Sectoral Expansion, Allocation of Talent, and Financial Development*

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Abstract
This paper presents a theory in which economic development manifests itself primarily as a process of sectoral differentiation. As the variety of sectors expands, the allocation of heterogeneously talented individuals improves. We claim that, besides increasing the average productivity of the economy, this process also reduces informational frictions that affect the performance of financial markets. In particular, sectoral expansion alleviates adverse selection problems linked to the allocation of talent, which would prevent the efficient operation of financial markets. Over the path of development, an economy typically exhibits a continuous increase in the variety of productive activities available to its individuals, and this leads to a reduction in agency-costs faced by financial institutions. However, the paper shows that a peculiar poverty-trap may also arise. This undesirable situation displays a very rudimentary productive structure, where agents find it very difficult to exercise their skills, and financial markets collapse as a consequence of adverse selection problems.

Key Words: Sectoral Diversification, Talent Allocation, Adverse Selection, Horizontal Innovation.

JEL Codes: O10, O16, O31, D82

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1 Introduction

Over the course of development, the number of productive activities in the economy tends to increase in conjunction with the aggregate stock of capital and output. This observation implies that economic development partly manifests itself as a process of sectoral diversification. Such dynamic pattern had originally been suggested by Adam Smith (1776) in his discussion on the division of labour and the size of the market (The Wealth of Nations, chapter 3) and has been robustly documented by Imbs and Wacziarg (2003). I propose a theory in which this process of sectoral diversification helps to reduce agency-costs affecting the operation of financial markets, and thereby fosters financial development.

The paper studies the evolution of an economy populated by heterogeneous individuals in terms of entrepreneurial skills. More precisely, individuals are characterised by distinct comparative advantages concerning different entrepreneurial activities. Entrepreneurial skills are, however, private information. This feature gives rise to an adverse selection problem linked to the allocation of talent and generates the main friction contaminating the operation of the economy. The fundamental proposition put forward by paper is that the more diversified an economy is, the less resources it will need to spend on dealing with private information and adverse selection.

A critical premise in this paper is that adverse selection stems from an underlying problem of sectors scarcity, because sectors scarcity hinders the efficient allocation of (unobservable) talent. In particular, the paper claims that some agents might be intrinsically gifted to specialise in sectors that, for some reason, are not feasible or available at the moment in the economy. These agents have then no other choice but specialising in activities for which they might not be exceptionally talented. Asymmetric information concerning skills, in turn, spreads the consequences of talent misallocation all over the economy, since it prevents the efficient (ex-ante) screening of heterogeneous agents. As a result, those agents who are not able to exploit their comparative advantages inflict a negative externality (through the adverse selection problem) on those who, in principle, would be able to fully exercise their skills.

In this model, adverse selection affects the allocation of productive capital because it prevents the efficient functioning of credit markets. Prospective entrepreneurs need to obtain credit in order to undertake their investment projects, but adverse selection impedes the provision of first-best credit contracts. As a consequence of this, entrepreneurial investment falls short of meeting its first-best level, and individuals’ comparative advantages are not fully exploited.

The economy modelled in this paper is constituted by a large number of potential sectors. Each sector represents a different industry or productive activity, and requires the application of some specific type of entrepreneurial skill. At a particular period of time, only a fraction of the potential sectors are available to agents (i.e. only a fraction of sectors actually exist). The appearance of new sectors is the result of successful innovations; this reflects the idea that carrying out new industrial activities or producing new types of goods requires first an increase in the stock of knowledge in the society. The key point in this
paper lies on the hypothesis that sectors variety facilitates the allocation of individuals’ talent. This fact reduces the severity of the adverse selection problem in the credit market, enabling the provision of more satisfactory credit contracts which fosters entrepreneurial investment. The impact of sectors variety on the credit market efficiency, in turn, gives rise to a novel positive feedback between financial development and innovation activities. Entrepreneurs are the agents who put innovations into practise in the economy. This means that the level of entrepreneurial investment is what ultimately determines the size of the market for innovations. As a result, better operation of financial markets spurs the incentives to invest in R&D (by fostering entrepreneurial investment) and, at the same time, higher investment in R&D contributes to financial development (by expanding the number of sectors available in the economy).

From a dynamic perspective, the development path followed by a successful economy in this paper is characterised by a continuous process of capital differentiation (sectoral diversification). In addition to that, the allocation of talent improves and financial institutions become increasingly efficient, as adverse selection problems tend to vanish away concomitantly with sectoral diversification. Nevertheless, this model may also generate a peculiar type of poverty-trap. In this undesirable situation, economies exhibit a rudimentary productive structure, with few active industries, poor allocation of individuals’ talent, and highly inefficient financial institutions. In that sense, this poverty-trap is the result of general organisational failure in the economy, leading to the collapse of several markets.

Historically, sectoral differentiation has been considered to increase productivity by either permitting the exploitation of economies of scale (e.g. Smith (1776), Young (1928), Yang and Borland (1991)) or enabling heterogeneous agents to obtain a better match (e.g. Rosen (1978), Miller (1984), Kim (1989)). My theory claims that sectoral expansion brings about an additional positive effect on output and growth, because a larger variety of activities helps to lessen adverse selection problems associated to the allocation of skills.

The possibility that credit markets efficiency might be influenced by agents’ payoffs in other markets of the economy has already been suggested by De Meza and Webb (2000). Yet, in their model these payoffs are exogenously set. Ghatak, Morelli and Sjöström (2002) follow this idea, but they explicitly endogenise agents’ payoffs, exploiting an interesting "two-way" interaction between the credit market and the labour market. In their model, when the economy is able to provide high wages, low-quality entrepreneurs find themselves better-off selling their work-force in the labour market. As a result, high wages help to "clean" the pool of credit applicants, reducing informational frictions and enabling better operation of the credit market.¹ My paper studies a different mechanism as the determinant of an efficient allocation of talent. I let innovation and the creation of new productive activities solve the adverse selection problem, by permitting individuals to specialise in the task they are best at. In that sense, one of the main insights of this model is that it concedes the innovation process a new role, very different from the one

¹Grüner (2003) also provides a model where entrepreneurial skills are more efficiently allocated in richer economies. However, in his model there is no interaction between different markets, and his results are purely driven by a "wealth-effect" that arises due to limited liability.
traditionally stressed in the growth literature. Innovation is not only desirable because it augments the productivity of inputs. It is also desirable because it helps to mitigate informational problems interfering with the operation of financial markets. From that perspective, this paper naturally contributes to the literature on horizontal innovation and growth initiated by Romer (1990), proposing an additional channel whereby variety expansion promotes development.\(^2\)

Acemoglu and Zilibotti (1999) also build a theory in which agents’ intrinsic performance improves during the process of development. However, they focus on how a society endeavours to provide correct incentives to agents, and why they become more effective as an economy grows. They do not study how the allocation of heterogeneous skills evolves during development. Furthermore, they do not incorporate innovation decisions into their theory, which precludes the variety of activities from expanding over time. In another paper, Acemoglu and Zilibotti (1997) construct a model where the degree of market incompleteness tends to disappear with capital accumulation, and sectoral differentiation leads to financial development (in particular, it improves risk-sharing). Nonetheless, neither this model deals with the issue of skills allocation and adverse selection. Financial markets are enhanced with sectoral expansion, simply because this allows better pooling of \textit{sector-specific shocks}. In my model, instead, financial development is the consequence of the alleviation of informational failures due to improvements in the skills-allocation technology.

The present paper is also related to the literature about financial markets imperfections and poverty: Galor and Zeira (1993), Banerjee and Newman (1993, 1994), Piketty (1997), Aghion and Bolton (1997), and Lloyds-Ellis and Bernhardt (2000). These papers stress the importance of the wealth distribution on the dynamic behaviour of the economy when agency-costs lead to credit rationing. As a general result, their models commonly lead to poverty-traps when the number of poor agents is large enough. My theory contributes to this literature by different channels. It first provides a fully micro-founded explanation of why agency-costs may arise. Secondly, it is able to produce dynamics where these agency-costs go down as an economy develops. As a result, \textit{rationing} is not just solved because people become rich enough (so that they can afford better credit or insurance contracts), but mainly because financial markets’ operation itself turns more efficient.

The rest of paper is organised as follows. Section 1.1 discusses some evidence regarding the main empirical observations that motivate this paper; this section could be perfectly skipped if the reader wants to proceed immediately to the model. Section 2 describes the basic set-up of the model. Section 3 studies the static equilibrium of the economy, in particular it analyses the entrepreneurs’ optimal portfolio allocation in the presence of adverse selection. Section 4 introduces the innovation activities into the model, which endogenises the variety of sectors available in the economy. Section 5 proceeds to the dynamic study of this economy. Section 6 discusses some extensions to the basic model. Section 7 concludes. Omitted proofs are provided in the Appendix A.

\(^2\)For an exhaustive survey on horizontal innovation and growth theories, see Gancia and Zilibotti (2005).
1.1 Empirical Motivation: Sectoral Diversification and Development.

Sectoral diversification is a feature recurrently observed over the process of development. Allyn Young (1928) writes "industrial differentiation has been and remains the type of change characteristically associated with the growth of production" (p. 537). Landes (1969) claims that the most evident effects brought about by the Industrial Revolution were both the gains in productivity and the increase in the variety of products and occupations (p. 5). In a passage of his book he writes "the whole tendency of industrialization and urbanization was to specialize labour ever farther and break down the versatility of the household", proceeding to enumerate a long list of new occupations (ranging from bakers, butchers, manufacturers of candles, soap and polish, to others like carpenters, masons, plumbers, plasterers, and tilers) which started to appear and expand with the Industrial Revolution (p. 119). Kubo et al (1986) show evidence that the share of intermediate goods substantially increased along with output for a sample of nine semi-industrialised countries in the post-war period. This suggests that industry differentiation took place in conjunction with output growth in those economies.

Econometric evidence also gives support to the premise that sectoral diversification is experienced over the path of development. For a panel of 67 countries, Imbs and Wacziarg (2003) show that sectoral concentration (the opposite to sectoral diversification) drastically falls at early stages of development, following a "U-shape" relation with respect to income per-head. They conclude that, along development, economies initially experience a long process of sectoral diversification which eventually reaches a maximum beyond where the process begins to revert. Given the implications of my paper, two observations need to be stressed here: (i) the "turning-point" in the diversification process tends to occur at relatively high income per-capita levels (the authors argue that this point is located roughly at the income per-head reached by Ireland in 1992), (ii) the eventual reconcentration process does only partly offset the effect of the initial diversification phase - see figures 1, 2 and 3 in their paper, p. 69.

Figure 1.A provides an overview of the association between sectoral diversification and income per-head. Sectoral concentration is measured by the Imbs and Wacziarg's Gini coefficients for employment shares based on the UNIDO 3-digit dataset (a smaller Gini coefficient would thus reflect a more diversified economy in terms of manufacturing industries). Income per-head is measured by GDP per-capita in thousands of PPP 1985 constant US dollars. To allow for the possibility of a non-monotonic relation between

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3 Countries are: Norway, Israel, Taiwan, Korea, Japan, Yugoslavia, Turkey, Mexico, and Colombia.

4 Imbs and Wacziarg (2003) use a non-parametric technique called locally weighted scatterplot smoothing (lowess) to capture the association between sectoral concentration and income per-capita. They build five different concentration indices based on employment shares (Gini coefficient, Herfindahl index, log-variance of sector shares, coefficient of variation, and the max-min spread). These indices are constructed for three different datasets: 1-digit level (9 sectors) from the International Labor Office (ILO), 3-digit level (28 sectors) from the United Nations Industrial Development Organisation (UNIDO), and 2-digit level (20 sectors) from the OECD. For the UNIDO and OECD data, value-added per sector is also available and utilised. All their results are robust to the use of different indices and datasets.

5 The author is indebted to Jean Imbs for kindly providing him with this data.
sectoral concentration and GDP per-capita, I run fifth-order polynomial regression. The regression additionally controls for country fixed-effects. We can observe the pattern described in Imbs and Wacziarg (2003): sectoral concentration initially decreases with income per-capita, eventually reaching a turning-point beyond which the relation reverts. This paper will focus on the initial stages of development, where sectoral diversification and income per-head grow together. The eventual re-specialisation pattern may presumably be partly explained by the effect of international trade and increasing returns to scale (both static and dynamic); two phenomena which are completely neglected in our theory.

Figure 1.A: Sectoral Concentration and Income Per-Head

The Gini coefficient measures the degree of inequality (in terms of employment) across sectors. A drawback of this indicator is that the level of disaggregation in the datasets is completely arbitrary; in particular, some sectors are in general "less disaggregated" than others. This fact could arguably be artificially driving some results in Figure 1.A if development tends to be biased towards some specific sectors. In that regard, I construct here an additional indicator of the degree of sectoral diversification that intends to take this issue into account. This provides further robustness to Imbs and Wacziarg’s findings. I construct a new variable (number of active sectors) which aims at measuring the number of active sectors in specific country at a specific period of time (based again on the UNIDO 3-digit dataset). The UNIDO 3-digit dataset disaggregates the manufacturing industries into 28 different sectors. For each of the 28 sectors, I calculate its world-average sectoral share, as the average share of the sector over the whole panel. Then I calculate the specific

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6Country fixed-effects are very important at determining the productive structure of economies. Since in this paper we are following individual economies over their path of development, it is then strictly necessary to control for fixed-effects to obtain a consistent picture of this process.
share of each particular sector, in each particular country, at each particular year of the sample. Finally, I contrast this last number against the world-average sectoral share, and define sector $i$ in country $j$ at date $t$ as active if and only if the share of $\text{sector}_{i,j,t}$ is at least equal to 20% of the corresponding world-average sectoral share.\footnote{I have also undertaken the same procedure with the threshold level at 5%, 10% and 30%; all the results are qualitatively identical to those in \textbf{Figure 1.B} (and available from the author upon request).} \textbf{Figure 1.B} shows the results of a fifth-order polynomial regression (controlling for country-fixed effects) of the number of active sectors on income per-head. These results are qualitatively analogous to those in \textbf{Figure 1.A}, showing that the number of active sectors initially increases with income per-capita, eventually reaching a maximum point beyond which economies start a process of re-specialisation.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1b.png}
\caption{Sectors Variety and Income Per-Head}
\end{figure}

Another stylised fact that motivates this theory is the positive association between financial development and output growth. This observation is long established and very well documented; e.g. King and Levine (1993), Atje and Jovanovic (1993), Levine and Zervos (1998), and Benhabib and Spiegel (2000). My paper presents a theory in which the driving force igniting long-run growth lies on a positive feedback between sectoral differentiation and financial development. In that respect, both sectoral differentiation and financial development should be experienced over the path of development. \textbf{Table 1} presents some evidence of these two variables moving together for a broad panel of countries. Following Imbs and Wacziarg (2003), I measure the degree of sectoral concentration by means of the \textit{Gini coefficient} for employment shares across sectors based on the UNIDO 3-digit dataset. To quantify financial development, I take four different indicators traditionally used in the literature of financial development and growth: 1) the ratio of
stock market value traded to GDP (SMVT/GDP), 2) the ratio of stock market capitalisation to GDP (SMK/GDP), 3) the ratio of total liquid liabilities to GDP (LL/GDP) (4) the ratio of private credit by financial institutions to GDP (Credit/GDP).

In Table 1, financial development is regressed on sectoral concentration, controlling for country fixed-effects and including GDP per-capita as an additional regressor. Country fixed-effects are included because the intention of the paper is to follow individual economies over their own path of development. On the other hand, including GDP per-head controls for the fact that financial indicators and sectoral diversification might be moving together just as consequence of income shocks affecting both variables simultaneously. The equations estimated in Table 1 display thus the following structure: $FD_{i,t} = \alpha + \beta Y_{i,t} + \gamma G_{i,t} + \zeta_i + \nu_{i,t}$. Where $FD_{i,t}$ denotes the level of financial development of country $i$ in year $t$, $Y_{i,t}$ stands for income per-head of $i$ in $t$, $G_{i,t}$ is the sectoral-shares Gini of $i$ in $t$, $\zeta_i$ is a country fixed-effect, and $\nu_{i,t}$ is an idiosyncratic shock. The estimated $\gamma$ exhibits the expected sign and is also significant in columns (1), (2), and (3). According to those three regressions, sectoral diversification is positively and significantly associated with financial development within each country over the years of the sample, even after removing the possible effect of income shocks. When financial development is measured by private credit to GDP, the estimated $\gamma$ keeps the expected sign, although it does not reach significance at standard levels.

<table>
<thead>
<tr>
<th>TABLE 1: Sectoral Diversification and Financial Development</th>
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<tr>
<td><strong>Independent Variable</strong></td>
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<td><strong>Dependent Variable</strong></td>
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<td>SMVT/GDP</td>
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<td>Sectoral Concentration (Gini)</td>
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<td>Income per-head (PPP)</td>
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<td>R squared (within)</td>
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<td>Obs. / Countries</td>
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Note: $t$-statistic in parentheses. All regressions include intercept and country fixed-effects.

| Regressions are run on an unbalanced panel of countries during years 1975 - 92. |
| "Income per-head" is GDP per-head in PPP in 1,000 of 1985 US dollars from Summers and Heston (1991). |
| The Gini coefficients are based on the UNIDO 3-digit employment dataset. |
| * significant at 10% level, ** significant at 5% level, *** significant at 1% level. |

2 Environment

This paper considers a small economy enjoying full access to international credit markets. Life evolves over a continuous time infinite-horizon, comprising a infinite sequence of non-overlapping cohorts of individuals. Each cohort is alive for a length of time equal to 1 unit of time, and we index each cohort by their (simultaneous) instant of birth. As a result, 8

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8All data on financial indicators is taken from Beck et al (1999). See Appendix B for a detailed explanation of these indicators and some descriptive statistics.
we have cohorts $t = \{0, 1, ..., \infty\}$, where each cohort-$t$ is alive during the time interval $[t, t+1)$. The economy is populated by two different types of individuals:

1. **Entrepreneurs**: These agents are endowed with entrepreneurial skills. Entrepreneurs apply their skills to organise the final-goods production process. Final-goods satisfy consumption needs.

2. **Innovators**: They carry out R&D in order to produce ideas which could be applied to the production of final-goods. Successful innovations (resulting from new ideas) expand the number of sectors available in the economy (horizontal innovations).9

The economy is composed by a continuum of sectors indexed by the letter $i \in [0, 1]$. Each sector $i \in [0, 1]$ represents a particular industry in the economy (nevertheless, for analytical simplicity, I will assume that in each sector $i$ the same single final-good is actually produced). The set of sectors $[0, 1]$ is constant over time; however, not all sectors are necessarily active at any moment in time. In particular, I suppose the economy starts off in $t = 0$ suffering from some degree of sectors inactivity. More precisely, at $t = 0$ only a fraction $n_0 \in (0, 1)$ of all sectors are able to enjoy the activity of productive industries. At the same time, the remaining fraction $(1 - n_0)$ lacks of any active industry whatsoever. Hereafter, $A_t \subset [0, 1]$ will denote the set of sectors with active industries at time $t$.

A key assumption in this paper is that the availability of productive industries is the result of innovations (either during the past or in the present). Once the industrial activity that corresponds to sector $i$ is created by an innovation, it does never disappear (i.e. if sector $i \in A_t$, then sector $i \in A_{t+\delta} \forall \delta \geq 0$). Therefore, $A_{t+\delta} = A_t \cup I_{(t,t+\delta)}$, where $I_{(t,t+\delta)}$ denotes the set of innovations designed during the time interval $(t, t+\delta)$.10 To ease notation, henceforth I skip the use of time-subscripts when creating no confusion. Sectors belonging to $A$ will be referred to as active sectors (while sectors that do not pertain to $A$ will be called inactive sectors).

A sector $i \in A$ provides agents the chance to invest in an entrepreneurial project called Project-$i$. The return of Project-$i$ is random, subject to an idiosyncratic shock. Project-$i$’s return also depends on the application of some specific entrepreneurial skills, and on the amount of capital ($k$) invested in the project.11 A full description of the final-goods production function is provided in the following subsection (Eq. (1) and (2) ahead in the text).

Additionally, I suppose that all individuals have access to a "backyard" activity which requires no investment and yields net return equal to $v$ with certainty. For simplicity, and without any loss of generality, I set $v = 0$ (which implies that the activities participation constraint never binds).

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9To illustrate, take the Pharmaceutical Industry as an example. The innovator would be represented by a biochemist whose task consists in designing a formula to produce a new drug. On the other hand, the pharmaceutical company would represent the entrepreneur. This agent organises the production process of the drug and takes it to the market, turning the formula into a final-good.

10Since $I_{(t,t+\delta)}$ denotes only horizontal innovations, (by construction) $A_t \cap I_{(t,t+\delta)} = \emptyset$.

11In terms of this model, $k$ could be indifferently interpreted as aggregate investment in physical capital only, or as aggregate investment in both physical and human capital.
2.1 Entrepreneurs

At any time \( t \in \mathbb{R}^+ \), there exists a continuum of (prospective) entrepreneurs who are also indexed by \( i \in [0, 1] \). The index \( i \) denotes the entrepreneur’s type. The entrepreneur \( i \) will be referred to as the Type-\( i \).

The cohort-\( t \) of entrepreneurs is born at the (integer) instant \( t = \{0, 1, \ldots, \infty\} \). All entrepreneurs live for one unit of time. A new cohort of entrepreneurs is born just at the end of the previous cohort’s lifespan. Each (dying) entrepreneur procreates 1 (new) entrepreneur, hence their population remains constant across time. For the moment, I assume agents are non-altruistic and are born with zero initial-wealth (in Section 6 this assumption is relaxed).

An entrepreneur \( i \in [0, 1] \) born at instant \( t = \{0, 1, \ldots, \infty\} \) reaches maturity at age \( s_{i,t} \), where \( s_{i,t} \) is the realisation of a random-variable following a uniform distribution over the interval \([0, 1]\). All economic decisions taken by an entrepreneur occur at the instant he reaches maturity.\(^{12}\) As a result, at each interval of time \( (t, t + \delta) \), such that \( t \in \mathbb{R}^+ \) and \( \delta > 0 \), an equal mass of entrepreneurs will be "at work" (almost surely) in the economy; furthermore, the types distribution of the mature entrepreneurs during \( (t, t + \delta) \) will be independent of time \( t \).

All entrepreneurs are risk-neutral, sharing identical preferences over the single consumption good. Accordingly, they all seek to maximise their expected consumption. The ex-post level of consumption will be determined by their ex-post portfolio net returns. Since entrepreneurs are born with zero initial-wealth, the only way in which they can provide themselves with future consumption is by borrowing capital and investing it in a risky entrepreneurial project. Diversification among entrepreneurial projects is not feasible; in other words, these agents must specialise in one particular project.

Entrepreneurs are heterogeneous with respect to their comparative entrepreneurial skills. In particular, if a Type-\( j \in [0, 1] \) invests \( k \) units of capital in Project-\( i \in \mathcal{A} \), then his Project-\( i \)’s gross return \( (y_{i,j}) \) is given by:

\[
y_{i,j} = \theta_{i,j} f(k_{i,j})
\]

The function \( f(k) \) is strictly increasing, strictly concave, twice continuously differentiable, and it satisfies inada conditions. The variable \( k_{i,j} \) represents the amount of capital invested in Project-\( i \) by the Type-\( j \). Finally, \( \theta_{i,j} \) is the realisation of a random-variable with two points of support \( \{0, 1\} \). At the moment of investing \( k_{i,j} \), the entrepreneur does not know \( \theta_{i,j} \), but he only learns its value ex-post. The value taken by \( \theta_{i,j} \) is drawn from the following distribution function:

\[
\theta_{i,j} = \begin{cases} 
1 & \text{with probability } p_{i,j} \\
0 & \text{with probability } 1 - p_{i,j}
\end{cases}
\]

Throughout the paper I assume:

\[ p_{i,i} > p_{i,j}, \text{ for all } j \neq i. \]

\(^{12}\)This "trick" is inspired in a similar one used by Banerjee and Newman (1993). Though seemingly artificial, these timing-assumptions permit the model behaving as if it evolved in continuous time, avoiding any sort discrete jumps in their state-variables.
In simple words, a Type-\(i\) is an agent with intrinsic comparative advantage in Project-\(i\). In the sake of analytical simplicity, hereafter it will be supposed that \(p_{i,j} = p \in (0, 1)\) for all \(j \neq i\), and \(p_{i,i} = 1\) for all \(i \in [0, 1]\). Hence, gross returns of Project-\(i\) are given by the following production functions:

\[
y_{i,i}(\theta_{i,i}) = f(k_{i,i})
y_{i,j}(\theta_{i,j}) = \begin{cases} f(k_{i,j}) & \text{with probability } p \\ 0 & \text{with probability } 1 - p \end{cases}, \text{ where } (j \neq i) \tag{2}
\]

Lastly, I assume capital fully depreciates during the process of production.

A key assumption in this paper is that types are private information (i.e. only each particular entrepreneur knows his own type). In other words, there is asymmetric information regarding entrepreneurial skills. In addition to that, I assume types are genetically uncorrelated, implying that parents’ historical outcomes provide no information whatsoever about the type of a child.

### 2.2 Credit Markets

All credit market transactions with the rest of the world (and also between natives) are mediated by some local firms called financial intermediaries. The local credit market is characterised by free-entry and absence of set-up or sunk costs. Since the economy is small and there is perfect international capital mobility, financial intermediaries are able to draw liquid funds from international credit markets facing a perfectly elastic supply at the international interest rate \(R^f\). For algebraic simplicity, I set \(R^f = 0\).

Financial intermediaries offer credit contracts stipulating fixed interest rates (i.e. interest rates that are not contingent upon ex-post output). When the borrower cannot pay back the amount agreed in the credit contract, he goes bankrupt and loses all rights on his final output, which goes entirely to the financial intermediary. These sort of credit contracts are standard loan contracts (Gale and Hellwig [1985]). A credit contract can thus be (in principle) specified as a pair \((l_j, r_j)\); where \(l_j\) represents the loan extended to the Type-\(j\) and \(r_j\) stands for the interest rate charged on the loan \(l_j\). Individuals are protected by limited-liability, meaning that their consumption cannot fall below a lower-bound which I set equal to zero.

### 2.3 Innovators

Finally, there exists a continuum of agents with mass 1 who are born with the particular skill to be able to produce new ideas. These ideas would, in turn, materialise as innovations and determine the set of active sectors available in the economy at any time \(t\) (i.e. the set \(A_t\)). Innovators are also indexed by the letter \(i \in [0, 1]\). A new cohort of innovators with mass 1 is born at instants \(t = \{0, 1, ..., \infty\}\). Innovators are also risk-neutral (with

\[^{13}\text{The concept of comparative advantage is defined in terms of average productivity (the average productivity of Type-}i\text{ in Project-}i\text{ is higher than the average productivity of Type-}j \neq i\text{ in Project-}i\text{).}\]
preferences defined over the single consumption-good), non-altruistic, and born with zero initial-wealth. As a result, innovators will also need to rely on financial intermediaries in order to obtain credit, so that to invest in R&D and produce innovations seeking to maximise their expected profits.¹⁴ Innovators behaviour will be explained in further detail in Section 4, as for the time being (in Section 3) the model can perfectly do without explicitly incorporating the innovators’ problem.

3 Static Equilibrium Analysis

Throughout this section the set of active sectors \( A_t \) is taken as exogenously given. Thus, the paper focuses on the entrepreneurs’ optimal behaviour, and on the set of credit contracts offered by financial intermediaries, given \( A_t \). This course of action will yield the equilibrium solution of the model at some particular instant of time \( t \in \mathbb{R}^+ \). In the next sections I proceed to study the dynamic evolution of the economy. This will require explicitly incorporating the innovators’ optimisation problem, thereby endogenising the set \( A_t \).

Let \( \mathcal{Q} \subset \mathbb{R} \times \mathbb{R} \) denote the set of all feasible credit contracts \((l, r)\), and \( C_t \subseteq \mathcal{Q} \) denote the subset of feasible credit contracts offered by financial intermediaries at time \( t \). If the entrepreneur \( j \in [0, 1] \) reaches maturity at time \( t \), he will choose an allocation \([(r_j, l_j)^*, \{k^*_i,j\}_{i \in A_t}] \), so that to solve:

\[
\begin{align*}
\max & : E[c_j(\theta_{i,j})], \\
\text{subject to} & : \\
& c_j(\theta_{i,j}) = \max\{0, y_j - (1 + r_j)l_j + (l_j - k_j)\} \\
& \text{where: } k_j \equiv \max\{k_{i,j}\}_{i \in A_t}, \quad y_j \equiv \theta_{i,j} f(k_j). \\
& k_j \leq l_j \quad \text{(budget constraint).} \\
& k_{i,j} \geq 0 \forall i \in A_t, \text{ and } k_{i,j} = 0 \forall i \notin A_t \quad \text{(technological feasibility).} \\
& (r_j, l_j) \in C_t. 
\end{align*}
\]

**Definition 1 (Equilibrium at time \( t \))** Given the set \( A_t \), an equilibrium at time \( t \in \mathbb{R}^+ \) is a set of entrepreneurial allocations \([(r_j, l_j)^*, \{k^*_i,j\}_{i \in A_t}] \) and a set of offered entrepreneurial credit contracts \( C_t \), such that the following two conditions are satisfied:

1) **Entrepreneurs’ optimal allocation:** Given the set \( C_t \), \( \forall j \in [0, 1] \) such that entrepreneur \( j \) reaches maturity at \( t \), the allocation \([(r_j, l_j)^*, \{k^*_i,j\}_{i \in A_t}] \) solves Problem (I).

2) **Credit markets (competitive) equilibrium:** (i) No credit contract belonging to \( C_t \) makes negative expected profits; and (ii) there exists no other credit contract \( z \in \mathcal{Q} \), such that \( z \notin C_t \), and which, if offered in addition to \( C_t \), would make positive expected profits.

¹⁴This paper will, however, focus the attention solely on the adverse selection problem in the credit market for entrepreneurial investment.
3.1 Credit Market Equilibrium Contracts

Following the literature on adverse selection in financial markets (e.g. Rothschild and Stiglitz (1976), Wilson (1977), and Milde and Riley (1988)), one would reasonably expect two different kinds of equilibria to possibly arise in this model’s credit market: 1) a pooling equilibrium, in which all types receive an identical credit contract; 2) a separating equilibrium, in which types are screened, receiving distinctive credit contracts which induce truthful self-revelation of their (unobservable) skills. Proposition 1 below establishes that any equilibrium in the credit market must necessarily entail pooling.

**Proposition 1** Assume the set of inactive sectors at time $t$ is non-empty (i.e. $A_t \neq [0,1]$). Take any sector $i \in A_t$ and any sector $j \not\in A_t$. Then, there can never exist an equilibrium at $t$ in which the Type-$i$ and the Type-$j$ are offered different credit contracts.

**Proposition 1** implies there cannot exist a separating equilibrium in this model. As a consequence, if an equilibrium is to exist at all, it should entail pooling credit contracts. The result in **Proposition 1** stems from the conjunction of three different assumptions: 1) agents displaying risk-neutrality, 2) the particular form of the production functions in Eq.(1) and Eq.(2), 3) the limited-liability constraint. Intuitively, given a set of offered credit contracts, any contract that maximises net returns for Eq.(1) must also necessarily maximise expected net returns for Eq.(2) (since, in the presence of limited-liability, expected net returns when Eq.(2) holds are proportional to net returns when Eq.(1) prevails).

Given the set of active sectors at time $t$, $A_t \subset [0,1]$, we may split the population of entrepreneurs alive at $t$ in two disjunct subsets. Firstly, we may gather all those entrepreneurs of type-$i \in [0,1]$, such that sector $i \in A_t$. Secondly, we may bunch together all those entrepreneurs of type-$j \in [0,1]$, such that sector $j \not\in A_t$. The first group of agents would be able to fully exploit their comparative skills, whereas the second one would not be able to do so, having no other choice but specialising in a sector for which they are not (exceptionally) talented. Abusing a bit of the language utilised in the adverse selection literature, I will call the first group the good-types, while the second group will be denoted as the bad-types.\(^{15}\)

In a pooling equilibrium, all entrepreneurs receive an identical credit contract $(l, r)$. Notice then that, in a pooling equilibrium, $C_t$ must comprise one single element; namely, $C_t = (l, r)$. Additionally, in any (competitive) pooling equilibrium, credit contracts must necessarily verify the following two properties. First, the contract must make non-negative expected profits; otherwise this contract would simply be withdrawn. Second, the contract must maximise the expected utility of the good-types; otherwise financial intermediaries could offer a different contract such that it makes non-negative profits and, at the same time, it makes these agents better-off.

\(^{15}\)More rigorously: $\text{good-types}_t = \{h \in [0,1] \mid \text{sector } h \in A_t\}$ and $\text{bad-types}_t = \{h \in [0,1] \mid \text{sector } h \not\in A_t\}$. Notice that in this paper whether a particular Type-$h \in [0,1]$ is a good-type or a bad-type is not fixed, but it is contingent of the set $A_t$. In that sense, from a dynamic point of view, everyone could eventually become a good-type, if the set of active sectors constantly expands over time.
Assume for the moment that the Type-\(i\) chooses to specialise in sector \(i \in \mathcal{A}\) (as it will become clear later on, this will necessarily be true in equilibrium). Then, given \(C_t = (l, r)\), his optimisation problem boils down to: \(^{16}\)

\[
\max_{k_{i,i} \geq 0} \left\{ 0, f(k_{i,i}) - (1 + r)l + (l - k_{i,i}) \right\} \\
s.t. \quad k_{i,i} \leq l \quad \text{(budget constraint)}
\]

Note that credit contracts offered in equilibrium must necessarily satisfy the condition \(f'(l) \geq 1\). Intuitively, since \(R^f = 0\), no entrepreneur would ever wish to invest in his project beyond the point in which the marginal productivity of capital falls below 1. As a result of this, the budget constraint will necessarily bind (so, \(k_{i,i} = l\)). Problem (I’) will thus yield the following (standard) first-order-condition:

\[
f'(k^*) = (1 + r)
\]

From Eq.(3), we can finally obtain the optimal amount of (physical) capital invested in the project, given the interest rate \(r\). That is, \(k^*(r)\); where \(k'(r) < 0\) since \(f''(\cdot) < 0\). An equilibrium pooling contract must, therefore, display the following structure: \((l, r) = (k^*(r), r)\). (So that it maximises the expected utility of the good-types.)

3.2 The Equilibrium Interest Rate (on Entrepreneurial Loans)

The pair \((k^*(r), r)\) characterises the equilibrium credit contract, given the interest rate \(r\). Therefore, in order to determine the exact credit contract that holds at time \(t \in \mathbb{R}^+\), it still remains to pin down the equilibrium value of \(r\) at \(t\). Let us denote this variable by \(r^*_t\). Perfect competition in the credit market implies that financial intermediaries must make zero profits in equilibrium. Thus, the equilibrium interest rate \(r^*_t\) should be such that the amount paid back by borrowers is just enough for the financial intermediaries to afford paying the depositors the agreed amount (recall the interest rate on deposits is \(R^f = 0\)).

Suppose sector \(i \in \mathcal{A}_{t-\varepsilon}\) and sector \(j \notin \mathcal{A}_{t-\varepsilon}\), where \(\varepsilon\) is an infinitesimal positive number. Additionally, assume the Type-\(i\) (alive at time \(t\)) reaches maturity at time \(t\). Imagine the Type-\(i\) decides to invest in Project-\(i\). Then, given the interest rate \(r\), his consumption \((c_{i,i})\) would be determined by:

\[
c_{i,i} = f(k^*(r)) - (1 + r)(k^*(r)).
\]

Now, imagine the Type-\(i\) chooses to invest in Project-\(x\) \(\in \mathcal{A}_{t-\varepsilon}\), where \(x \neq i\). In that case, his consumption \((c_{x,i})\) would amount \(c_{x,i} = p[f(k^*(r)) - (1 + r)(k^*(r))].\) From these expressions, it must be quite straightforward to observe that \(c_{i,i} > c_{x,i}\), no matter the

\(^{16}\)Bear in mind that \((l, r) \in [0, \infty) \times [0 \times \infty)\). Although nothing precludes the fact that \(l\) could be in principle negative (i.e., entrepreneurs could lend capital to financial intermediaries), this possibility will never arise in equilibrium, as entrepreneurs are born with zero initial-wealth. In addition to that, in equilibrium, financial intermediaries would never offer loan contracts with \(r < 0\), as these contracts would entail (expected) losses.
value of \( r \). Therefore, as long as sector \( i \in \mathcal{A}_{t-\varepsilon} \), the Type-\( i \) (mature at \( t \)) will specialise in Project-\( i \).

Take now the type-\( j \) entrepreneur, and suppose he reaches maturity at time \( t \) as well. This agent could invest in Project-\( i \) (or in any Project-\( x \), such that sector \( x \in \mathcal{A}_{t-\varepsilon} \)), obtaining as expected consumption \( (c_{i,j}) \):

\[
c_{i,j} = p \left[ f(k^*(r)) - (1 + r)k^*(r) \right].
\] (5)

Notice that, because of \( f(k) \) satisfies inada conditions, Eq.(5) yields \( c_{i,j} > 0 \), irrespective of the value taken by \( r \). This means it will always be desirable for the Type-\( j \) to invest \( k^*(r) \) in Project-\( i \).

From the previous discussion, we can then deduce that a fraction \( n_t \) of the population of entrepreneurs (the good-types) will always pay back the financial intermediaries the agreed amount \( (1 + r)k^*(r) \). On the other hand, the remaining fraction \( 1 - n_t \) (the bad-types) will go bankrupt with probability \( 1 - p \). Being protected by limited-liability, the bad-types are expected to pay back only the amount \( p(1 + r)k^*(r) \). Then, the zero-profit condition on financial intermediaries reads as follows:

\[
n_t(1 + r)k^*(r) + (1 - n_t)p(1 + r_t^*)k^*(r_t^*) = (1 + Rf)k^*(r_t^*).
\]

Proposition 2 The equilibrium interest rate charged on credit contracts offered to entrepreneurs is a decreasing function of the number of active sectors. More precisely,

\[
r_t^* = r^*(n_t) = \frac{(1 - n_t)(1 - p)}{n_t + (1 - n_t)p},
\] (6)

which is (strictly) decreasing in \( n_t \).

From Eq.(6), it can also be noted that: \( r^*(0) = (1 - p)/p \), \( r^*(1) = 0 \), and \( r''(n_t) > 0 \).

Proposition 2 reflects one the key insights of this paper. Increasing the number of active sectors induces a more efficient operation of financial institutions; this is the case because a higher value of \( n_t \) improves the allocation of entrepreneurial talent, alleviating the adverse selection problem affecting this economy. Intuitively, as the set active sectors \( \mathcal{A}_t \) expands, a higher fraction of agents find it feasible to specialise in the sector they are most talented at. This fact reduces the average default rate in the economy, enabling the financial intermediaries to charge a lower interest rate on the loans they extend to entrepreneurs, without incurring in expected losses.

### 3.3 Entrepreneurial Consumption Level / Net Returns

Take again some Type-\( i \in [0, 1] \), such that sector \( i \in A \) (i.e. a good-types representative). His consumption level will be dictated by Eq.(4). Denote by \( U_g(r) \) the utility level achieved by an entrepreneur who belongs to the subset of good-types. Differentiating Eq.(4) with respect to \( r \), and taking Eq.(3) into account, we get:

\[
U'_g(r) = -k^*(r).
\] (7)
Select now some Type-$j \in [0, 1]$, such that sector $j \notin \mathcal{A}$ (i.e. a bad-types representative). His expected consumption will be given by Eq.(5). Hence, denoting by $U_b(r)$ the level of expected utility reached by a bad-type, we obtain:

$$U'_b(r) = -k^*(r)p$$

(8)

where derivation of Eq.(8) also makes use of Eq.(3).

**Lemma 1** Let $\Delta(r) \equiv U_g(r) - U_b(r)$. Then, $\Delta(r) > 0$ and $\Delta'(r) < 0$, for all possible values $r$ may take in equilibrium.

The proof of Lemma 1 is straightforward from inspection of Eq.(7) and Eq.(8). The derivative $\Delta'(r) < 0$ means that good-types benefit from a fall in the interest rate $r$ more than bad-types do. The reason for this result lies on the fact that good-types do never go bankrupt, thus they appropriate the full cost-reduction induced by a lower $r$. On the other hand, since bad-types go bankrupt with probability $(1 - p)$, they will profit from a smaller $r$ only with probability $p < 1$. Lemma 1 will play a key role in the next section when I present the innovators’ optimisation problem.

So far, the set $\mathcal{A}_t$ (and the state-variable $n_t$) has been taken as exogenously determined. In this way, the model has managed to characterise the entrepreneurs’ equilibrium allocations at some particular moment in time $t \in \mathbb{R}^+$. In order to endogeneise the set $\mathcal{A}_t$ and study the dynamics of this model, the innovators’ behaviour needs to be explicitly incorporated into the model. I now proceed to do so.

### 4 Innovators, Innovations and Sectoral Expansion

I model the appearance of new active sectors as the result of (successful) innovations. Following the Endogenous Growth Theory paradigm (Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992)), innovations are the consequence of deliberate profit-maximising R&D policies undertaken by private agents which I refer to as innovators. I will focus only on horizontal innovations, as those are the kind of innovations that will lead to improvements in the allocation of agents’ talent; the key mechanism at work in this paper.

Recall at any time $t \in \mathbb{R}^+$ there is a continuum of innovators indexed by $i \in [0, 1]$. Innovators alive at $t \in \mathbb{R}^+$ belong to a specific cohort $t = \{0, 1, \ldots \infty\}$. Except for their particular index $i$, all innovators within the same cohort are ex-ante identical; displaying risk-neutrality, living for one unit of time, and starting off their lives with zero initial-wealth. These conditions are identically reproduced for every cohort $t = \{0, 1, \ldots \infty\}$. I suppose the innovator $i$ can only possibly innovate for sector $i$. Since vertical innovations are precluded, the subset of innovators who (would) innovate for sectors which are already active will thus not play any relevant role in the model.

Innovators are agents who are able to produce or generate new ideas (this is their particular skill) - think of an idea as a blueprint, which contains the required information
or know-how needed to produce new types of goods. In order to come up with an idea, they need before to invest in R&D (alternatively, we could interpret this as investment in human capital). An idea is, however, not per-se knowledge (or technology); for that to be so, the idea must by applied by an entrepreneur. In other words, there exists some sort of strong intrinsic complementarity between innovators and entrepreneurs, and this requires both agents’ specific skills to be properly exercised for the technological frontier of the economy to expand.\(^{17}\)

In this model, an idea designed by innovator \(i \in [0,1]\) (abusing a bit of the notation, let’s call it idea \(i\)), when is put into practise by some entrepreneur \(j \in [0,1]\), materialises as Project-\(i\) (turning sector \(i\) into an active sector). Knowledge is supposed to be a pure public-good; that is, its use is non-rival and non-excludable. More precisely, once some particular entrepreneur \(j \in [0,1]\) applies an idea \(i \in [0,1]\) at time \(t \in \mathbb{R}^+\), the underlying knowledge becomes readily (and instantly) available to all the other entrepreneurs from \(t\) onwards. (N.B.: it is only knowledge the good whose nature is public; an idea is on the contrary assumed to be excludable, hence able to be traded).

**Example:** To clarify the modelisation of the innovation process, take the Pharmaceutical Industry as an example. The process begins with a biochemist (innovator) who designs a new drug (idea). What does this idea consist of? It is basically a "recipe" stating the required combinations of certain chemical elements so as to generate the drug, plus an explanation of how and when this drug is to be used, and the list of its beneficial results and side-effects. Yet, as such, this new idea is not a new good; it still necessitates going through the process of (physical) production and, more importantly, reaching the market. This second part of the innovation process is what pharmaceutical companies (entrepreneurs) do. These agents take the ideas from the biochemists and turn them into new goods available for consumption (the branded drugs in the market). Notice that the design of the drug is completely excludable; the biochemist can keep this idea with him as long as he wants, simply by not transmitting it to other agents. However, once the drug (as a good) reaches the market, any pharmaceutical company can copy the drug and start producing it without the help of the biochemist.

An innovator that comes up with a new idea, will try to sell it to an entrepreneur. Given the public nature of knowledge, only the Type-\(i\) would be willing to pay a positive price to obtain the idea generated by innovator \(i\). To see this, recall from Lemma 1 that \(\Delta(r) > 0\) for any possible value that \(r\) may take in equilibrium. This \(\Delta(r)\) equals the increment in (expected) utility that the Type-\(i\) would get by applying idea \(i\) (were this idea given to him for free!). Notice \(\Delta(r)\) is a surplus resulting from a bilateral-monopoly relation between the Type-\(i\) and the innovator \(i\). In principle, the surplus \(\Delta(r)\) could be

\(^{17}\)This idea is in accord with the schumpeterian view of economic development. Joseph A. Schumpeter (1934) writes "Entrepreneurship must be distinguished from 'invention'. As long as they are not carried out into practice, inventions are economically irrelevant. And to carry any improvement into effect is a task entirely different from the inventing of it, and a task, moreover, requiring different kinds of aptitudes. Although entrepreneurs of course may be inventors, they are inventors not by nature of their function but by coincidence.", pp. 88-89. Related, Hobsbawm (1977) claims it was not scientific supremacy what explains why the Industrial Revolution occurred first in UK; in fact, he asserts that both France and Germany were notably above UK in terms of scientific knowledge at that time (pp. 29-30).
distributed between the two parties according to various different rules; I will assume that the whole surplus $\Delta(r)$ will be appropriated by the innovator, leaving the entrepreneur just indifferent between buying or not the new idea (in other words, the innovator makes a take-it-or-leave-it-offer to the entrepreneur for the transfer of the idea).\footnote{Nonetheless, as long as it is assumed (reasonably) that the innovator’s income is increasing in the total surplus $\Delta(r)$, none of the paper’s main findings would be affected if the entrepreneur could appropriate part of $\Delta(r)$. For instance, this would be the case if the surplus were split following a Nash-bargaining rule.}

### 4.1 Innovators’ Production Function

Denote by $\nu_i$ the amount invested in R&D by innovator $i \in [0, 1]$. Additionally, denote by $\Pr(I_i \leq t + s)$ the probability that innovator $i$ will generate an idea before time $t + s$ elapses, where $s \in [0, 1]$. If the innovator $i$ belonging to cohort-$t = \{0, 1, \ldots, \infty\}$ invests $\nu_i$ in R&D, then

$$\Pr(I_i \leq t + s) = \beta(\nu_i) \cdot s,$$  \hspace{1cm} (9)

where: $\beta’(\nu) > 0$, $\beta''(\nu) < 0$, $\beta(0) = 0$, $\lim_{\nu \to -\infty} \beta(\nu) = 1$, and $\lim_{\nu \to 0} \beta’(\nu)$ is finite.

To interpret Eq.(9), notice there exist two distinct sources of failure risk from the innovator’s perspective. First, there is the chance the innovator does not succeed in actually managed to create an idea, the innovator cannot find the type to whom to sell this idea. In that sense, imagine the innovator $i$ of cohort-$t$ comes up with an idea at time $t + s$, where $s \in [0, 1]$; the Type-$i$ born at $t$ (who is the only entrepreneur that would buy his idea) becomes mature at some point in time within $(t + s, t + 1)$ with probability $1 - s$. As a result, having created an idea at time $t + s$, there is a chance equal to $s$ that this idea cannot find a buyer (and turns "irrelevant").

### 4.2 Innovators’ Optimisation Problem

Innovators seek to maximise expected profits derived from the generation and sale of new ideas. Consider sector $i \notin A_t$, and take the innovator $i$ born at time $t$, where $t$ can in principle be any element of the set $\{0, 1, \ldots, \infty\}$. This innovator must choose the value of $\nu_i$ that maximises his expected profits function.\footnote{Note that if sector $i \in A_t$, then the innovator $i$ born at time $t$ trivially chooses $\nu_i = 0.$}

Denote by $\nu_{i,t}$ the level of R&D investment chosen by all the innovators belonging to the subset $-A^{-1}_t$, where $-A^{-1}_t = \{ j \in [0, 1] \mid j \neq i \text{ and sector } j \notin A_t \}$.\footnote{This $\nu_{i,t}$ should actually be a function $\nu_{i,t} : -A^{-1}_t \to [0, \infty)$, summarising the choice of each innovator belonging to $-A^{-1}_t$. However, in the optimum, all these innovators will select the same value of $\nu$. Hence, a singleton $\nu_{i,t}$ turns out in fact sufficient to represent their aggregate behaviour.}

Lemma 2 states the optimisation problem of this innovator $i$.

**Lemma 2** Consider sector $i \notin A_t$, and take the innovator $i$ born at time $t$, where $t$ can be any element of the set $\{0, 1, \ldots, \infty\}$. Then, innovator $i$ solves:

$$\max_{\nu_{i,t} \geq 0} \Pi_{i,t}(\nu_{i,t}, n_t, \nu_{i,t}) = \beta(\nu_{i,t}) \cdot \Psi(n_t, \nu_{i,t}) - \nu_i$$  \hspace{1cm} (II)
Where the function $\Psi(n_t, \bar{n}_t) : [0, 1] \times \mathbb{R}^+ \rightarrow \mathbb{R}^+$ is increasing in both of its arguments. More precisely: (i) $\Psi_t'(\cdot) > 0$, $\forall n_t \in [0, 1]$ and $\bar{n}_t \geq 0$; and (ii.a) $\Psi_t'(\cdot) > 0$, $\forall n_t \in [0, 1]$ and $\bar{n}_t \geq 0$, (ii.b) $\Psi_t'(\cdot) = 0$ if $n_t = 1$.

From Lemma 2 it follows that $\Pi_{i,t}(n_t, \bar{n}_t, \bar{\bar{n}}_t)$ must be increasing in both $n_t$ and $\bar{n}_t$. To grasp some intuition, notice that the variable $n_t$ displays positive serial correlation. More precisely, since active sectors do not ever turn inactive, the higher $n_t$ is in the present, the higher it is expected to be in the future. As a result, relatively high values of $n_t$ will be associated with relatively low levels of $r^*$ in the future (Proposition 2). This, in turn, implies that the surplus generated by new innovations (i.e. $\Delta(r^*)$) is expected to be large in the future (Lemma 1), allowing innovators to charge a relatively high price on their ideas. Similarly, larger values of $\bar{n}_t$ are also associated with less severe adverse selection problems in the future leading to lower $r^*$ and higher $\Delta(r^*)$. In this case, the reason for this positive effect is that a larger $\bar{n}_t$ means more innovations will actually be produced, rising thus the value of $n_t$ in the (near) future. In addition to that, note $\Psi_t'(\cdot) > 0$ implies that there exists a positive externality across innovators. This externality arises because when an innovator $j \in [0, 1]$ comes up with a new idea, this may turn sector $j$ into an active sector and increase the value of $n$ (something which all innovators will benefit from).

Problem (II) leads to the following first-order-condition:

$$\beta'(\bar{i}_t^*) \cdot \Psi(n_t, \bar{n}_t) \leq 1 \quad \text{and} \quad \bar{i}_t^* \left[\beta'(\bar{i}_t^*) \cdot \Psi(n_t, \bar{n}_t) - 1\right] = 0 \quad (10)$$

Proposition 3 Let $\bar{i}_t^* \equiv \arg \max_{\bar{i}_t} \{ \Pi_{i,t}(n_t, \bar{n}_t, \bar{\bar{n}}_t) \}$. Then, $\bar{i}_t^* = \bar{i}_t^*(n_t, \bar{n}_t) : [0, 1] \times [0, \infty) \rightarrow [0, \infty)$, and it exhibits the following properties:
1) $\bar{i}_t^*(n_t, \bar{n}_t)$ is (weakly) increasing in $n_t$.
2) $\bar{i}_t^*(n_t, \bar{n}_t)$ is (weakly) increasing in $\bar{n}_t$.

Results in Proposition 3 are straightforward implications of Lemma 2 and Eq.(10). Intuitively, as $\partial \Pi_{i,t}(/\cdot)/\partial n_t$ is increasing in both $n_t$ and $\bar{n}_t$, larger values of either variables incite innovators to increase the amount invested in R&D.

The impact of $n_t$ on $\bar{i}_t^*$ represents the main result of this section. This feature is the underlying force generating the positive feedback between financial development and innovation activities proposed in this paper. Basically, a larger $n_t$ is associated with weaker distortions in the credit market, thereby leading to higher entrepreneurial investment which provides higher profit prospects to innovators. This induces higher R&D investment which, in turn, leads to a faster rate of innovations, feeding back on $n_t$ by expanding it even further. This positive feedback will give rise to the possibility of non-ergodic dynamics in the model (in particular, dynamics that will depend on the value of $n_0$), as it will be discussed in detail in Section 5.1.

Hereafter, it will be convenient to restrict the parameters configuration in the model such that the following two conditions hold:
Assumption 1. \( \exists \bar{n} \in (0, 1) \), such that: \( \beta'(0) \Psi(\bar{n}, 0) = 1 \).

Assumption 2. \( \exists \underline{n} \in (0, 1) \), such that: \( \beta'(0) \left[ \lim_{\bar{t}_t \to \infty} \Psi(\underline{n}, \bar{t}_t) \right] = 1 \).

Corollary 1 If Assumption 1 holds, then: (i) \( \forall n_t \leq \bar{n} : n_t = 0 \Rightarrow i_t^* = 0 \); (ii) \( \forall n_t > \bar{n} : i_t^* > 0 \), regardless of the value taken by \( \bar{t}_t \).

Corollary 2 If Assumption 2 holds, then: \( \forall n_t \leq \bar{n} : i_t^* = 0 \), regardless of the value taken by \( \bar{t}_t \). (Notice Lemma 2 implies \( \underline{n} < \bar{n} \)).

Figure 2 provides a visual description of the results stated in Proposition 3.\(^{21}\) The left panel plots \( i_t^* \) against \( n_t \), given four different values of \( \bar{t}_t \) (these values are: \( 0 < \bar{t}_B < \bar{t}_A < \infty \)). Analogously, the right panel plots \( i_t^* \) against \( \bar{t}_t \), given five different values of \( n_t \) (\( n_A < n_B < \bar{n} < n_C < 1 \)). Notice that the notation in both panels is consistent with each other (i.e., the value \( \bar{t}_A \) in panel (a) corresponds to the value \( \bar{t}_A \) in panel (b), and so on and so forth). Additionally, in Figure 2.b (although not plotted) for \( n_t = \bar{n} \) we should have \( i_t^*(n_t, \bar{t}_t) = 0 \) for all values of \( \bar{t}_t \).

4.3 Innovators Nash Equilibrium Solution

Figure 2 characterises the result of the optimisation problem faced by the innovator \( i \) born at time \( t \) when sector \( i \notin A_t \), given \( n_t \) and the (expected) behaviour of the rest of the innovators \( (\bar{t}_t) \). Nevertheless, I haven’t yet discussed whether innovators’ expectations, summarised by \( \bar{t}_t \), are indeed correct. In fact, expectations play an important role in the model because R&D investment by a particular innovator exerts a positive externality on

\(^{21}\) The graphs are plotted given Assumption 1 and Assumption 2.
the others. More specifically, as it can be observed from result (2) in Proposition 3, the optimal response by an innovator depends on his expectations about the behaviour of the other innovators. As a result, we must restrict the attention only to those solutions of Problem (II) which also represent a Nash Equilibrium (NE) when we consider the whole set of innovators.

Given the structure of the model, any NE will be symmetric (SNE) - see Vives (2005), p. 441. The SNE are determined by the intersections between a 45° line and the curves plotted in Figure 2.b. For some ranges of \( n_t \in (\bar{n}, 1) \), the model might lead to multiple SNE.\(^{22}\) Equilibrium multiplicity may arise as a consequence of innovators’ behaviour displaying strategic complementarity (Cooper and John (1988)). Figure 3 shows two possible SNE schedules as a function of \( n_t \) (I only plot the SNE schedule for an innovator \( i \) born at time \( t \) such that sector \( i \notin A_t \)). In (b) the parameters configuration leads always (i.e. for all values of \( n_t \)) to unique SNE.\(^{23}\) On the other hand, in (a) multiple equilibria emerge for values of \( n_t \in (\bar{n}, \bar{n}) \) - two equilibria are possible in this case; one where \( t^*_i = 0 \), and the other one in which \( t^*_i > 0 \). Bear in mind that, as it can be readily deduced from Corollary 2, for any \( n_t \leq \bar{n} \), the SNE must necessarily be unique and encompass \( t^*_i = 0 \).

Additionally, for values of \( n_t \) sufficiently close to 1, the SNE must also be necessarily unique (since \( \lim_{n_t \to \infty} \Psi_i = 0 \)); but in those cases comprising \( t^*_i > 0 \) (because \( 0 < \pi < 1 \)).

![Figure 3: Innovators’ Symmetric Nash Equilibrium.](image)

\(^{22}\)In what follows I restrict the analysis only to stable SNE though.

\(^{23}\)A sufficient condition for uniqueness of SNE is that: \( \frac{\partial n^*}{\partial \bar{n}} = -\frac{\beta')(\bar{n}) \Psi_{\bar{n}}' < 1, \forall n \in [0, 1] \) and \( \bar{n} \geq 0 \). Generally speaking, uniqueness requires innovators’ external effects not to be too strong, so that the curves plotted on Figure 2.b do never cross the 45° line from below - see Cooper and John (1988).
5 Aggregate Dynamic Analysis

The analysis of the economy in Section 3 has been conducted within a static framework, in the sense that initial conditions, determined by the set $\mathcal{A}_t$, have been taken as exogenously given. Section 4 provides the bridge between the static and the dynamic study of this economy. More precisely, it is the innovators’ behaviour what determines the evolution of the set $\mathcal{A}_t$ which, in turn, dictates the exact equilibrium that holds at time $t$ according to Definition 1. Since agents are assumed to be born with zero initial-wealth and all sectors are (ex-ante) symmetric, $n_t$ remains as the only variable whose behaviour we need study in order to keep track of the economy’s dynamics. That is to say, $n_t$ represents the sole relevant state-variable in this model.

**Definition 2 (Dynamic Equilibrium)** A dynamic equilibrium is a (continuous) sequence of static equilibria, linked together across time by the "law of motion" of $n_t$ specified in (11).

**Law of motion:** Take the infinite sequence of cohorts $\tau = \{0, 1, \ldots \infty\}$. Then, the value of $n_t$ at any instant of time $t \in \mathbb{R}^+$ is determined by the following equation:

$$n_t = n_{\tau + \delta} = n_{\tau} + \beta(i^*_\tau)(1 - n_{\tau})\delta.$$  
(11)

and $i^*_\tau$ represents the R&D investment by innovator $h \in [0, 1]$ born at time $\tau$ when sector $h \notin \mathcal{A}_\tau$, resulting from the SNE described in Section 4.3. More precisely, $\forall h \notin \mathcal{A}_\tau : i^*_\tau \in [0, \infty)$ solves Problem (II), given the function $\Upsilon^*: [0, 1] \times (0, \infty) \rightarrow (0, 1)$, that summarises the optimal choice $i^*_k, \tau$ for all $k \neq h \in [0, 1]$ at time $\tau$.

5.1 Stagnation vs. Development (multiple dynamic equilibria)

This subsection restricts the attention to the distinct characteristics of the dynamic paths followed by economies which differ only on initial conditions. In particular, it studies whether economies that are dissimilar in terms of $n_0$ will follow divergent dynamic paths, reaching different long-run equilibria. For this reason, during this subsection, I impose the following condition on the parameters configuration (so that the innovators’ SNE is always unique, leading to a situation as the one depicted in Figure 3.b).

**Assumption 3 (sufficient condition for uniqueness of SNE).**

$$\frac{\partial i^*_\tau}{\partial i} = -\frac{\beta'(i^*_\tau)}{\beta''(i^*_\tau)} \Psi^*_h < 1,$$
for all $n \in [0, 1]$ and $\bar{t} \geq 0$.

**Proposition 4 (Stagnation vs. Development)** Suppose Assumptions 1 and 3 hold. Then:

(i) Any economy that starts off with $n_0 \leq \bar{n}$ remains forever at $n_0$ and displays no innovation activities. That is, if $n_0 \leq \bar{n}$, then: $n_t = n_0 \ \forall t > 0$, and $i^*_\tau = 0 \ \forall \tau = \{0, 1, \ldots \infty\}$.

(ii) In any economy where $n_0 > \bar{n}$, $n_t$ will continuously grow over time converging monotonically to $n_\infty = 1$. During the transition, $i^*_\tau$ is positive and increases along with $n_t$. 


Secular Stagnation: Take an economy for which \( n_0 \leq \bar{n} \). Then, for this economy, the equilibrium at time \( t = 0 \) encompasses \( I_0^* = 0 \). In addition to zero investment in R&D and absence of innovation, this economy will exhibit highly inefficient credit provision and low levels of entrepreneurial investment. The credit market inefficiency is the consequence of severe adverse selection problems, which derive from the high degree of sectors incompleteness. On the other hand, repressed entrepreneurship is the result of both lack of opportunities (few active sectors) and inadequate credit provision.

From (11), since \( I_0^* = 0 \), then \( n_t = n_0 \) for all \( t \in [0, 1] \). This, in turn, implies that \( I_1^* = 0 \) will hold again at \( t = 1 \), leading to \( n_t = n_0 \) for all \( t \in [0, 2] \). Furthermore, in the absence of any substantial exogenous shock, this stagnant equilibrium will perpetuate itself for all \( t \in \mathbb{R}^+ \).

Prosperity and Development: Consider now an economy in which \( n_0 \) is large enough; more specifically, \( n_0 > \bar{n} \). In this case, the equilibrium at \( t = 0 \) displays \( I_0^* > 0 \). Intuitively, the degree of sector incompleteness is not too high, hence the adverse selection problem does not become too serious, and the operation of the economy does not turn out severely distorted (in particular, innovation activities do not completely disappear).

From (11), \( I_0^* > 0 \) implies \( n_t \) will be growing over time for \( t \in [0, 1] \). As a consequence of this, \( n_1 > n_0 > \bar{n} \), and \( I_1^* > I_0^* > 0 \). Moreover, this prosperous dynamics will be perpetuated \textit{ad infinitum}, and this economy will eventually reach a long-run equilibrium characterised by \textit{complete markets} \( (n_\infty = 1) \). During the transition period, the economy experiences development and growth, which manifests itself as a continuous process of sectoral horizontal expansion (capital differentiation) and a more efficient allocation of skills. At the same time, financial markets operation concomitantly improves, as adverse selection problems tend to vanish away with a higher \( n_t \).

### 5.2 History vs. Expectations (multiple static equilibria)

Section 4.3 has shown that, within the range of \( n_t \in (n, 1) \), for some set of parameters configurations the model might display multiple SNE in the innovators game. As a particular example, in Figure 3.a for \( n_t \in [\hat{n}, \pi] \), where \( \hat{n} \in (\bar{n}, \pi) \), there are two possible (stable) SNE. Multiplicity of innovators’ SNE will lead to multiplicity of static equilibria in this model. It is beyond the scope of this paper to study this sort of equilibrium multiplicity, as the main intention here is to analyse how dynamic paths may be affected by economies’ initial conditions. Nevertheless, I provide below a brief discussion of the equilibrium characteristics of an economy whose parameters configuration leads to a situation as the one depicted in Figure 3.a.\(^{24}\)

If parameters in the model lead to as situation as the one plotted in Figure 3.a, then if the value of \( n_0 \in [\hat{n}, \pi] \), this economy will be subject to multiple static equilibria. Equilibrium multiplicity will be driven by innovators’ expectations. In particular, if expectations coordinate in \( \bar{I}_0 = 0 \), then \( I_0^* = 0 \) will prevail. Besides this bad equilibrium,

\(^{24}\)A more general and rigorous characterisation of the static equilibrium multiplicity is available from the author upon request.
we can observe that there also exists some specific value $\tilde{r}_0^* > 0$, which would lead to a better equilibrium comprising $\tilde{r}_0^* = \tilde{r}_0^* > 0$. More importantly, from a dynamic perspective, whether expectations in $t = 0$ lead to $\tilde{r}_0^* = 0$ or $\tilde{r}_0^* > 0$ may carry dramatic future consequences. Dynamically, $\tilde{r}_0^* = 0$ entails that $n_t$ stays stagnant during $t \in [0, 1]$; as a result, initial conditions in $t = 1$ would identically replicate those faced in $t = 0$, with the economy still at risk of suffering from coordination failures. On the other hand, $\tilde{r}_0^* > 0$ means that $n_1 > n_0$ and, consequently, this could possibly shoot up $n_1$ above $\bar{n}$, and ignite a process of continuous prosperity and development. For an economy with $n_t \in [\tilde{n}, \bar{n}]$, the larger $n_t$ is, the higher the chances that $n_{t+\delta} > \pi$ will hold if $\tilde{r}_t^* > 0$. Hence, when the economy is located within $[\tilde{n}, \bar{n}]$, both history and expectations matter in the sense of Krugman (1991), and the economy might display periods of growth and technical change, followed by periods of stagnation.

6 Incorporating Wealth into the Model

So far it has been supposed that all individuals are born with zero initial-wealth. In many aspects this assumption might seem far too extreme. Nevertheless, the zero initial-wealth assumption has allowed the model to completely isolate the impact of the fraction of active sectors on the operation of the economy. In this section, I let agents be born with positive initial-wealth; furthermore, I allow initial-wealth to differ across individuals of the same cohort. In particular, this section features individuals who are warm-glow altruistic and, accordingly, bequeath a fraction of their net life-time income to their offspring (this bequest will constitute the next generation’s initial-wealth) - see Andreoni (1989). Briefly, this section shows that none of the main results and insights presented in this paper will be altered when we permit agents’ initial-wealth to be positive, stemming from parental bequests.

To keep this section as brief and simple as possible, I will mainly restrict the analysis to study the static equilibrium of the economy. That means I am going to freeze the analysis at some moment in time, say $t \in \mathbb{R}^+\cup\{0\}$, which encompasses a given set $\mathcal{A}_t$. Once the properties of the static equilibrium are clearly stated, proceeding to the dynamic analysis of the economy should be a straightforward extension of Sections 4 and 5.

Let $w_{i,t}$ denote the initial-wealth of the Type-$i \in [0, 1]$ born at time $t = \{0, 1, ..., \infty\}$. Initial-wealth is publicly observable, and is distributed in the population of entrepreneurs according to the cumulative distribution function $\Omega_t(w)$. Initial-wealth is publicly observable. I will assume that the type of the father is uncorrelated with his son’s type. This last assumption, within a full dynamic framework, implies that initial-wealth and types will be uncorrelated, hence the particular value of $w_{i,t}$ will provide no information whatsoever about the individual’s type.
6.1 The Participation Constraint

When initial-wealth is positive we need to take care of the participation constraint in the credit market (PC). In particular, when \( w > 0 \) a bad-type might prefer not to engage in any credit market transaction, behaving as if he were in complete autarky. In other words, when \( w > 0 \) any individual may invest some positive amount of capital \( (k < w) \) in an entrepreneurial project, without needing to borrow from financial intermediaries. As a result, individuals have access to an outside option with strictly positive payoff, which determines their PC.

Suppose a bad-type with initial-wealth \( w \) must choose his portfolio allocation in autarky. In such situation, he will solve:

\[
\max_{0 \leq k \leq w} : pf(k) + (w - k). \quad (III)
\]

This optimisation problem yields the following investment policies:

\[
\begin{align*}
  k^* &= w & \text{if} & & w \leq k^*_B, \\
  k^* &= k^*_B & \text{if} & & w > k^*_B.
\end{align*}
\]

Where \( pf'(k^*_B) = 1 \) (i.e. \( k^*_B \) is the first-best investment of bad-types).

Imagine now that this bad-type decides to participate in the credit market. In this case, he will invest \( k^*_P(r) \) units of capital in the project, paying an interest rate \( r \) on the borrowed amount \( (k^*_P(r) - w) \). The function \( k^*_P(r) \) stems from the first-order-condition \( f'(k^*_P) = 1 + r \); analogous to Eq.(3) in the main model. Notice that \( 1 + r < p^{-1} \), hence \( k^*_P(r) > k^*_B \). A bad-type will participate in the credit market only if the PC is not violated; this requires that \( p [f(k^*_P(r)) - (1 + r)(k^*_P(r) - w)] > pf(k^*_B) + (w - k^*_B) \). From this condition, it follows that a bad-type will participate in the credit market if and only if his initial-wealth does not surpass a certain threshold \( \hat{w} \in (k^*_B, k^*_P(r)) \); that is, iff \( w < \hat{w} \), where

\[
\hat{w}(r) \equiv \frac{p [f(k^*_P(r)) - f(k^*_B) - (1 + r)k^*_P(r)] + k^*_B}{1 - p(1 + r)}.
\]

6.2 The Incentive Compatibility Constraint

Take an entrepreneur whose \( w \geq \hat{w}(r) \). If he is a good-type, he must get a separating credit contract (paying an interest rate equal to \( R^f = 0 \)), as no bad-type with \( w \geq \hat{w}(r) \) wishes to participate in the credit market. Despite that, a good-type with \( w \geq \hat{w}(r) \) will not necessarily obtain a first-best credit contract. In order to obtain a first-best credit contract, an equally rich bad-type should find no incentives to imitate his first-best behaviour. Denote with \( k^*_G \) the result coming from the first-order-condition \( f'(k^*_G) = 1 \); i.e., \( k^*_G \) designates the first-best entrepreneurial investment of the good-types. Notice that \( k^*_G > k^*_P(r) \), since \( 1 + r > 1 \). A good-type will receive a first-best credit contract if and only if: \( p [f(k^*_G) - (k^*_G - w)] < pf(k^*_B) + (w - k^*_B) \). This last condition requires that his initial-wealth is larger than a certain threshold \( \tilde{w} \in (\hat{w}(r), k^*_G) \); that is, it calls for \( w > \tilde{w} \),
where
\[
\tilde{w} \equiv \frac{p[f(k^*_G) - f(k^*_B) - k^*_G] + k^*_B}{1 - p}.
\]

What happens to a good-type whose \( w \in [\tilde{w}(r), \tilde{w}] \)? This agent will certainly receive a separating contract with interest rate equal to \( R^f = 0 \). However, he won’t be able to get a first-best contract, as this would violate the incentive-compatibility constraint (IC). In fact, the IC will bind for those entrepreneurs with \( w \in [\tilde{w}(r), \tilde{w}] \). As a result, the amount of credit received by a good-type with \( w \in [\tilde{w}(r), \tilde{w}] \) is derived from the following equation:
\[
p[f(k^*_G) - (k^*_S - w)] = pf(k^*_B) + (w - k^*_B).
\] (12)

Eq. (12) (implicitly) yields a function \( k^*_S(w) \); which displays the following properties: (i) \( dk^*_S/dw = \frac{1-p}{p} (f'(k^*_G) - 1)^{-1} > 0 \), (ii) \( d^2k^*_S/(dw)^2 > 0 \), (iii) \( k^*_S(w) \to k^*_G \) as \( w \to \tilde{w} \), and (iv) \( k^*_S(\tilde{w}) < k^*_B(r) \). Table 2.A characterises the main features displayed by the credit contracts offered to entrepreneurs.\(^{25}\)

<table>
<thead>
<tr>
<th>Table 2.A: Equilibrium Contracts (main features)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w )</td>
</tr>
<tr>
<td>( &lt; \tilde{w}(r) )</td>
</tr>
<tr>
<td>( \in [\tilde{w}(r), \tilde{w}] )</td>
</tr>
<tr>
<td>( &gt; \tilde{w} )</td>
</tr>
<tr>
<td>type of contract</td>
</tr>
<tr>
<td>pooling</td>
</tr>
<tr>
<td>sub-optimal separating</td>
</tr>
<tr>
<td>first-best separating</td>
</tr>
<tr>
<td>good-types’ investment</td>
</tr>
<tr>
<td>( k^*_B(r) )</td>
</tr>
<tr>
<td>( k^*_S(w) )</td>
</tr>
<tr>
<td>( k^*_G )</td>
</tr>
<tr>
<td>interest rate (on credit)</td>
</tr>
<tr>
<td>( 0 &lt; r &lt; \frac{1-p}{p} )</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

6.3 Entrepreneurial Consumption and Sketch of Dynamics

As in Section 3.3, denote by \( U_g \) (\( U_b \)) the expected utility level achieved by a good-type (bad-type) entrepreneur. When initial-wealth is incorporated into the model, it will naturally be the case that \( U_g(r, w) \) and \( U_b(r, w) \). Table 2.B summarises how entrepreneurial expected utility depends on \( w \) (and \( r \)).

<table>
<thead>
<tr>
<th>Table 2.B: Entrepreneurial Consumption - ( U_g(r, w) ) and ( U_b(r, w) ).</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w )</td>
</tr>
<tr>
<td>( &lt; \tilde{w}(r) )</td>
</tr>
<tr>
<td>( \in [\tilde{w}(r), \tilde{w}] )</td>
</tr>
<tr>
<td>( &gt; \tilde{w} )</td>
</tr>
<tr>
<td>good-types ( f(k^<em>_B(r)) - \frac{1}{1+r}(k^</em>_B(r) - w) )</td>
</tr>
<tr>
<td>( f(k^<em>_S(w)) - \frac{1}{1+r}(k^</em>_S(w) - w) )</td>
</tr>
<tr>
<td>( f(k^<em>_G) - (k^</em>_G - w) )</td>
</tr>
<tr>
<td>bad-types ( pf(k^<em>_B) + \frac{1}{1+r}(k^</em>_B(r) - w) )</td>
</tr>
<tr>
<td>( pf(k^<em>_B) + (w - k^</em>_B) )</td>
</tr>
</tbody>
</table>

\(^{25}\)The underlying reason why richer agents receive more favourable credit contracts is identical as in all the papers on financial markets imperfections and poverty cited in the Introduction. Namely, since richer agents have more of their own wealth at stake in the projects, their incentives are more aligned with those of lenders.
From the results presented in Table 2.B, this lemma follows,

**Lemma 3** Let \( \Delta(r, w) \equiv U_g(r, w) - U_b(r, w) \). Then: (i) \( \Delta(\cdot) > 0, \forall w, r \geq 0 \); (ii) \( \Delta'(\cdot) < 0, \forall r \geq 0 \) and \( w \in [0, w(\bar{r})] \); (iii) a) \( \Delta'_w(\cdot) > 0, \forall w \in [0, \bar{w}) \) and \( r \geq 0 \); and (iii) b) \( \Delta'_w(\cdot) = 0, \forall w > \bar{w} \).

**Lemma 3** is just the counterpart of **Lemma 1**, when entrepreneurs start their lives with positive wealth. On the one hand, **Lemma 3** shows that **Lemma 1**’s key result \( \Delta'(\cdot) < 0 \) holds as well when \( w > 0 \). On the other hand, it shows that the gap \( \Delta(\cdot) \) is (weakly) increasing in \( w \), which implies that richer entrepreneurs benefit from a larger \( n_t \) more than poorer entrepreneurs do. Furthermore, recall that the larger \( \Delta(\cdot) \) is, the higher the incentives for innovators to invest in R&D - **Lemma 2** and **Proposition 3**. Therefore, \( \Delta'_w(\cdot) > 0 \) entails that, for a given value of \( n_t \) -which, following **Proposition 2**, will determine \( r^*(n_t) \)-, the aggregate distortions generated by the adverse selection problem in the credit market will turn out less severe the wealthier the economy is.

Notice, finally, that economies exhibiting a larger \( n_t \) tend to be richer as well. This is the case because the larger the fraction of active sectors, the higher the average productivity of the economy. As a result, introducing wealth dynamics into the model (by means of bequests, or any other reason that would still generate positive serial correlation in \( w_t \)) will not invalidate any of the main findings of this paper. In fact, as \( n_t \) and wealth affect the economy’s performance in the same direction, the presence of bequests will actually reinforce the dynamics discussed in the previous section.

### 7 Concluding Remarks

This paper has proposed a theory in which financial markets efficiency is a key condition for growth and development. I have suggested that expanding the variety of activities available in the economy may account for a very important factor leading to financial development. In particular, this theory stresses a side-effect associated to the innovation process that had not been explored before, but which could exert significant impact on development. I have argued that innovation can lead to a reduction of agency-costs in financial markets, because by expanding the variety of productive activities in the economy, it concomitantly permits a smoother allocation of skills and thus mitigates adverse selection problems.

The core model that illustrates this theory has made use of several simplifying assumptions. One assumption that may seem particularly worrying is the fact that individuals are born with no initial-wealth. In that regard, Section 6 has shown that none of the model’s main findings would be affected if we allowed agents to be born with positive initial-wealth. Despite not altering its main insights, introducing wealth may carry some additional interesting implications within a more general model. Imagine we gave room for increasing returns to scale and international trade. If sectoral expansion really matters as a mechanism to solve adverse selection problems only at early stages of development
(as suggested by Section 6), then in the presence of increasing returns to scale and international trade, at some point in the development path economies might find worthwhile to revert the diversification tendency and embark in some sort of re-specialisation process. This feature would be in fact consistent with the evidence found in Imbs and Wacziarg (2003), providing a sound explanation for the "non-monotonic" relation between sectoral diversification and income per-head.

From a policy perspective, an important implication of this theory concerns poverty-alleviation programmes. Section 5 has shown that some economies might get stuck in a peculiar type of poverty-trap. This is the result of a "deep-rooted" organisational failure, affecting several markets at the same time. Underdevelopment is characterised by few sectors in which individuals can specialise, inefficient financial markets, and scant innovation activities. The market failure contaminating the operation of the economy stems from the incapacity of some individuals to find the activity for which they are comparatively talented. Most theories on poverty-traps imply that economies can be easily rescued from poverty by receiving a sufficiently large wealth transfer. Instead, my theory suggests that foreign-aid should presumably also include important transfers of technology and know-how, as standard wealth transfers alone might not suffice to suppress the adverse selection problem (at least in a reasonably short time frame).

**Testing the theory:** Table 1 in Section 1.1 has shown that sectoral diversification and financial development are positively correlated, even after removing the possible effect of income shocks. This result conveys important evidence that motivates this paper, yet by no means does that represent an empirical proof of this theory. In particular, it does not prove the fundamental premise put forward in this paper; namely, that sectoral expansion enhances financial markets efficiency, by helping to alleviate informational failures linked to the allocation of skills. Two main empirical difficulties need to be tackled in order to rigorously test this premise. On the one hand, specialisation decisions are endogenous and may itself be affected by financial development through channels that have not been considered in this paper (see, for example, Kalemli-Ozcan et al. [2003]). Dealing with this issue would require finding good instruments for sectoral diversification. On the other hand, even if we counted with these instruments, sectoral differentiation could be fostering financial development because, as proposed by Acemoglu and Zilibotti (1997), it enables better risk-pooling of sectoral shocks. In that regard, we would ideally like to count with an exogenous shock that suddenly shrinks (or increases) the set of productive activities available to agents, without necessarily improving the risk-pooling technology within the country. The European Union (EU) past enlargements in 1981 and 1986 could maybe be exploited as a such shock. In 1981 the EU incorporated Greece, and later in 1986 Spain and Portugal became part EU. At the moment of incorporation, income per-head in those three new members was significantly lower than for the previous EU countries. From Greece, Spain and Portugal perspective, the incorporation to the EU expectably meant a sudden expansion in terms of both product markets and labour markets they would have access to. This expansion in the set of economic activities available to individuals should facilitate the allocation of skills and, consequently, improve the operation of financial
institutions within those new EU members. I let this issue pending for future research.

References


Appendix A: proofs

Proof of Proposition 1. Take two different credit contracts \((l^*, r^*) \in [0, \infty) \times [0, \infty)\) and \((\tilde{l}, \tilde{r}) \in [0, \infty) \times [0, \infty)\), such that \(f'(k = l^*) \geq 1\) and \(f'(k = \tilde{l}) \geq 1\).\(^{26}\) Hence, in equilibrium, all the amount that is borrowed by the entrepreneurs will be invested in the entrepreneurial projects. Accordingly, let’s denote: \(k^* = l^*\) and \(\tilde{k} = \tilde{l}\). Assume that:

\[
 f(k^*) - (1 + r^*)k^* > f(\tilde{k}) - (1 + \tilde{r})\tilde{k}
\]

(P.1.1)

Then, from (P.1.1), if a Type-\(i\) decides to specialise in sector \(i \in A\), he will prefer contract \((k^*, r^*)\) to contract \((\tilde{k}, \tilde{r})\).

Take now an entrepreneur of type-\(j\), such that sector \(j \notin A\). This entrepreneur will specialise (indifferently) in any sector \(h \in [0, 1]\), such that sector \(h \in A\). Given limited-liability, the Type-\(j\) will (weakly) prefer contract \((\tilde{k}, \tilde{r})\) to contract \((k^*, r^*)\), if and only if:

\[
 p[f(\tilde{k}) - (1 + \tilde{r})\tilde{k}] \geq p[f(k^*) - (1 + r^*)k^*]
\]

(P.1.2)

But, since \(p > 0\), (P.1.2) contradicts (P.1.1). Hence, it cannot be true that, while the Type-\(i\) prefers contract \((k^*, r^*)\) to contract \((\tilde{k}, \tilde{r})\), the Type-\(j\) prefers \((\tilde{k}, \tilde{r})\) to \((k^*, r^*)\) instead. Finally, since \((\tilde{k}, \tilde{r})\) and \((k^*, r^*)\) can be any credit contracts; whenever Type-\(i \in A\) prefers \((k^*, r^*)\) to \((\tilde{k}, \tilde{r})\), then Type-\(j \notin A\) also prefers \((k^*, r^*)\) to \((\tilde{k}, \tilde{r})\), and no equilibrium can possibly encompass separating credit contracts among those types.  

Proof of Proposition 2. Eq.(6) follows from the previous discussion in Section 3.2. Then, differentiating Eq.(6) with respect to \(n_t\), we obtain:

\[
 \frac{dr^*_t}{dn_t} = -\frac{1 - p}{[n_t + (1 - n_t)p]^2} < 0. 
\]

Proof of Lemma 2. Assume that the innovator \(i \in [0, 1]\) born at time \(t\) invests \(\iota\) units of capital in R&D. Additionally, suppose he manages to generate a new idea at time \(t + s\), where \(s \in (0, 1)\). This idea could be sold to the Type-\(i\) at any time \(t \in [t + s, t + 1]\). Suppose the Type-\(i\) reaches maturity at time \(t + \sigma\), where \(\sigma \in [s, 1]\). Then, from Lemma 1, it should be straightforward that the innovator \(i\) will charge a price equal to \(\Delta(r^*_t, \sigma)\) to transfer the idea. Making use of Proposition 2, we can write \(\Delta(r^*(n_{t+\sigma}))\). For brevity, denote \(\Delta(r^*(n_{t+\sigma})) = \tilde{\Delta}(n_{t+\sigma})\), where \(\tilde{\Delta}'(n_{t+\sigma}) = \Delta'(\sigma)\frac{dr^*_t}{dn_t} > 0\) (from Proposition 2 and Lemma 1). How is the value \(n_{t+\sigma}\) determined? Assume innovators belonging to \(-A_{t}^{-i}\) choose \(\iota_t\). Then, recalling Eq.(9),

\[
 n_{t+\sigma} = n_t + (1 - n_t)\int_0^\sigma \beta(\iota) d\sigma \quad \Rightarrow \quad n_{t+\sigma} = n_t + (1 - n_t)\sigma \beta(\iota_t)
\]

(L.2.1)

\(^{26}\)It must be straightforward to notice that entrepreneurs only borrow in order to finance entrepreneurial investment. Therefore, in equilibrium, they would never borrow beyond the point \(f'(k) = 1\).
Notice that, because $\beta(\bar{t}_t)$ is bounded away from 1, (L.2.1) implies $n_{t+\sigma}$ is increasing in both $n_t$ and $\bar{t}_t$.

Now, since the age of maturity of any entrepreneur is governed by a uniform distribution over the interval $[0, 1]$, the expected profits generated by an idea created at time $t + s$ will be given by the following expression:

$$E(profits / \iota, I = s) = \int_s^1 \Delta(n_{t+\sigma}) \, d\sigma - \iota = \int_s^1 \Delta(n_t + (1 - n_t)\sigma \beta(\bar{t}_t)) \, d\sigma - \iota \quad (L.2.2)$$

In order to work out the innovator $\iota$’s expected profits function, we still need to take into account the probability that an idea is actually found at time $t + s$. Eq.(9) tells us that, if $\iota$ is invested in R&D, an idea is produced during the interval of time $ds$ with probability $\beta(\iota) \, ds$. This means, $E(profits) = \int_0^1 \beta(\iota) \, E(profits / I = s) \, ds$. Therefore, using Eq.(L.2.2), given the value of $\iota$, we must have that:

$$E(profits / \iota) = \beta(\iota) \int_0^1 \left[ \int_s^1 \Delta(n_t + (1 - n_t)\sigma \beta(\bar{t}_t)) \, d\sigma \right] \, ds - \iota \quad (L.2.3)$$

Finally, let us define

$$\Psi(n_t, \bar{t}_t) \equiv \int_0^1 \left[ \int_s^1 \Delta(n_t + (1 - n_t)\sigma \beta(\bar{t}_t)) \, d\sigma \right] \, ds \quad (L.2.4)$$

From which the it can immediately be deduced that $\Psi(n_t, \bar{t}_t) : [0, 1] \times \mathbb{R}^+ \to \mathbb{R}^+$, with the following properties: (i) $\Psi'_i(\cdot) > 0$, (ii) $\Psi'_i(\cdot) > 0$ whenever $n_t < 1$, (iii) $\Psi'_i(\cdot) = 0$ if $n_t = 1$. Properties (i), (ii), and (iii) derive from the fact that $\Delta'(n_{t+\sigma}) > 0$ and (L.2.1).²⁷ Finally, plugging Eq.(L.2.4) into Eq.(L.2.3), we may write:

$$\Pi_{\iota,t}(\iota_i; n_t, \bar{t}_t) = \beta(\iota_i) \cdot \Psi(n_t, \bar{t}_t) - \iota_i.$$ 

Which is the expression stipulated in Lemma 2. ■

**Proof of Proposition 3. Part I:** Firstly, take two values of $n_t$; $n_0, n_1 \in [0, 1]$, such that $n_0 \neq n_1$. Assume: $\iota_0^* \equiv \iota_0^*(n_0, \bar{t}_t) = 0$ and $\iota_1^* \equiv \iota_1^*(n_1, \bar{t}_t) > 0$; where $\bar{t}_t \geq 0$. Thus, from (10), $\beta'(\iota_0^*)\Psi(n_0, \bar{t}_t) \leq 1$ and $\beta'(\iota_1^*)\Psi(n_1, \bar{t}_t) = 1$. Since, $\beta''(\iota) < 0$, then $\beta'(\iota_0^*) = \beta'(0) > \beta'(\iota_1^*)$. As a result, for $\beta'(\iota_0^*)\Psi(n_0, \bar{t}_t) \leq \beta'(\iota_1^*)\Psi(n_1, \bar{t}_t)$ to hold, it must necessarily be the case that $\Psi(n_0, \bar{t}_t) < \Psi(n_1, \bar{t}_t)$. From Lemma 2, $\Psi'_i(\cdot) > 0$; therefore:

$$\Psi(n_0, \bar{t}_t) < \Psi(n_1, \bar{t}_t) \iff n_0 < n_1.$$ 

Secondly, take a value $n < n_0$. Since $\Psi_n(\cdot) > 0$, then: $\beta'(0)\Psi(n, \bar{t}_t) < 1$. Hence, $\beta''(\iota) < 0$, together with the condition $\iota^*_i [\beta'(\iota^*_i) \cdot \Psi(n_t, \bar{t}_t) - 1] = 0$ stated in (10), imply $\iota^*_i(n, \bar{t}_t) = 0$ for all $n < n_0$.

²⁷ From (L.2.1) we can observe that: $\partial n_{t+\sigma} / \partial n_t = 1 - \sigma \beta(\bar{t}_t) > 0$, and $\partial n_{t+\sigma} / \partial \bar{t}_t = (1 - n_t)\sigma \beta'(\bar{t}_t)$. It is immediate that $(1 - n_t)\sigma \beta'(\bar{t}_t) > 0$ whenever $n_t \in [0, 1)$, and $(1 - n_t)\sigma \beta'(\bar{t}_t) = 0$ if $n_t = 1$. 

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Lastly, given \( (10) \), from (P.3.3) it follows that: \( \beta'(i_t^*) \Psi(n, i_t) > 1 \); because \( \Psi_n'(\cdot) > 0 \). Consequently, given the fact that \( \beta''(i) < 0 \), for all \( n > n_1 \), we must necessarily have \( i_t^*(n, \tilde{i}_t) > i_t^* \), so that \( \beta'(i_t^*(n, \tilde{i}_t)) \Psi(n, \tilde{i}_t) = 1 \) holds. ◆

**Part II:** Proof is analogous to the proof of Part I, where \( \Psi'_n(\cdot) > 0 \) from Lemma 2 must be used instead of \( \Psi'_n(\cdot) > 0 \) all throughout the proof. ■

**Proof of Corollary 1.**

(i) Since, from Proposition 3, \( \Psi'_n(\cdot) > 0 \), setting \( \tilde{i}_t = 0 \) we obtain:

\[
\beta'(0) \Psi(n_t, 0) \leq \beta'(0) \Psi(\pi, 0) = 1, \quad \forall n_t \leq \pi. \tag{C.1.1}
\]

Thus, given \( \beta''(i) < 0 \) and the conditions stated in (10), (P.3.2) entails that \( i_t^* = 0 \) must necessarily prevail for any value of \( n_t \leq \pi \) if \( \tilde{i}_t = 0 \). ◆

(ii) Since \( \Psi'_n(\cdot) > 0 \), it follows that:

\[
\beta'(0) \Psi(n_t, \tilde{i}_t) > \beta'(0) \Psi(n_t, 0) > \beta'(0) \Psi(\pi, 0) = 1, \quad \forall n_t > \pi \text{ and } \tilde{i}_t > 0.
\]

Therefore, in order to comply with (10), \( i_t^* > 0 \) must be true \( \forall n_t > \pi \) and \( \tilde{i}_t \geq 0 \). ■

**Proof of Corollary 2.** Since \( \Psi'_n(\cdot) \geq 0 \), then: \( \beta'(0) \Psi(n_t, \infty) \geq \beta'(0) \Psi(n_t, \tilde{i}_t) \), for all values of \( \tilde{i}_t \geq 0 \) and \( n_t \in [0, 1] \). As a result, if \( \beta'(0) \Psi(n, \infty) = 1 \), it must be true that:

\[
\beta'(i_t) \Psi(n_t, \tilde{i}_t) \leq \beta'(0) \Psi(n_t, \infty) \leq 1, \quad \forall n_t \leq \pi, \text{ and } i_t, \tilde{i}_t > 0. \tag{P.3.3}
\]

Lastly, given (10), from (P.3.3) it follows that \( i_t^* = 0 \) must hold for all values of \( n_t \leq \pi \) and \( \tilde{i}_t \geq 0 \). ■

**Proof of Proposition 4.**

(i) Take an economy in which \( n_0 \leq \pi \). Given Assumption 1, Corollary 1 implies there must exist a SNE for the innovators game in which \( i_0^* = 0 \). On the other hand, Assumption 3 implies that, for any \( n_0 \in [0, 1] \), the SNE for the innovators game is unique. As a result, for any \( n_0 \leq \pi \), \( i_0^* = 0 \) represents the unique SNE.

Since \( \beta(0) = 0 \), then (11) entails that \( n_t = n_0 \leq \pi \) for all \( t \in [0, 1] \). As a consequence, at \( t = 1 \) conditions for the innovators game remain identical as they were at \( t = 0 \); thus, \( i_1^* = 0 \) represents the unique SNE at \( t = 1 \). Finally, repeating the same argument \textit{ad infinitum}, it follows that: \( n_t = n_0 \ \forall t \geq 0 \) and \( i_t^* = 0 \ \forall \tau \in \{0, 1, \ldots, \infty\} \). ◆

(ii) Take an economy where \( n_0 > \pi \). Given Assumption 1, Corollary 1 implies that \( i_t^*(n_0, 0) > 0 \). As a result, there must necessarily exist a SNE for the innovators game in which \( i_0^* > 0 \). Given Assumption 3, \( i_0^* > 0 \) must represent the unique SNE.

---

\(^{28}\) From Eq.(L.2.4) and the fact that \( \beta(0) = 0 \), it can be observed that: \( \Psi(n_t, 0) = \Delta(r^*(n_t)) \int_0^1 (\int_0^1 d\sigma) ds = \Delta(r^*(n_t))/2 \).
Since \(t^*_0 > 0\), from (11) it follows that \(n_\delta = n_0 + \beta(t^*_0)(1 - n_0)\delta\), where \(\delta \in [0, 1]\). Hence, \(n_\delta > n_0, \forall \delta \in (0, 1]\). In particular, this leads to \(n_1 > n_0 > n\). Proposition 3 then implies that \(t^*_1 > t^*_0 > 0\). As a result of this, \(n_{1+\delta} > n_1, \forall \delta \in (0, 1]\). Repeating this argument ad infinitum, we can observe that: \(n_\infty < n_0 < n_1 < n_2 < \ldots < n_\infty\). Furthermore, since \(\beta(t^*_\tau)(1 - n_\tau)\delta \to 0\) as \(n_\tau \to 1\), and \(\beta(t^*_\tau)(1 - n_\tau)\delta\) is bounded away from zero for any \(n_\tau \in [0, 1]\); then it can be deduced that \(\lim_{\tau \to \infty} n_\tau = 1\). ■

Appendix B: Descriptive Statistics for Section 1.1

Financial Indicators (source: Beck, Demirgüç-Kunt and Levine [1999]):

Stock Market Value Traded to GDP: It equals the total value of shares traded on the stock market exchange divided by GDP.

Stock Market Capitalisation to GDP: It equals the total value of listed shares divided by GDP.

Liquid Liabilities to GDP: it equals currency plus demand and interest-bearing liabilities of banks and other financial intermediaries divided by GDP.

Private Credit by Financial Institutions to GDP: It equals claims on private sector by deposit money banks and other financial institutions divided by GDP.

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<th>Std. Dev.</th>
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<th>Max</th>
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<td>SMVT/GDP</td>
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Summary of Correlations

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Summary of Statistics for Table 1 and Table 2