1)\left(1-\alpha(1-\theta)(1-l_t)\right)} > 0$ and $\Psi(l_t) = -\frac{\eta\rho l_t}{1-\alpha(1-\theta)(1-l_t)} > 0$.

We summarize the equilibrium conditions as follows:

Definition *An equilibrium in this economy is given by the time paths of consumption, and aggregate output,* $[C_t, Y_t]_{t=0}^{\infty}$ *that satisfies (4.18b), and (4.11a), time paths of R&D expenditure, state of the art technology, stock of physical capital and net present value of the assets,* $[N_t, A_t, K_t, V_t]_{t=0}^{\infty}$ *given by (4.15b), (4.4), (4.7b) and (4.16), time paths of interest rate, and wage rate,* $[r_t, w_t]_{t=0}^{\infty}$ *consistent with (10b) and (10a) and time paths of labor supply, migration rate, social capital, and the strength of institutions* $[l_t, m_t, s_t, \phi_t]_{t=0}^{\infty}$ *given by (4.18a), (4.12c), (4.8), and (4.2).*

We define a balanced growth path as an equilibrium path in which all variables grow at a constant rate except for labor allocation, interest rate, migration rate, social capital and the strength of institutions, which are constant. Following our definition of balanced growth path, it is convenient to write the system in terms of stationary productivity adjusted variables. It is straightforward to express the dynamics of the decentralized economy as

$$\dot{k_t} = y - c - n - g - \lambda \, n \ln\gamma \;\; k \tag{4.19a}$$

$$\dot{s_t} = (1 - l_t) - m_t s_t \tag{4.19b}$$

$$\dot{c_t} = c \, \Omega(l_t) \left[r_t - \beta + (\rho - 1)\lambda \, n_t \ln\gamma + \Psi(l_t) \, \alpha\theta \frac{\dot{k}_t}{k_t} \right] \tag{4.19c}$$

along with labor market clearing conditions (4.10a) and (4.18a), research-arbitrage condition (4.15b), labor migration rate (4.12c) and market interest rate (10b). Imposing the steady-state conditions $\dot{k} = \dot{s} = \dot{c} = 0$, we can solve for the steady-state values of productivity-adjusted variables, level of physical capital ($\tilde{k}$), consumption ($\tilde{c}$), R&D investment ($\tilde{n}$), and wage rate ($\tilde{w}$), and the other variables, interest rate ($\tilde{r}$), labor ($\tilde{l}$), migration rate ($\tilde{m}$), social capital ($\tilde{s}$), and the strength of institutions ($\tilde{\phi}$). Finally, productivity-adjusted output ($\tilde{y}$), and value of assets ($\tilde{v}$) can be found by using (4.11a), and (4.16) respectively.

Linearizing equations (4.19a) - (4.19c) around the steady-state yields an approximation to the underlying dynamic system. This system forms the basis for our dynamic simulations. For all plausible parameter values, the system has one positive (unstable) and two negative (stable) eigenvalues, leading us to conclude that it is saddle point stable.

4.3 Numerical Results

Due to the complexity of the model, we calibrate it in order to obtain further insight. The baseline parameter values are given as follows: $\alpha = 0.9$; $\theta = 0.3$; $\beta = 0.02$; $\gamma = 2$; $\rho = -1.5$; $\eta = 0.1$; $\sigma = 0.5$; $\psi_s = 1, \psi_g = 1,2$. Our choice of the preference parameters, α, β and θ are standard. The parameter η describes the degree of substitution between socialization/leisure and consumption. We chose η as 0.1 in order to ensure that people socialize 10-20% of the total available time out of working and socializing, however, the results are qualitatively similar for other values of η. This is in contrast with the previous literature where the estimated work time is approximately 1/3 of the total available time. The reason for this difference is that we are not considering any other leisure activities and therefore our total time is approximately 10 hours a day, not 24 hours. The choice of γ, the size of innovation, and λ, innovation probability parameter, are such that the growth rate is approximately 2% in the baseline model. However, we can easily change these parameters to reflect varying growth experience of different countries. In this regard, it can be argued that the countries experiencing higher growth are able to either innovate more frequently or acquire the necessary resources (for example, foreign investment) in order to sustain higher growth. Once again, the qualitative results of the model are unchanged for other reasonable parameter values as well. ψ_s and ψ_g capture the effectiveness of social capital and formal institutions respectively in the production process. We have considered different values of ψ_g $(= 1,2)$ which may reflect varying impact of formal institutions in different countries. Although some of the parameters are difficult to pin down, the calibration exercise still provides useful insights into the dynamics of social capital and economic growth.

In the baseline model, people consume 85 percent of their income, spend 12 percent of the total available time socializing and 13 percent of them switch jobs at any point of time. The market interest rate is 6.7 percent, the expenditure on research activities are 7.7 percent of total output and the rate of growth is given by 1.8 percent. Since g is equal to zero, the strength of institutions ($\phi = 0.9$) are determined solely by the amount of social capital.

The long-run impact of increase in the rate of innovation (increase in λ from 0.3 to 0.4) and the increase in the expenditure on formal institutions, $g = 0.01$, ($g = 0$ in the baseline model) are reported in Table 4.1A while the short-run effects are reported in Table 4.1B. Transitional paths of an increase in innovation rate are shown in Figure 4.1 while that of an improvement in formal institutions are shown in Figure 4.2. In addition, the final columns in Table 4.1A and 4.1B summarize the effects on long-run welfare, [ΔW], and short-run welfare, [ΔW(0)] , both measured by the optimized utility of the representative agent where c and l are evaluated along the equilibrium path. These welfare changes are measures of equivalent variation, calculated as the percentage change in the initial stock of physical capital necessary to maintain the level of welfare unchanged following the particular shock

4.3.1 Increase in Innovation Parameter (λ)

We now introduce a permanent increase in the innovation parameter, λ, from 0.3 to 0.4. ***Short-Run (Table 4.1B):*** On impact, with an increase in the rate of innovation, productivity-adjusted investment into the R&D sector rises from 0.090 to 0.102 as this sector becomes more productive. In addition, productivity adjusted consumption also rises (from 0.982 to 1.023) because of an increase in the private financial wealth. Consequently, investment into physical capital falls. Increase in consumption induces people to work less (labor hour falls from 0.8815 to 0.8769) leading to an increase in the productivity adjusted wage rate (from 0.828 to 0.832). With physical and social capital being sluggish variables, decline in labor hour reduces the marginal productivity of physical capital and thereby reduces the market rate of interest from 6.65 to 6.37 percent. Labor migration rate and the growth rate of economy increases, first with an increase in λ and then with an increase in n.

Dynamics (Figure 4.1): Decline in productivity-adjusted output coupled with the increase in both consumption and R&D investment at time zero implies that $\dot{k}_t$ is negative (Eq. 4.19a). Productivity adjusted stock of physical capital, therefore, declines over the transition period. Also, a decline in the market interest rate, an increase in R&D investment together with a decline in investment in physical capital implies that $\dot{c}_t$ is negative (Eq. 4.19c) and therefore, productivity-adjusted consumption declines during the transition period. Subsequently, labor continues to rise after its initial fall and wage continues to fall after its initial rise. Although, on impact, people socialize more but as the increase in labor migration dominates, $\dot{s}_t$ is negative leading to a decline in social capital during transition. Overtime, as labor hour increases, that is, as the time allocated to socialization falls and labor migration remains above the new steady state, social capital continues to fall. Although social capital declines during the transition which reduces the marginal productivity of physical capital, the increase in labor hour together with the decline in productivity-adjusted physical capital raises it. Overall, the second effect dominates and therefore market interest rate increases during the transition. As the cost of borrowing rises, productivity adjusted investment in the R&D sector falls overtime which, in turn, imply that labor migration rate and the growth rate of the economy declines over the transition period. This decline in social capital which is a result of higher economic growth in the economy affects the performance of the economy adversely. In the long-run, it reduces wage, productivity-adjusted output, stock of physical capital and investment into R&D sector and thereby reducing the extent to which the economy would have growth, had the stock of social capital not declined (see Table 4.1A row 3 and 4).

Long-run (Table 4.1A): Overall, even though productivity adjusted R&D investment and physical capital are lower in the new steady state, as both the variable are rising at a faster rate, the proportion of income devoted to both R&D investment and physical capital rises. It implies that not only the productivity adjusted consumption is lower but also consumption to output ratio falls. Consequently labor rises and productivity adjusted wage falls. An increase in labor hour and a fall in productivity adjusted physical capital imply that marginal physical product of capital rises. The market rate of interest, therefore, is also higher in the new steady state. Even though n has fallen, but the initial increase in λ results in higher rate of innovation, λn leading to higher rate of migration and the rate of economic growth. Long-run welfare rises by 7.55 percent.

4.3.2 Improvement in Formal Institutions (Increase in g)

We next turn our attention to the impact on the economy when formal institutions are improved, that is, g rises from 0 to 0.01 when the effectiveness of the formal institution is twice as that of social capital ($\phi_g = 2$). We then analyze the situation where formal institutions are less effective ($\phi_g = 1$).

Short-run (Table 4.1B)**:** On impact, since the social capital is sluggish to adjust, improvement in formal institutions increases the strength of institutions (from 0.896 to 1.315) in the economy. Since the marginal benefit of improving the formal institutions are greater than marginal cost, net private wealth rises leading to an instantaneous upward jump in the productivity-adjusted consumption (from 0.98 to 1.005).[47] Although this increase in consumption tends to reduce the supply of labor, better institutional environment raises its demand. Overall, the demand side dominates, leading to an instantaneous rise in labor hour (from 0.8815 to 0.8831) and productivity adjusted wage rate (0.828 to 0.86). Increase in labor hour together with improvement in formal institutions increases productivity-adjusted output (from 1.158 to 1.205). Physical and social capital being fixed at time zero, increase in labor hour and the strength of formal institutions increase the demand for funds into R&D sector which raises the productivity-adjusted investment (from 0.090 to 0.093) in research activities. Improvement in institutions and the increase in labor hour raise the marginal productivity of physical capital. The market interest rate, therefore, rises from 6.65 to 6.92 percent at t=0. Increase in n raises the labor migration rate (from 14.2 to 14.7 percent) and the growth rate (from 1.16 to 1.96 percent) of the economy. The percentage improvement in the short-run welfare is 2.24.

Dynamics (Figure 4.2): At time t=0, since output jumps above the new steady state, while consumption and R&D investment remain below their respective new equilibrium values, investment in physical capital increases implying that $\dot{k} > 0$ (Eq. 4.19a). Productivity-adjusted physical capital, therefore, rises during the transition. Also, since marginal physical productivity of capital rises above its steady state equilibrium, the rate of return on consumption must also rise implying that productivity adjusted consumption must rise during the transition period which is accompanied by the fall in labor supply. However, the reduction in socialization time coupled with the increase in labor migration rate imply that $\dot{s}_t < 0$. That is, social capital declines over the transition period reducing the strength of institutions which, in turn, reduces the demand for labor leading to fall in both labor hour and the wage rate. This decline in the strength of

[47] If, however, the marginal cost is higher than the marginal benefit, the overall welfare would decline and the economy would do better without any improvement in formal institutions.

institutions together with the rise in physical capital and the fall in labor hour reduces the marginal productivity of physical capital and therefore lowers the market rate of interest during the transition period. Lower rate of interest, in turn, increases the investment made in R&D sector as it reduces the cost of borrowing. Finally, with increasing n, both labor migration rate and the rate of growth of economy rises during the transition period.

Long-run (Table 4.1A): Overall, since the total benefit of improving formal institutions exceeds its cost, overall output rises (from 1.158 to 1.20). Increase in net wealth raises productivity adjusted consumption from 0.982 to 1.008). Better formal institutions and therefore overall better institutions raise the marginal productivity of both capital and labor leading to increase in the market interest rate (from 6.65 to 6.85 percent) and the wage rate (from 0.828 to 0.859). Also, both the stock of productivity adjusted physical capital (from 4.70 to 4.74) and labor hour (from 0.8815 to 0.8826) rises. Higher profit raises the demand for funds in R&D sector leading to increase in productivity adjusted investment (from 0.090 to 0.093) which, in turn, raises labor migration rate (14.22 to 14.76 percent) and the economic growth rate (from 1.86 to 1.94 percent). However, social capital declines (from 0.896 to 0.853) as the time allocated to socialization falls and migration rate rises which drags the growth rate down during the transition period. The long-run welfare rises by 4.12 percent points. Less effective formal institutions have smaller impact on the economy. That is, the increase in the stock of productivity adjusted physical capital, consumption, R&D investment, wage rate, labor, market interest rate, the labor migration and the growth rate and the decline in social capital is less (see the second-last row of Table 4.1A and second row of Table 4.1B).

4.4 Conclusions

In this chapter, we have introduced social capital and formal institutions as productive units. We, then, analyzed the impact of increase in the rate on innovation and the improvement in formal institutions in the economy. We find that while both shocks increase the rate at which the economy grows and decrease the stock of social capital, productivity adjusted physical capital and R&D investment declines when innovation rate goes up while they increase when the formal institutions are improved. They both result in long-run welfare gain. More effective formal institutions result in even higher economic growth and long-run welfare gain.

Table 4.1: Comparative Statics

Baseline Parameters: $\alpha = 0.9$; $\theta = 0.3$; $\beta = 0.02$; $\gamma = 2$; $\rho = -1.5$; $\eta = 0.1$; $\sigma = 0.5$; $\psi_s = 1, \psi_g = 1,2$

Table 4.1A: Long-Run Effects

	k	***s***	***c***	***l***	***w***	***r* %**	***n***	***y***	***m* %**	**ϕ**	***G* %**	**ΔW %**
$\lambda = 0.3, g = 0$ Benchmark Model	4.702	0.896	0.982	0.8815	0.828	6.65	0.090	1.158	14.22	0.896	1.861	-
Increase in λ (ϕ endogenous)												
$\lambda = 0.4, g = 0$	4.678	0.720	0.893	0.8822	0.758	7.79	0.084	1.062	16.35	0.720	2.317	7.55
Improvement in Formal Institutions (Exogenous)												
$\lambda = 0.3, g = 0.01, \psi_g = 1$	4.723	0.870	0.990	0.8825	0.843	6.75	0.091	1.181	14.50	1.067	1.902	1.59
$\lambda = 0.3, g = 0.01, \psi_g = 2$	4.742	0.853	1.008	0.8826	0.859	6.85	0.093	1.203	14.76	1.262	1.940	4.12

Table 4.1B: Short-Run Effects

	c(0)	***l(0)***	***w(0)***	***r(0)* %**	***n(0)***	***y(0)***	***m(0)* %**	**$\phi(0)$**	***G (0)* %**	***W(0)* %**
$\lambda = 0.4, g = 0$	1.023	0.8769	0.832	6.37	0.102	1.155	19.74	0.896	2.819	4.68
$\lambda = 0.3, g = 0.01, \psi_g = 1$	0.989	0.8828	0.845	6.80	0.091	1.183	14.50	1.096	1.901	0.63
$\lambda = 0.3, g = 0.01, \psi_g = 2$	1.005	0.8831	0.860	6.92	0.093	1.205	14.74	1.315	1.937	2.24

Figure 4.1: Dynamic Responses to Innovation Shock (λ)

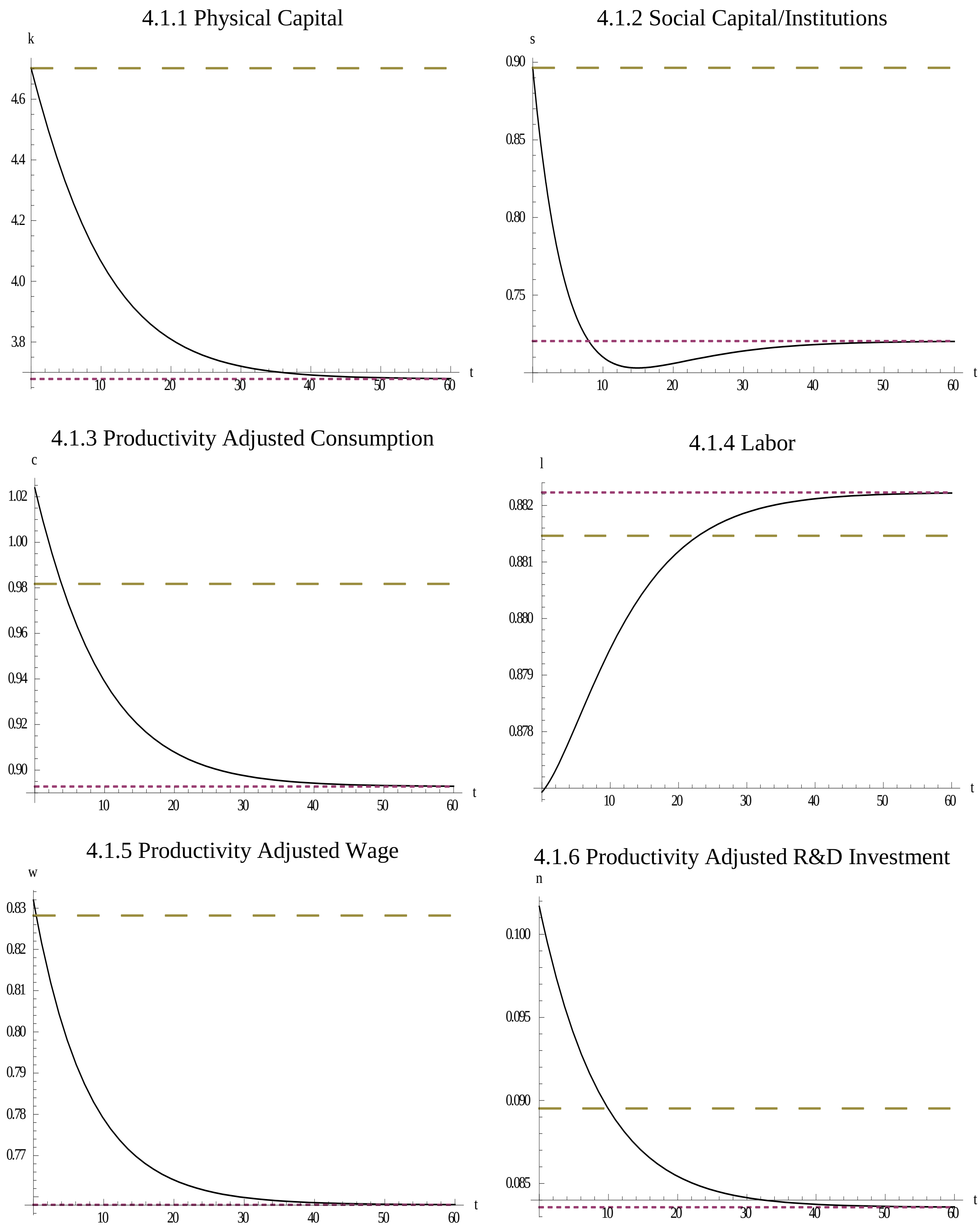


Figure 4.1 Continued

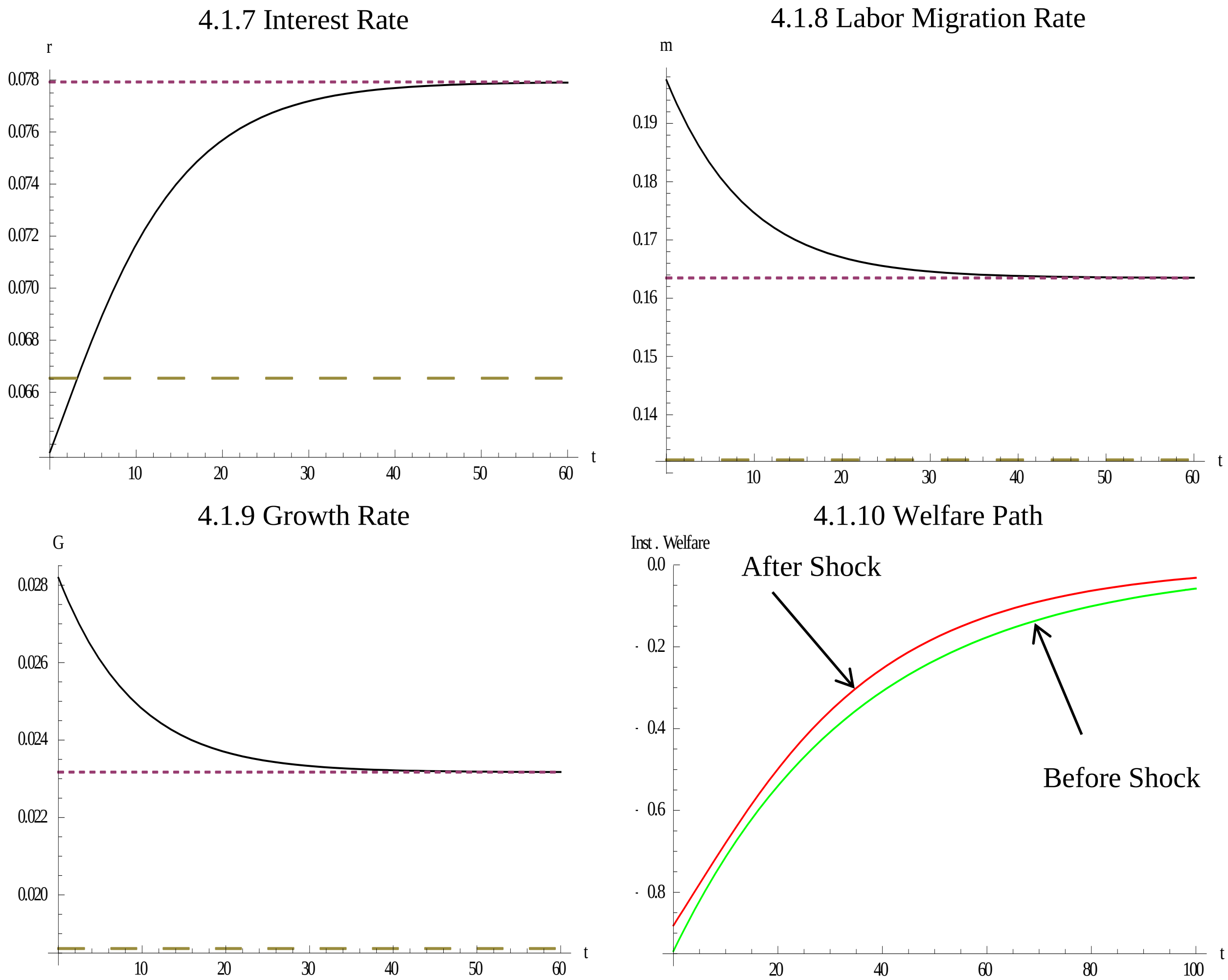
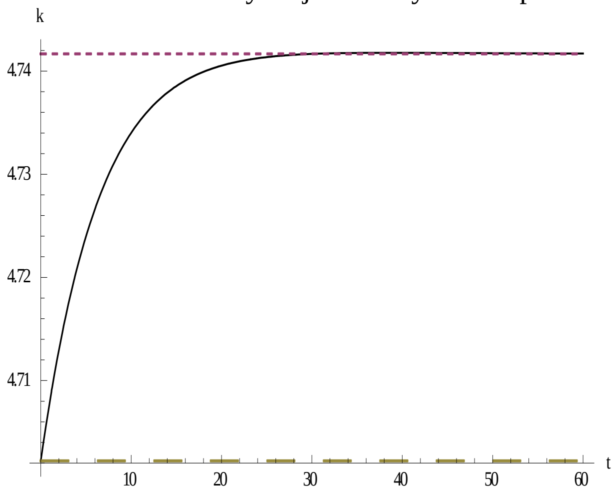


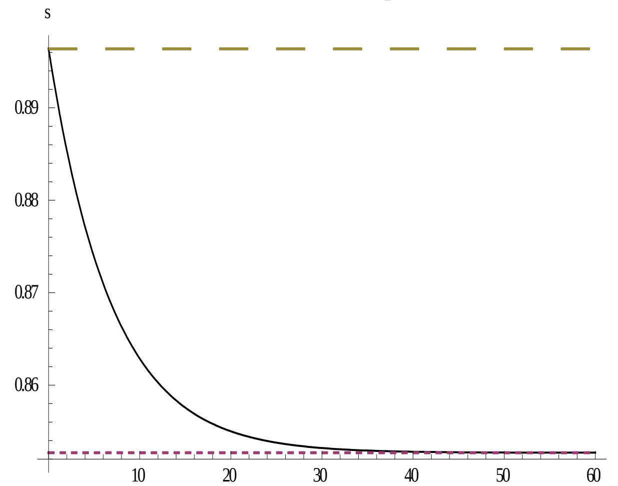
Figure 4.2: Dynamic Responses to Improvement in formal Institutions (g)

$$\psi_g = 2$$

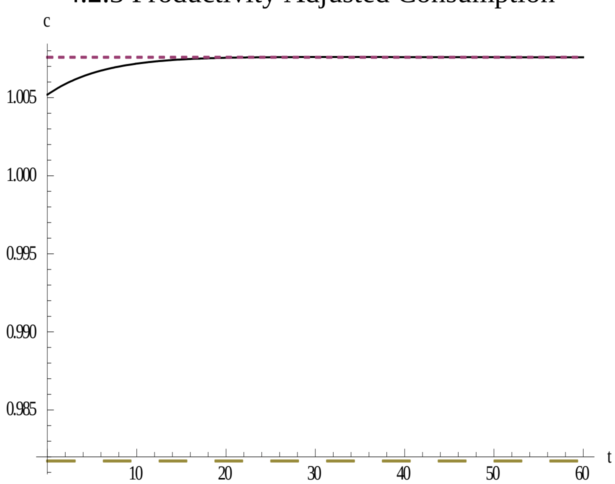
4.2.1 Productivity Adjusted Physical Capital



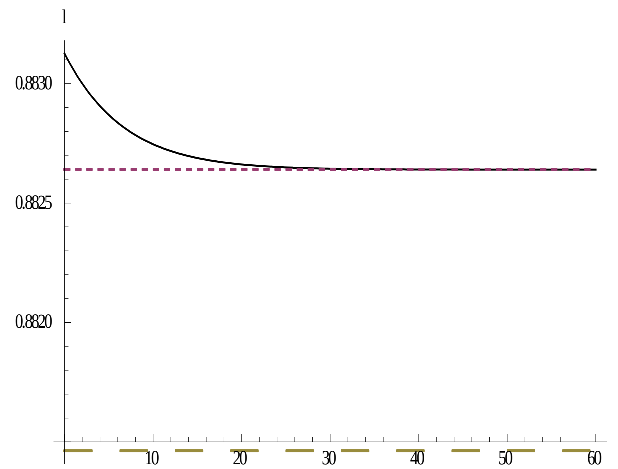
4.2.2 Social Capital



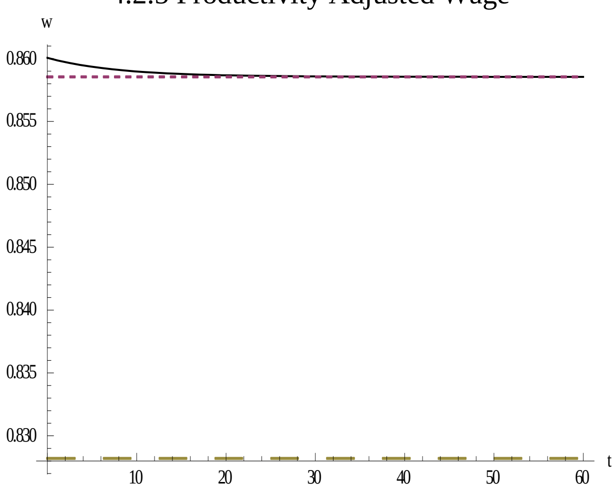
4.2.3 Productivity Adjusted Consumption



4.2.4 Labor



4.2.5 Productivity Adjusted Wage



4.2.6 Productivity Adjusted R&D Investment

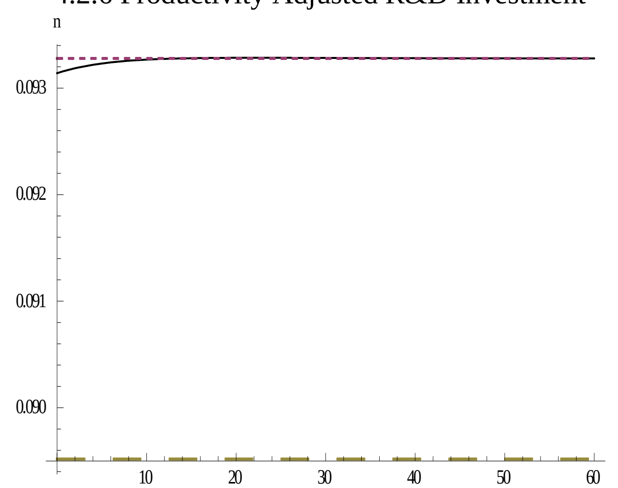
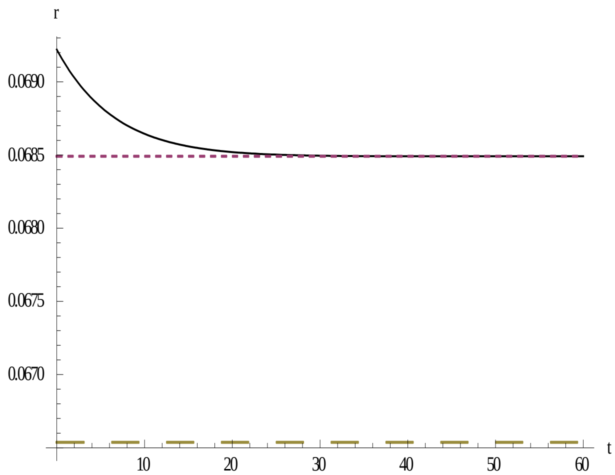
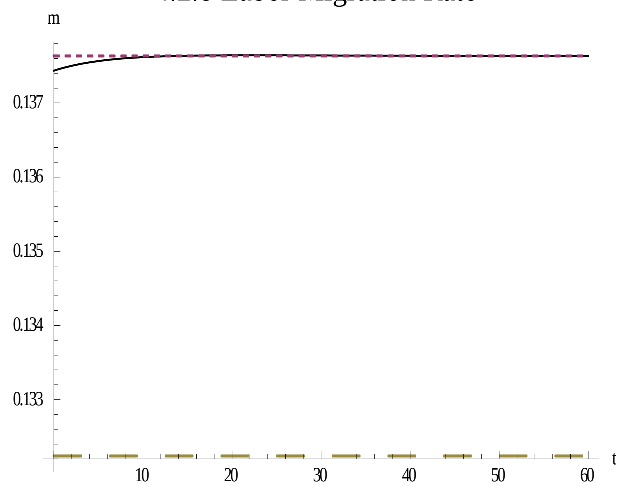


Figure 4.2 Continued

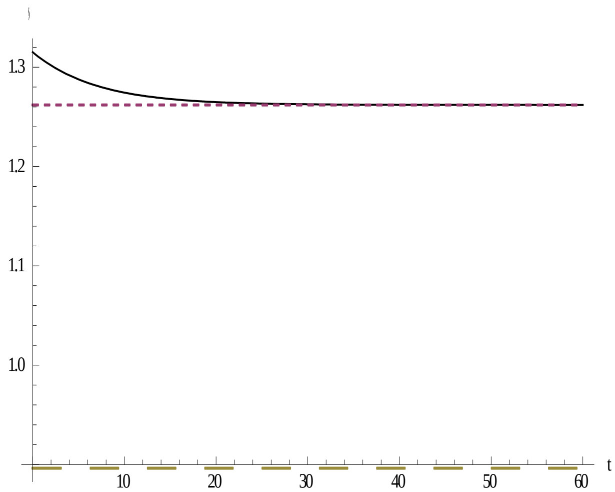
4.2.7 Interest Rate



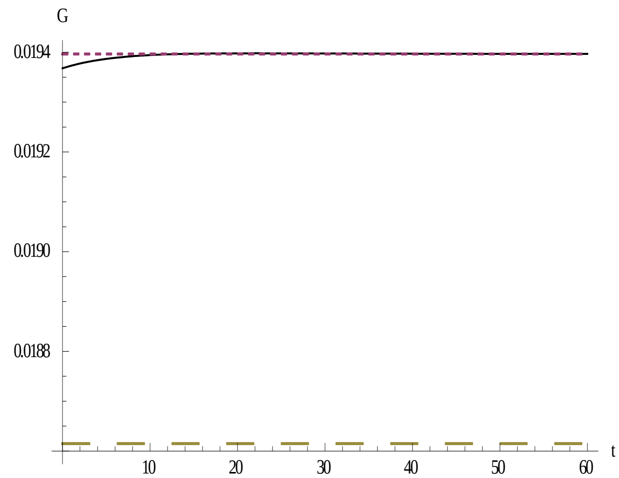
4.2.8 Labor Migration Rate



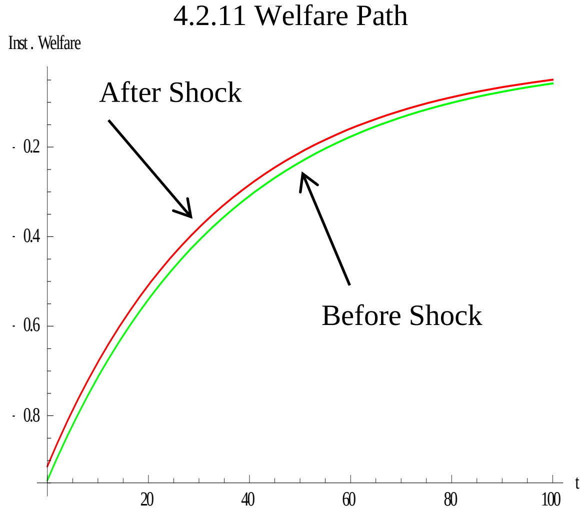
4.2.9 Institutions



4.2.10 Growth Rate



4.2.11 Welfare Path



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Appendix

Chapter 2

Appendix A.2: ***Resource constraint of the Social Planner***

Since the social planner takes into account only the incremental profit when considering the value of an innovation, the profit generated by any innovation continues forever. Therefore, value of all the assets held by consumers is the present discounted value of all future profit at the current level of innovation.

That is, $V = \frac{\Pi}{r} \quad \Rightarrow rV = \Pi$ (A1)

Resource constraint is given by:

$$Y = C + N + G - (1-\phi)rV \quad \text{(A2)}$$

Using $rV = \Pi = (1-\alpha)Y$, we get

$$N_t = \big(\alpha + \phi\,(1-\alpha)\big)Y_t - C_t - G_t \quad \text{(A3)}$$

Appendix B.2: ***Dynamic Equations for Social Planner***

$$(u_{Cl}^2 + \Gamma_1\,\mu_2 m_{NN} s + \Gamma_2\,\mu_2 m_{NN} N_l s - u_{CC}\,\Gamma_3)\dot{C} =$$

$$-\Gamma_1\,\lambda \ln\gamma\;\dot{\mu_1} + (\Gamma_1 m_N s + \Gamma_6)\dot{\mu_1} + (\Gamma_1\Gamma_4\mu_2 - \Gamma_6 u_C N_{ls})\dot{s} + (\Gamma_1\Gamma_5\mu_2 s - \Gamma_6 u_C N_{lA})\dot{A} \quad \text{(B1)}$$

and

$$(u_{Cl}^2 + \Gamma_1\,\mu_2 m_{NN} s + \Gamma_2\,\mu_2 m_{NN} N_l s - u_{CC}\,\Gamma_3)\dot{l} =$$

$$\Gamma_2\,\lambda \ln\gamma\;\dot{\mu_1} - (\Gamma_2 m_N s + \Gamma_7)\dot{\mu_2} - (\Gamma_2\Gamma_4\mu_2 s - \Gamma_7 u_C N_{ls})\dot{s} - (\Gamma_2\Gamma_5\mu_2 s - \Gamma_7 u_C N_{lA})\dot{A} \quad \text{(B2)}$$

where,

$\Gamma_1 = u_{ll} + u_C N_{ll} + u_{Cl} N_l$

$\Gamma_2 = u_{Cl} + u_{CC} N_l$

$\Gamma_3 = u_{ll} + u_C N_{ll}$

$\Gamma_4 = m_N + m_{NN} N_s s$

$\Gamma_5 = m_{NN} N_A + M_{NA}$

$\Gamma_6 = U_{Cl} + \mu_2 m_{NN} N_l s$

$\Gamma_7 = u_{CC} - \mu_2 m_{NN} s$

$$U_{CC} = \frac{1}{A}\frac{(\rho-1)}{c} u_C, \quad U_{ll} = \frac{\eta(\eta\rho-1)c\,A}{(1-l)^2} u_C, \qquad U_{Cl} = -\frac{\eta\rho}{1-l} u_C,$$

$$N_A = y - \phi_g g\,(1-\alpha)y,\; N_l = \frac{\alpha Y}{l}, N_s = \phi_s(1-\alpha)y\,A, N_{lA} = \frac{\alpha}{l} y, N_{ll} = \frac{\alpha(\alpha-1)y}{l^2}\;A$$

$$m_N = \frac{1}{1-\alpha}\frac{\lambda \ln\gamma}{A}(1-2\lambda\,n), m_A = -\frac{1}{1-\alpha}\frac{\lambda\ln\gamma}{A} n(1-2\lambda n)$$

$$m_{NN} = -\frac{1}{1-\alpha}\frac{\lambda\ln\gamma}{A}\;\frac{2\lambda}{A}, \qquad m_{NA} = -\frac{1}{1-\alpha}\frac{\lambda\ln\gamma}{A}\frac{1}{A}(1-4\lambda n)$$

$$\mu_1 = \frac{1}{\lambda\;\ln\gamma}\left(1-\left(\frac{\eta\;c\;A}{1-l} - N_l\right)m_N s\right)u_c \quad , \qquad \mu_2 = -\left(\frac{\eta\;c\;A}{1-l} - N_l\right)u_C$$

$$\dot{\mu_1} = \left(\beta\; - \left(\lambda\ln\gamma - \frac{\mu_2}{\mu_1} m_N s\right)N_A - \frac{\mu_2}{\mu_1}\;m_A s\right)\mu_1 \quad , \quad \dot{\mu_2} = \left(\beta - \left(\frac{\mu_1}{\mu_2}\lambda\ln\gamma - m_N s\right)N_s - m\right)\;\mu_2$$

$$\dot{s} = (1-l) - m\;s \quad , \qquad \dot{A} = \lambda\;n\ln\gamma\;\;A$$

VITA

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