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WAS PROMETHEUS UNBOUND BY CHANCE?
RISK, DIVERSIFICATION AND GROWTH

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Abstract

This paper offers a theory of development which links the degree of market incompleteness to capital accumulation and growth. At early stages of development, the presence of indivisible projects limits the degree of risk-spreading (diversification) that the economy can achieve. The desire to avoid highly risky investments slows down capital accumulation and the inability to diversify all the idiosyncratic risks introduces high uncertainty in the growth process. As a result of these forces, the typical development pattern of a society will consist of a lengthy period of "primitive accumulation" followed by take-off and financial deepening and finally, steady growth. "Lucky" countries will spend relatively less time in the primitive accumulation stage while with sufficiently risk-averse agents, economies that receive a series of unlucky draws may get locked into underdevelopment. We also identify a pecuniary externality as a source of inefficiency in the decentralized equilibrium that makes the average speed of development suboptimal. Further, it is shown that our results generalize to an open economy and that capital flows may increase or reduce the rate of industrialization.

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1) Introduction

"The advance occurred very slowly over a long period and was broken by sharp recessions. The right road was reached and thereafter never abandoned only during the eighteenth century and then only by a few privileged countries. Thus, before 1750 or even 1800 the march of progress could still be affected by unexpected events, even disasters." F. Braudel (1962), p. xi.

This view of slow and uncertain progress between the tenth and early nineteenth century is shared by many economic historians, for instance North and Thomas (1973) who describe the fourteenth and fifteenth centuries as times of *"contractions, crisis and depression"* (p. 71) or De Vries (1990) who refers to this period as *"The Age of Crisis"*. The same phenomenon is observed today; Lucas (1988) observes that whereas *"within the advanced countries, growth rates tend to be very stable over long periods of time..."*, for poorer countries *"...there are many examples of sudden, large changes in growth rates, both up and down."* (p.4). Furthermore, for many of these countries, the process of development is painfully slow. Why are the early stages of development slow and subject to so much randomness? The models of economic development based on threshold effects, e.g. Azariadis and Drazen (1990), may predict the slow progress at the early stages of development but without additional assumptions have no implications about randomness of growth. This paper in contrast argues that these patterns are predicted by the neoclassical growth model augmented with the natural assumptions of micro level indivisibilities and micro level uncertainty. In particular, we link the availability of diversification opportunities to the incompleteness of markets which in turn depends on the process of capital accumulation. We show that such links both make the early stages highly random and, by endogenously reducing the rate of return on savings, slow down development.

We start from a number of observations that will be elaborated and empirically supported in the next section. Firstly, most economies have access to a large number of imperfectly correlated projects, thus a significant part of the risks they face can be diversified. Secondly, a large proportion of these projects are subject to significant indivisibilities, especially in the form of *minimum size requirements* or *start-up costs*. Thirdly, agents normally dislike risk. Fourthly, there often exist investment opportunities that are less productive but relatively safe. And finally, societies at the early stages of development have less capital to invest than developed countries. These features naturally lead to a number of important implications. **(i)** at the early stages of development, due to the scarcity of capital, only a limited number of imperfectly correlated projects can be undertaken and agents will seek insurance by investing in safe but less productive assets. As a result, poor countries will endogenously have lower productivity and this will contribute to their slow development. **(ii)** since a large part of the savings are invested in safe investments, the more productive ventures that are undertaken will bear more of the diversifiable risks. This will make the earlier stages of development highly random. It will also slow down economic progress even further, because many runs towards progress will be stopped by crises and failed take-offs. **(iii)** chance will play a very important role;

economies that are lucky enough to receive good draws at the early stages will have more capital, thus will achieve better risk-diversification and higher productivity. Therefore, although Prometheus will not be unbound accidentally, chance will always play a key role in his unchaining and may even condemn him to permanent imprisonment.

In our model, agents decide how much to save and how much of their money to invest in a safe asset with lower return. The rest of the funds are used to invest in imperfectly correlated risky projects. However, not all risky projects are available to agents at all points in time because of the minimum size requirements that affect some of these sectors. The more "sectors" (projects) are open, the higher is the proportion of the savings that agents are willing to put in risky investments. In turn the higher is the capital stock of the economy, the higher are the incomes and savings, and the more sectors can be opened; thus development goes hand in hand with the expansion of markets and better diversification opportunities. However, this process is full of perils, because with limited investments in imperfectly correlated projects, the economy is subject to considerable randomness and spends a long time fluctuating in the stage of low accumulated capital. At this stage economies that receive "lucky draws" will grow while those that are unfortunate enough to receive a series of "bad news" will stagnate. As the lucky economies grow, the take-off stage will be eventually reached and a larger stock of savings will be made available to be invested in productive investments, or to use Braudel's terms, to *"open the sluice-gates"* of the economy. Over the course of take-off, the number of projects expands quickly, and the induced financial development provides better opportunities for diversification. Eventually, industrial growth is reached with idiosyncratic risks being completely diversified and *"the right road thereafter will never be abandoned"*.

That take-off will eventually occur is due to the feature that the equilibrium path of our baseline economy is unique and the stochastic process associated with it has a unique ergodic set that corresponds to full diversification and "industrialization"; all economies will eventually reach this stage and they will never abandon it. However, we show that this feature only arises when preferences induce a sufficiently low rate of relative risk aversion. With more risk-aversion, the equilibrium stochastic process no longer has a unique ergodic set. This implies that economies that receive a series of unlucky draws may fall to a region from where no escape is possible, thus they will be trapped in underdevelopment. It has to be noted that the nature of this underdevelopment trap is quite different from others in the development literature that are mainly driven by the form of the technology (e.g. Boldrin (1992), Matsuyama (1991)). In our case, although the sectoral indivisibilities are important, it is the attitudes towards risk that condemn an economy to underdevelopment; when only a few sectors can be opened, risk-averse agents are willing to invest a limited amount in risky assets and aggregate productivity is low.

Theoretically our model corresponds to a general equilibrium economy with an endogenous commodity space because the set of traded financial assets (or open sectors) is determined in equilibrium. We use the competitive equilibrium concept suggested by Makowski (1980) for this type of economies. This equilibrium is Walrasian conditional upon the number of sectors that are open; therefore all agents are still kept as price-takers and there are no unexploited gains in any activity. We find that despite the innocuous and simple form of the indivisibilities in this economy, the competitive economy is inefficient and this inefficiency will take the form of too few projects being undertaken. The underlying problem is that each sector creates a positive "*pecuniary externality*" on other open sectors as consumers now bear less risks when they buy the shares of these sectors. Not only do we show that the competitive equilibrium is inefficient but we also establish the stronger result that there is no decentralized market structure that can avoid this inefficiency.

It may be conjectured that since our mechanism is related to capital shortages, its validity will be limited in the presence of international capital flows. We turn to this problem in section 6 and identify two factors that need to be taken into account. Decreasing return technologies would make foreign capital flow towards poor economies, and yet, domestic capital would also flow out towards richer countries in order to obtain outside insurance. To discuss these issues, we extend our model to a two-country world. In this case the problems that our paper emphasizes do not disappear and the general pattern of development in this two-country world takes an interesting form that matches the historical facts of the development of Western Europe (see Neal (1990)); at the early stages, capital flows more into one of the countries, thus capital flows create divergence; but as the world economy becomes richer, the direction of capital flows is reversed and as a result, the rate of convergence increases. Yet, we also show that in many cases, the outflow of domestic capital for the purpose of outside insurance, which is quite common in practice, will be harmful to industrialization and to the welfare of future generations.

Our model is related to the growing literature on credit and growth (among others Bencivenga and Smith (1991), Greenwood and Jovanovic (1990), Greenwood and Smith (1993) and Zilibotti (1994)). These papers make valuable contributions but derive most of their dynamic effects from the presence of fixed costs. Our model, instead, concentrates on the diversification role of the credit markets (as emphasized by Gurley and Shaw (1955)) and argues that better diversification opportunities enable the allocation of funds to the most productive investments. One result is that in the presence of micro-level non-convexities (but without fixed costs of financial intermediation), endogenous dynamics that link economic growth to financial deepening are introduced. The paper most closely related to ours is Saint-Paul (1992) who discusses the insurance (risk-diversification) role of the stock market. Saint-Paul's main argument is that when stock market insurance is possible, there will be more productive specialization. Our paper differs from his in a number of important ways; the degree of diversification is endogenized, the dynamic interaction between the degree of market incompleteness and growth is investigated and the implications for the role and evolution of randomness in development are derived. Also none of the above papers investigate the links between credit markets and international capital flows. Another literature that relates to our paper is the one pioneered by Allen and Gale (1988,1991) where the incompleteness of markets is endogenized by introducing costs of issuing financial securities (see also Bisin (1994) and Pesendorfer (1991)). In our model too, the market structure is endogenized, but without explicit costs of issuing securities and the main focus is on the interaction between the incompleteness of markets, the opportunities for diversification open to agents and the process of development.

The plan of the paper is as follows. The next section discusses some historical and empirical motivation to this investigation. Section 3 lays out the basic model and characterizes the equilibrium. Section 4 shows why the decentralized equilibrium is not Pareto efficient and characterizes the Pareto optimal allocation. Section 5 shows that in the presence of a rate of relative risk-aversion greater than one, poverty traps are possible. Section 6 presents an open economy extension of the model in which international capital flows are allowed. Section 7 concludes.

2) Motivation and Historical Evidence

Many economic historians (e.g. Braudel (1962,1979), North and Thomas (1973), De Vries (1990)) emphasize that countries at the early stages of development experienced high degrees of uncertainty. McCloskey (1976) calculates the coefficient of variation of output net of seed in Medieval England at 0.347 and that "famines" were occurring on average every 13 years. Part of the variability was certainly due to the fact that agricultural productivity was largely dependent on weather, but this heavy reliance on agriculture is itself a symptom of an undiversified economy. Additionally, there is considerable evidence that non-agricultural activities were also subject to large uncertainties. Braudel describes the development of industry before 1750 as *"subject to halts and breakdowns"* (1979, p.312) and points out the presence of failed take-offs. More specifically, he documents *"three occasions in the West when there was an expansion of banking and credit so abnormal as to be visible to the naked eye* (Florence 1300s, Genoa late 1500s and Amsterdam 1700s)...*three substantial successes, which ended every time in failure or at any rate in some kind of withdrawal."* (1979, p. 392). Also the pattern of these failures is informative; these cities grew gradually by expanding the scope of industrial and commercial activities and the collapse took the form of an abrupt end ignited by a few bankruptcies. This is suggestive of large undiversified risks whose resolution impacts significantly on the rest of the economy[1].

And also today, poor countries exhibit considerably higher variability of output (and of consumption) than more developed economies. To support this claim, we estimate an AR(2) process

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[1] Among the historical examples of sparks that triggered more widespread failures, we can recall the Spanish state default of 1557 which led to the decline of Genoa and Antwerp (Braudel (1984, p. 153)) , the Clifford bankruptcy of December 1772, the starting episode of the crisis of Amsterdam (Braudel (1984, p. 271), or more recently the Austrian Bourse Crash of 1873 (Rudolph (1972, p.29)).

for the growth rate of income per capita for each country, using annual data for 117 countries for the period 1960-85 from the Summers and Heston (1991) Dataset. Formally, for each country, we ran the regression equation $\Delta \log GDP_{i,t} = \alpha_{(0,i)} + \alpha_{(1,i)} \Delta \log GDP_{i,t-1} + \alpha_{(2,i)} \Delta \log GDP_{i,t-2} + \epsilon_{i,t}$. The innovation obtained from this equation, $\epsilon_{i,t}$, is then used to calculate the variability of the growth rate for the corresponding country. We consider two different samples of countries. The former includes the whole set of 117 countries, the latter only a subset of them, excluding those five countries whose estimated standard deviation of the innovations exceeds 0.10 (Iran, Iraq, Gabon, Somalia and Uganda), since we suspect political unrest and wars to have been the main source of their exceptionally high variability. In Figure 1, using the smaller sample, we plot the (log of) GDP per capita in 1960 on the horizontal axis and the (log of) the standard deviation of the innovation $\epsilon_{i,t}$ for the corresponding country on the vertical axis. The solid curve traces the regression line of the (log) standard deviation on (log) GDP1960. In particular, after controlling for an outlier (i.e. Indonesia, a very poor country in 1960 which has grown at a very steady rate), the regression coefficient is -0.26 (tstat = -5.41) with the larger sample, and -0.25 (t-stat = -5.74) with the smaller sample. The goodness of fit is $R^2=0.208$ for the first and $R^2=0.232$, for the second[2].

Analogous results are obtained by pooling cross-sectional and time series information. We consider pairs of observations $\{GDP_{t,i}\ ,\ |\epsilon_{t+1,i}|\}$, that is the GDP at time t and the absolute value of the one period-ahead growth innovation in country i as obtained above (we have 117x23 such pairs). We then fix some threshold income levels and divide the panel of innovations into four groups according to increasing GDP ranges, i.e. $\{|\epsilon_{i\cdot,t\cdot+1}|\} \in \{GROUP_k\}$ *iff* $\bar{x}_k < GDP_{i\cdot,t\cdot} < \bar{x}_{k+1}$ where $\{\bar{x}_k\}$ k=1,2,3,4 denote the thresholds. Finally, we compute the sample mean for the (pooled) absolute value innovations belonging to each group. The results are reported in table 1, with the standard error of the mean in brackets (GDP per capita in US Dollars 1980 for all countries). The first column shows that the average size of innovations is decreasing with the income range, i.e. lower income ranges are associated with higher variability than higher income ranges.

GDP Range	*Avg. (innov) No control FE*	*Avg. (innov) Control FE*	*N° Obs*
$0<GDP_{i,t}<700$	0.046 (0.0025)	0.007 (0.0048)	404
$700<GDP_{i,t}<1500$	0.044 (0.0016)	0.006 (0.0030)	687
$1500<GDP_{i,t}<4500$	0.039 (0.0014)	0.000 (0.0026)	894
$4500<GDP_{i,t}$	0.028 (0.0013)	-0.010(0.0023)	706

Table 1. Variability of growth rate innovations (panel).

[2] To control for the possible convergence effects in this cross-sectional regression, we added a deterministic polynomial trend to the AR(2) that we ran for each country and this was found not to change the results. Nor did the inclusion of the average growth rate as a regressor change the significant negative coefficient of the initial GDP. A source of concern may be that measurement error could be larger for poorer economies. Yet, this is unlikely to lead to as strong and significant a relation as shown in Figure 1. Thus we interpret the evidence as very supportive of the main implication of our theory.

FIGURE 1 HERE

In the second column (*Control FE*), we report the sample averages for the corresponding income ranges after controlling for fixed country and time effects, by subtracting from each observation the respective country and the time means (averaged across t and i, respectively). Since we compute deviations from averages, some observations will now be negative. As the results show, the negative correlation between GDP levels and growth variability remains. Since country averages have been removed, this finding suggests that our results are not only driven by cross-country variations, but the time series variations are also consistent with our prediction[3].

Recent empirical work by Quah (1993, 1994), and Benhabib and Gali (1994) provide further evidence supportive of the general implications of our model. On the one hand it seems difficult for very poor countries to achieve growth and improve their condition. On the other, the probability for a country to experience "set-backs" is a decreasing function of its (relative) income level. Quah (1993) studies the cross country dynamics of growth by estimating a Markov chain transition matrix by classifying the countries in four groups according to their GDP per capita relative to the world average (Table 1, p.431). Table 2 below report a summary of his results for a 23-year transition matrix 1962-1985 (where x denotes GDP per capita relative to the world average):

	Prob(↓)	Prob(=)	Prob(↑)
$x<1/4$	-	0.76	0.24
$1/4<x<1/2$	0.52	0.31	0.17
$1/2<x<1$	0.29	0.46	0.26
$1<x<2$	0.24	0.53	0.24
$2<x$	0.05	0.95	-

Table 2. Estimated 23-year transition matrix (Quah 1993, p.431).

In the three different columns, we report the estimated probability that a country belonging to a certain group falls to a relatively poorer group, remains in the same group, or moves up to a richer group, respectively. Observe that the probability for a country to get worse decreases as we consider higher income groups (also found by Benhabib and Gali (1994, p. 11)). These findings give further support to the claim that the process of development is "full of perils" at the earlier stages.

From a different perspective, some recent empirical work on financial development and growth points at a decreasing relation between risk-premia and development. More precisely, Sussman (1993), Sussman and Zeira (1993) and Zilibotti (1993) show that the gap between borrowing and lending rates applied by banks - which can be taken as a proxy for risk-premium -

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[3] It should also be reported that regressions of the (log) of absolute value of innovations over the (log of) lagged GDP per capita also give encouraging results. The point estimate of the coefficient of lagged GDP is -0.20 (tstat=-8.91) when only a constant is included, and -0.35 (tstat = -2.6) when we control for country and time effects. Yet, note that the non-stationarity of the regressor, the level of GDP, in this case raises some inference issues the discussion of which is beyond the scope of this informal analysis.

are negatively correlated with the income level across countries, and across regions and time in the United States. These findings give further support to the mechanism proposed in this paper.

A possible explanation for the decreasing variability (and for the decreasing risk-premia) is technological. Countries at the early stages of development may only have access to technologies that are risky and low productivity (e.g. agriculture). This however does not seem to be the whole story. The adoption of new technologies is more often subject to economic as well as scientific constraints. North and Thomas (1973) and Rosenberg and Birdzell (1985) argue that many of the technologies that were later used in improving agricultural productivity were actually known in Medieval Europe and attribute the failure to adopt these technologies earlier to the lack of monetary incentives. Hobsbawm (1968) goes even further and asserts that there was nothing new in the technology of the British Industrial Revolution and most of the new productive methods could have been developed at least 150 years before.

On the other hand, as an obstacle to expansion and growth, capital scarcities and limited savings appear important in many instances. Bagehot (1873, p.4) more than a century ago argued that indivisibilities and capital shortages were a significant hurdle to overcome, in his words, "*...in poor countries, there is no spare money for new and great undertakings..*", even when they were very promising. Gerschenkron (1962, p.14) also echoed the same view in writing; "*...in a relatively backward country capital is scarce and diffused, the distrust of industrial activities is considerable and finally there is greater pressure for bigness...*". The size of the required activity was certainly a relevant factor in the minds of innovators; Scherer (1984, p.13) quotes Boulton, James Watt's partner, writing to Watt that the production of the engine was not profitable for just a few countries but would be so if the whole world were the market. In line with the view of capital constraints, certain economic historians, for instance Wrigley (1988), argue capital shortages that led to shortages of energy to be the main reason for heavy reliance on agriculture and a key constraint on industrialization, while a large part of the development literature, implicitly or explicitly, defines underdeveloped countries as those that have shortages of capital (see for instance Viner (1958), Singer (1958), Lewis (1958))[4].

The mechanism which we offer in this paper is crucially related to the attitudes towards risk.

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[4] The important empirical question of course concerns at what level the indivisibilities (non-convexities) and the savings constraint will apply. For instance, the start-up investment for an industrial activity will definitely be too large for a single village or even town. However, if all the resources of Medieval Europe or even those of a small developing country today were pulled together, it is unlikely that many sectors would have binding minimum size requirements. On the other hand, both actual transaction costs and those created by incentive and enforcement problems imply that the relevant unit of accumulation will often not be a whole continent nor even a whole country. Identification of the relevant unit of accumulation is at the heart of the empirical relevance of this question and does not have an easy answer. The regressions reported above for instance takes it as given that political borders are related to the size of the accumulation unit - though this relation may be quite imperfect.

Risk-aversion is recognized as an important factor in economic behavior, witness for instance the institutions developed in many societies to deal with the problems of insurance and risk-pooling (Persson (1988), Townsend (1990)). It is then natural that agents will try to reduce the risk they bear, even when this has a cost in terms of expected return. In our model, when diversification opportunities are limited, agents choose investments which are safe but less productive, for instance, the storage technology and the scattering of fields widely used in Medieval Europe, both of them chosen because of their relative safety[5]. Braudel emphasizes that unproductive hoarding (storage) frequently occurred in poor undiversified economies subject to capital shortages. More specifically he writes (1979, p.386); *"Every society accumulates capital which is then at its disposal, either to be saved and hoarded unproductively, or to replenish the channels of the active economy... If the flow was not strong enough to open all the sluice-gates, capital was almost inevitably immobilized, its true nature as it were unrealized"*. The pattern of change in the portfolios between the eighteenth and 19th century Britain also illustrates how the use of relatively safe assets has decreased as the array of available assets has expanded and the income level has increased, thus giving agents better diversification opportunities through a wider variety of risky assets (see Kennedy (1987), table 5.1).

Finally, this paper stresses that at early stages, lack of diversification gives an important role to "luck". In particular, we emphasize that if large and risky investments undertaken at early stages are successful, the economy grows, more risk-diversification becomes possible and new projects can be undertaken. Here the historical role of the railways can be viewed as an example of the importance of the success of large projects in opening the way to steady growth. For instance, according to Alfred Chandler (1977), railways constituted a turning point in the historical development of US capitalism because after the efforts of the Wall Street to raise the necessary funds required for the large railway investments, it was also possible to finance other large scale projects (although the main aspect emphasized by Chandler is that Wall Street "learned-by-doing" to cut big deals). On the other hand, Spanish railroads attracted more than 15 times the amount invested in all other manufacturing in Spain by the end of 1864; but, in contrast to the US experience, the returns in the second half of the nineteenth century were very disappointing and all the sectors of the economy suffered turmoil and capital scarcities as a result of these heavy losses in railways (Tortella (1972, pp. 118-121)). Regarding this episode and a similar one in Italy, Cameron (1972, p. 14) writes, *"Spain in the 1850's undertook a vigorous program of railway construction and financial promotion not unlike the later Russian program; Italy did the same in the 1860's. But in both cases the result was a fiasco which set back the progress of industrialization and economic development by at least a generation."* Another case of a large project's destiny getting interwoven with that of

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[5] Storage is widely believed to be common in Medieval Europe and yet McCloskey and Nash (1976) argue that storage was scarcely used but interpret the open field system and scattering of cultivation as an inefficient technology adopted for insurance reasons.

the whole economy is that of the Dutch versus the English East India companies (see Neal (1990) and an earlier version of our paper for discussion).

3) The Basic Model and the Decentralized Equilibrium

We consider a simple overlapping generations model with non-altruistic agents who live for two periods. There is a continuum of agents normalized to 1 in each living generation and agents of the same generation are all identical. The production side of the economy consists of a single final good sector and a continuum of intermediate sectors normalized to 1. The final good sector transforms the capital and labor of the economy into final output. The intermediate sectors transform savings of time t into capital to be used at time t+1 without using labor.

In their youth, our agents work in a final sector firm, receiving the competitive wage rate of this sector. At the end of this period they take their consumption and saving decision. This decision entails how much to save and how much of their savings to put in a safe asset. The safe asset has a non-stochastic rate of return equal to r, therefore one unit of capital at time t is transformed into r units of capital at time t+1. Alternatively, they can invest part of their savings in some of the risky projects of this economy. After the investment decisions, the uncertainty unravels and the amount of capital that is brought forward to the next period is determined. The capital that agents own in their retirement period is rented by final sector firms and old agents consume the rent they receive. Figure 2 summarizes the sequence of events in our model.

FIGURE 2 HERE

The crucial issue concerns the form of the uncertainty. For this, we assume that there is a continuum of equally likely states (again with measure normalized to 1) and project j pays only in state j. More formally, let $g_j(F_j)$ denote the return from asset j when an amount F_j is invested. Then:

$$g_j(F_j) = \begin{cases} \lim_{dj \to 0} \frac{R}{dj} F_j & \text{if state } j \text{ occurs and } F_j \geq M(j) \\ 0 & \text{otherwise} \end{cases}$$

where $R > r$. Also if we denote the probability density function over states by $v(j)$, since all states are equally likely, we will have $v(j)=1$, for all j. To start with, ignore the second requirement that $F_j \geq M(j)$; then, investing in a sector is equivalent to buying a Basic Arrow Security that only pays in one state of nature. This formalization is adopted for mathematical convenience and captures two features that will drive all our results; first, the risky investment has a higher expected return than the safe asset (since $R>r$); second, different risky investment projects are imperfectly correlated so that there is safety in numbers. Other formulations with these two features will also yield all the main results of the paper. A convenient implication of this formulation is the following; a \$1 equiproportional investment in a proportion p of projects (thus a total of \$p invested) will yield \$R with probability p and zero with probability 1-p. Formulated in this way the allocation problem of the economy is straightforward: invest all the savings in each of the risky sectors simultaneously. This result will also be true in more general models as long as all these sectors exhibit decreasing or constant returns to scale. However, in the presence of some projects with non-convexities, a trade-off is introduced between diversification and high productivity. In our case, this trade-off will arise due to the presence of M(j), the minimum size requirements. Thus, the technology of this economy implies that all intermediate sectors exhibit constant returns to scale but some sectors require a certain size (M(j)) before being productive. We also assume that the distribution of minimum size requirements, M(j), is given by (see Figure 3 for a diagrammatic representation):

$$M(j)=Max\left\{0,\ \frac{D}{1-\gamma}(j-\gamma)\right\}$$

This specification implies that all sectors $j \leq \gamma$ have no minimum size requirement and for the rest of the sectors, the minimum size requirement increases linearly. Our results are not however dependent on this linear specification[6], and the ranking of projects from lower to higher size is without loss of any generality and imposes no timing constraint; any project can be adopted first, but obviously in equilibrium, sectors with smaller minimum size requirements will be opened before the others. Also note that the minimum sectoral size requirements introduced here may be thought as operating at either the firm or the sectoral level.

Preferences over final goods

The preferences of consumers over final goods is defined as

$$E_t U(c_t,c_{t+1})=\log c_t+\beta\int_0^1 \log c_{t+1}^j dj \tag{1}$$

where j represents the states of nature which are assumed, as noted above, to be equally likely. Each agent discounts the future at the rate β and has logarithmic preferences which will give us a constant saving rate. Note that, although the realization of the state of nature does not influence the productivity of the final good sector, the final consumption of our representative agent depends on this since it determines how much capital he takes into the final good production stage.

[6] Except the result we will obtain in section 5 that the value of 1 for the relative degree of risk-aversion is a critical level above which underdevelopment traps are possible. With a different functional form for M(n), the critical value of the relative rate of risk aversion would be different.

Final good production technology

Output of a typical final good producer is given by

$$y_t = Ak_t^{\alpha} l_t^{1-\alpha} \tag{2}$$

where lower case letters denote the levels hired by this firm.

Bearing in mind that the labor and capital markets are competitive and that aggregate labor supply is equal to 1, the relative prices of these factors, respectively w_t and ρ_t, are obtained as

$$\begin{aligned} w_t &= (1-\alpha)AK_t^{\alpha} \\ \rho_t &= \alpha AK_t^{\alpha-1} \end{aligned} \tag{3}$$

Organization of the Stock Market

We will think of each intermediate sector as represented by a set of firms that sell the particular Arrow security and compete "a la Bertrand" by calling prices P^j for each unit of security (one unit of security entitles the holder to R units of t+1 capital in state j) and each agent decides how much of each traded security to buy. Naturally, for the sectors that have binding minimum size requirements only one firm will be active but the potential of competition will force it to make zero profits (see below for the precise equilibrium concept). For simplicity we assume that intermediate firms function without using any additional resources. The intermediate sector trading can be thought as a stock market, but for our present purposes this can also correspond to a situation in which a financial intermediary collects the funds from the consumers (again by selling similar securities) and then lends it directly to firms.

In the analysis of this section, we will assume that inter-firm share trading is not allowed. This assumption will rule out the situation where some firm or intermediary can buy-up the whole "security market" and in essence, it will act as a restriction that financial intermediaries are only allowed to offer Basic Arrow Securities. Although at this stage this looks quite *ad hoc*, it is actually no more than a simplifying assumption that enables us to derive the main results using a simple concept of equilibrium. In section 4, it will be shown that a natural refinement of our equilibrium concept will make this assumption redundant.

An immediate implication of competition among financial intermediaries and of ruling out inter-firm share trading is that investors will face a constant (linear) price for each share equal to the marginal cost of supplying it; thus $P^j=1$ for all securities that are traded. To see this note that Bertrand competition will lead to zero profits and in the absence of inter-firm share trading, this implies zero profit in each state of nature. If a firm demands a price higher than \$1 for any unit of its security, a competitor can enter and undercut this price. The same applies if a firm pays less than \$R when it is successful and since firm j is not allowed to hold shares of other firms, it has to pay zero in all states of nature other than j.

The Equilibrium Concept

A competitive equilibrium for this economy is defined as a proportion of open sectors and a price function that assigns a price level to each open sector. All agents act as price-takers and the number of open sectors is determined from a zero-profit condition. More formally;

Definition 1: Consider the vector $\left(n_t^*, \{P_t^{*j}\}_{0\leq j\leq n_t^*}\right)_{t\geq 0}$ where n_t^* denotes the proportion of open sectors and P_t^* prices of securities at time t. This vector characterizes an equilibrium iff
(i) $ed_t^j(n_{t*}, P^*)=0$ for all $j \leq n_t^*$ (supply is equal to demand in all the open (n_t^*) sectors);
(ii) no additional firm can enter at any time, offer a security conditional on a feasible production plan and make positive profits even if consumers re-optimize.

Note that we have defined the equilibrium as a dynamic concept. However, we will see that because of the limited intertemporal interaction, the equilibrium prices and the measure of active sectors can be determined separately for each period, conditional upon the earned income of the old generation. The relation of this equilibrium concept to others is discussed in section 4.

Individual Maximization Problem

We denote the saving of each individual at time t by s_t, the amount they devote to the safe asset by ϕ_t and their investment in sector j by F_t^j. Since we have a representative agent model, these also correspond to their respective aggregate amounts. Also we denote the proportion of sectors open at time t by n_t. Each agent solves the following maximization problem

$$\max_{s_t,\phi_t,\{F_t^j\}_{0\leq j\leq 1}} \log c_t + \beta\int_0^1 \log c_{t+1}^j \, dj \tag{5}$$

subject to

$$\phi_t + \int_0^1 F_t^j \, dj = s_t \tag{6}$$

$$c_{t+1}^j = \rho_t^j (r\phi_t + RF_t^j) \tag{7}$$

$$F_t^j = 0 \ \textit{for all} \ j > n_t \tag{8}$$

$$c_t + s_t \leq w_t \tag{9}$$

and taking w_t, n_t and ρ_t^j as given, ρ_t^j denoting the marginal product of capital in state j at time t. Note also, in writing the budget constraint of the individual consumer, we have used the fact that $P_t^j = 1$

for all j that is traded. It is particularly important to note that n_t is taken as given by these price taking individuals and will be determined by competition among intermediate sector firms and the aggregate resource constraint that is obtained by summing (6) across all individuals. Using (8), this aggregate constraint is expressed as

$$\int_0^{n_t} F_t^j dj = s_t - \phi_t \tag{10}$$

Finally, the marginal product of capital in equilibrium is determined as $\rho_t^j = \alpha A(r\phi_t + RF_t^j)^{\alpha-1}$.

Individual Decision Rules

From logarithmic preferences we directly obtain the following saving rule

$$s_t = \frac{\beta}{1+\beta} w_t \tag{11}$$

In other words, the logarithmic specification implies that the exact risk-return trade-off will not influence their saving rate. Before we move to the characterization of the individual's portfolio decision, we state a simple Lemma that will be important throughout our analysis[7];

Lemma 1: Let J(t) be the set of securities traded in equilibrium at t; then $F_t^j = F_t^{j'} \quad \forall\, j, j' \in J(t)$.

The main idea of this lemma is that, because of Bertrand competition in the stock market, each individual is facing a constant price for each of these symmetric Basic Arrow securities and therefore would want to purchase an equal amount of all the securities that are being traded. Therefore, when $j \le n_t$ sectors are open, it will follow that $F_t^j = F_t$. Now noting that the second period utility is given by $\int_0^1 \log[\rho_t^j (RF_t^j + r\phi_t)]dj = n_t \log[\rho_t^1 (RF_t + r\phi_t)] + (1 - n_t)\log[\rho_t^0 (r\phi_t)]$ with ρ's treated as given by the individual, the maximization problem can be written as

$$\max_{\phi_t, F_t} \; n_t \log(RF_t + r\phi_t) + (1 - n_t)\log(r\phi_t) \tag{12}$$

subject to $s_t = \phi_t + n_t F_t$ where again n_t is treated as a parameter. Maximization yields the following decision rules;

[7] Since we have a maximization problem with respect to a continuum of choice variables, all our claims should be read as "almost everywhere". However, this technical detail does not affect any of our results. The proofs of Lemma 1, Propositions 1-3, and Corollaries 1-3 are in Appendix A, the proofs of Lemmas 2-6 and Proposition 4-7 that are longer and more cumbersome are provided in the Appendix B, available from the authors.

$$\phi_t = \frac{(1-n_t)R}{R-rn_t} s_t \tag{13}$$

$$F_t^j = \begin{cases} \dfrac{R-r}{R-rn_t} s_t & \forall j \leq n_t \\ 0 & \forall j > n_t \end{cases} \tag{14}$$

Equation (14) is expressed diagrammatically in Figure 3 as a relationship between a pseudo-aggregate demand for each risky asset (solved for the equilibrium price) and the number of sectors that are already open. It is clear from both the diagram and equation (14) that the demand for each asset grows as the measure of sectors that are open increases. This is due to the fact that the more sectors are open, the better are the risk diversification opportunities and the more willing are the consumers to further reduce their investments in the safe asset and increase their investments, F_t^j, in the risky projects that are available to them.

We also make an assumption to ensure that risky investments are sufficiently productive relative to the safe asset. This will guarantee the uniqueness of the equilibrium path. It will be shown in section 5 that with a refinement of our equilibrium concept, multiplicity of equilibria will never arise and assumption (A) will be unnecessary, but for now it simplifies the exposition.

<u>Assumption (A)</u>: $R \geq (2-\gamma)r$

<u>Equilibrium</u>

Proposition 1: Suppose (A) holds and let K_t be given. Then there exists a unique equilibrium characterized by a vector $(n_t^*, \{P_t^{*j}\}_{0 \leq j \leq n_t^*})$ where $P_t^{*j} = 1$ for all $j \in [0, n_t^*]$ and

$$n_t^* = \min \left\{ \frac{(R+r\gamma) - \sqrt{(R+r\gamma)^2 - 4r\left[\dfrac{(R-r)(1-\gamma)}{D}\dfrac{\beta(1-\alpha)A}{1+\beta}K_t^\alpha + \gamma R\right]}}{2r}, 1 \right\} \tag{15}$$

All security demands are given by (14).

FIGURE 3 HERE

This equilibrium is expressed as the intersection of the pseudo-aggregate demand of each risky asset with the curve that traces minimum size requirements in Figure 3. It can be checked that when $s_t = D$ so that there is enough money to open all the intermediate sectors, n_t^* indeed takes the value 1 and thus (15) defines a continuous function as drawn in Figure 3. Note that n_t^* is one of the roots of a second order polynomial; if assumption (A) were violated existence would be still guaranteed, but the two schedules F(n) and M(n) could cross more than once in the admissible range [0,1], so multiple equilibria could arise[8].

Proposition 1 characterizes the equilibrium allocation and prices for given K_t. To obtain the full stochastic equilibrium process, we need to determine the equilibrium law of motion of K_t. This is straightforwardly given as;

$$K_{t+1}=\begin{cases} \dfrac{r(1-n_t^*)}{R-rn_t^*}R\Gamma K_t^\alpha \equiv \sigma_B(n^*(K_t),r,R)\Gamma K_t^\alpha & prob.\ 1-n_t^* \\ R\Gamma K_t^\alpha \equiv \sigma_G(n^*(K_t),r,R)\Gamma K_t^\alpha & prob.\ n_t^* \end{cases} \tag{16}$$

where $n_t^*=n^*(K_t)$ is given by equation (15) and $\Gamma=A(1-\alpha)\beta/(1+\beta)$.

The important feature to note is that the level of capital stock next period will depend on whether the society is lucky in the current period (which happens when the risky investments pay-off, probability n_t^*) or not (probability $1-n_t^*$). Moreover, the probability of this event also changes over time. As the economy develops, it can afford to open more sectors, i.e. higher n_t^*, and the probability of transferring a large capital stock to the next period, that is the probability of a lucky event, increases. Also from (16), the expected productivity of an economy depends on its level of development and diversification; as n_t increases, the expected "total factor productivity" (conditional on the proportion of sector open, or on the capital stock of the economy), given by $\sigma^e(n^*,r,R)=n^*\sigma_G(n^*,r,R)+(1-n^*)\sigma_B(n^*,r,R)=\dfrac{R^2(1-n^*)}{(R-rn^*)}$, increases as well. However, interestingly, the productivity level conditional on good news, $\sigma_G(n^*,r,R)$, is independent of the diversification level of the economy. This is a feature of logarithmic preferences as the effect of higher investment in risky assets as n increases is exactly offset by the fact that no money was invested in projects that did not pay-off. We will return to this issue when we consider more general preferences in section 5.

To formalize the dynamics of development, we define the following concepts;

(i) QSSB: "quasi steady state" of an economy which always has unlucky draws in the sense that the sectors invested by this economy never pay-off.

(ii) QSSG: "quasi steady state" corresponding to an economy which always receives good news.

The capital stocks corresponding to these two quasi steady states will respectively be

$$K^{QSSB}=\left\{\frac{r(1-n^*(K^{QSSB}))}{R-rn^*(K^{QSSB})}R\Gamma\right\}^{\frac{1}{1-\alpha}} \tag{17}$$

[8] Yet, for $s_t<D$, uniqueness is guaranteed even if (A) is violated (see section 5 for more discussion).

$$K^{QSSG}=\{R\Gamma\}^{\frac{1}{1-\alpha}} \tag{18}$$

In particular, if uncertainty can be completely removed (i.e. $n(K^{QSSG})=1$), there will exist a steady state; a point, if reached, from which the economy will never depart. From equation (15), the condition for this steady state to exist is that the saving level that corresponds to K^{QSSG} should be sufficient to ensure investment in all the intermediate sectors. Thus

$$D<\Gamma^{\frac{1}{1-\alpha}}R^{\frac{\alpha}{1-\alpha}} \tag{19}$$

We will refer to this particular case of (18) as K^{SS}.

When this steady state exists, the pattern of development will typically look as represented in Figure 4. At very low capital levels (region I), the concavity of the production function guarantees positive growth. Then, there is a range (region II) in which growth only occurs conditional on good draws - i.e. some of the risky investments paying off. Regions I and II are separated by K^{QSSB}; although this level of capital is not a steady-state, it is a point around which the economy will spend some time; when they are below this level, all economies will grow towards it. On the other hand, when they are above this level, they will go back to K^{QSSB} in case they receive bad shocks, and since the probability of bad news is increasing in the level of capital stock, the probability of a set-back is highest when the economy has a level of capital stock just above K^{QSSB}. Yet as good news are received, the capital stock will grow and the probability of a lucky draw next period will also increase (but bad news now becomes more damaging since more is invested in risky projects[9]). Note that even when it grows, the economy is still exposed to large undiversified risks, and will typically experience some set-backs. As finally the economy enters region III, all idiosyncratic risks will be removed (since all sectors are open and an equal amount is invested in all sectors) and we will observe a deterministic convergence to K^{SS}.

FIGURE 4 HERE

So far, we have established that an economy that receives a series of lucky draws will be

[9] The current specification of the model has the unrealistic prediction that set-backs in the pre-take-off stage can only take the form of true economic disasters, taking the economy back to a very primitive stage of development. The reason is that the more sectors are open, the less will be the amount that agents are willing to put in the safe asset for insurance purposes. Therefore, a bad realization, though now much more unlikely, will have devastating effects. In contrast, the set-backs observed in the historical development process that were mentioned in the introduction do not have this feature. This feature of the model can be avoided by altering the specification for the structure of returns of the risky assets. An example would be to assume that in every period, a fixed measure $z>0$ of all possible projects have positive return, with each asset having the same probability of success. In this case the probability of a catastrophe in which no risky asset gives a positive returns would be decreasing in the number of active sectors and, tend to zero as n tends to z. But, bad realizations and crises in which a small proportion of the risky assets is successful, can still occur with positive probability until full diversification is reached.

unchained from its low productivity "primitive accumulation" stage and will reach full diversification and full industrialization. As Figure 4 suggests, given the specification of this economy the equilibrium stochastic process has a unique ergodic set - which in this case is just a point. Therefore, no underdevelopment trap exists and take-off will occur almost surely, though it will take longer and may be painfully slow for countries that are unfortunate.

Corollary 1: Suppose (19) is satisfied, then $plim_{t\to\infty}(K_t)=K^{SS}$.

What will happen to the randomness of the growth process? To answer this question, the natural measure to look at is the conditional variance of the "total factor productivity" defined above. Let $\sigma(n^*,.)$ be a random variable that takes the values $\sigma_G(n^*,.)$ and $\sigma_B(n^*,.)$ with respective probabilities n^* and $(1-n^*)$. Then, taking logs, we can rewrite the dynamic equations (16) as;

$$\Delta\log(K_{t+1}) = \log\Gamma + (\alpha-1)\log(K_t) + \log(\sigma(n^*(K_t)) \tag{20}$$

It is clear from this equation that capital (and output) growth volatility, after removing the deterministic "convergence effects" induced by the neoclassical technology, will be entirely determined by the stochastic component σ. Define the conditional variance of σ as V_n (observe that conditioning on n^* is equivalent to conditioning on the capital stock of the economy). We want to determine how this volatility measure evolves as a function of n^* (and K). Two forces have to be considered; *(i)* as the economy develops, more money is invested in risky assets, *(ii)* as more sectors are opened idiosyncratic risks are better diversified. Corollary 2 establishes that at later stages the variance is always decreasing in the capital stock. At early stages the result is ambiguous; under some parameter configurations the first effect dominates and early stages of the development process may be associated with an increase in the variability of economic activity, whereas under some other configurations, the variance may be decreasing throughout.

Corollary 2: *(a)* $V_n \equiv Var(\sigma(n^*,.)|n^*) = n^*(1-n^*)R^2\left[\frac{R(R-r)}{R-rn^*}\right]^2$

(b)-(i) If $\gamma>\frac{R}{2R-r}$, then $\frac{\partial V_n}{\partial K_t}\leq 0, \quad \forall K_t$.

(b)-(ii) If $\gamma<\frac{R}{2R-r}$,then $\exists\ \tilde{K}$ *s.t.* $n^*(\tilde{K})=\frac{R}{2R-r}<1$,and

$$\frac{\partial V_n}{\partial K_t}\leq 0, \quad \forall K_t>\tilde{K}\ ; \text{ whereas } \frac{\partial V_n}{\partial K_t}\geq 0, \quad \forall K_t<\tilde{K}.$$

Therefore, our model predicts that the conditional variance of the growth rate is either uniformly decreasing with the size of the accumulated capital (case *(a)*) or exhibits an inverse U-shaped relation with respect to it (case *(b)*). More precisely, if either γ is sufficiently large, or the productivity of risky projects is much higher than that of the safe asset, then the relation will be monotonic.

Endogenous Growth

It is straightforward to extend our analysis for endogenous growth and the main return from this would be that the distinction we drew earlier between primitive accumulation, take-off and industrial growth will now fit more nicely since at the last stage the economy will exhibit steady growth. To do this we can simply modify the final good production function (3) to

$$y_t = A k_t^{\alpha} l_t^{1-\alpha} K_t^{1-\alpha} \tag{21}$$

where K_t is the aggregate stock of physical capital in this economy.

It suffices to note here that all our results carry through to this case and the law of motion of the capital stock takes the form;

$$K_{t+1} = \begin{cases} \dfrac{r(1-n_t^*)}{R-rn_t^*} R\Gamma K_t & prob.\ 1-n_t^* \\ R\Gamma K_t & prob.\ n_t^* \end{cases} \tag{22}$$

It can be seen that as n_t reaches one, the growth rate increases until the economy eventually reaches a constant and non-random growth path.

4) Pareto Optimal Allocations and Sources of Inefficiency

The Socially Optimal Portfolio Decision

In this section we will explain why the equilibrium of section 3 is not Pareto optimal, characterize the optimal allocation and discuss when this type of inefficiency may be important. Yet, first, it has to be noted that we are only dealing with the issue of static efficiency. The additional source of inefficiency arising from the overlapping generations aspect will not be discussed in this section, though we will return to it later. For the purpose of the analysis of static efficiency, a social planner chooses the allocation of resources in order to maximize the welfare of the current generation. The planner would also solve the program given by (5), with the only difference that n_t will also be a choice variable and (10) will become an additional constraint. The constant saving rule of the individual maximization will again apply due to the simple form of the preferences. Yet, since it no longer follows that the same amount will be invested in all open sectors, (12) changes to

$$\max_{n_t,\phi_t,\{F_t^j\}_{0\le j\le n_t}} \int_0^{n_t} \log(RF_t^j+r\phi_t)dj+(1-n_t)\log(r\phi_t) \tag{23}$$

We now characterize the solution to this problem.

Proposition 2: Let $n^*(s_t)$ be given by (15), then $n^{FB}(s_t)>n^*(s_t)\ \forall s_t<D$, and $n^{FB}(s_t)=n^*(s_t)\ \forall\ s_t\geq D$. The allocation of funds in the first best is as follows $\exists\ j_t^*<n^{FB}(s_t)$ *s.t.* $F_t^j=F_t$ *if* $j<j_t^*$; $F_t^j=M(j)$ *if* $n^{FB}(s_t)\geq j_t>j_t^*$; *and* $F_t^j=0$ *if* $j>n^{FB}(s_t)$.

FIGURE 5 HERE

Figure 5 gives the diagrammatic form of the first-best allocation (represented by the shaded area). Note that the qualitative properties of the first best are very similar to our dynamic equilibrium. The economy is still characterized by three stages; primitive accumulation, take-off and steady growth but progress is faster on average. Also the transition equation looks considerably more complicated than (16), because the total return is different in each state.

The reason for the failure of the decentralized economy to reach the first best can be seen as a form of *pecuniary externality* due to missing markets. As an additional sector opens, all the existing projects become more attractive relative to the safe asset because the amount of undiversified risks associated with them are reduced (i.e. more of the risk is diversified) and as a result, risk-averse agents are more willing to buy the existing securities. However, it is important to note that markets are not assumed to be missing, but this is endogenously determined in equilibrium.

The pecuniary externality is not internalized in our economy because the project level indivisibilities make the aggregate production set non-convex and as a result a full Arrow-Debreu Equilibrium does not exist. A full Arrow-Debreu equilibrium is defined as a price mapping P^* that assigns a price to each commodity (project) in each time period such that for all $P_t^{j*}>0$, the excess demand for security j at time t, $ed_t^j(P^*)$, is equal to zero, and for all $P_t^{j*}=0$, $ed_t^j(P^*)\leq 0$. Note that this concept of equilibrium assigns a price level to all commodities, irrespective of whether they are being traded or not. The non-existence problem can be explained using Figure 6. In the top part, we have the supply and demand of a security for a sector that has no minimum size requirement. The supply is horizontal at \$1 because competition forces prices to be equal to marginal cost (as in standard competitive analysis) and the marginal cost of investing \$1 in this sector is \$1. The bottom panel has the supply and demand schedules for a sector with positive minimum size requirement. The supply is discontinuous because at no price we can supply x units of this security when x is below the minimum size. If as drawn in Figure 6, demand is sufficiently low there is no equilibrium price and the market for this security is missing. If price falls below 1, supply is zero and there is excess demand. If the price is larger than 1, there is excess supply. This is the reason why a decentralized equilibrium exists only *conditional* on the number of sectors that are open and the auctioneer has to look for a fixed point of a mapping that has n_t in it as well as the prices of securities. (It can also be seen that, because due to the correlation of the sectors, micro level indivisibilities are translated into aggregate non-convexities, lotteries will not be useful and in this equilibrium will not be used). This is however not a surprising result, full Arrow-Debreu equilibrium is too strong a concept for an economy with endogenously determined commodity space (proportion of open projects) and is not normally used in these circumstances (see for instance Hart (1979), Makowski (1980), Allen and Gale (1991)).

FIGURE 6 HERE

The alternative equilibrium concept that we offered instead captures all the salient features of a competitive situation; in particular, it keeps all agents as price-takers and all the gains from trade that can be exploited via a decentralized trading procedure are exploited. The main distinction is that the requirement that for non-open sectors $ed_t^j \leq 0$ at $P_t^j = 0$ is replaced with the condition that the number of open sectors is determined by a zero-profit condition[10]. This equilibrium concept is essentially the same as the one proposed by Makowski (1980) (also used by Allen and Gale (1991)). Makowski defines a Walrasian Equilibrium as a feasible competitive allocation sustained *by the set of traded commodities*. A Full Walrasian Equilibrium (FWE) is then a Walrasian Equilibrium with the added condition that *"no firm sees that it can increase its profits by altering its trade decisions assuming that the set of marketed commodities other than its own will remain the same"* (p.228). It can further be noted that the spirit of the equilibrium concept is also related to Rothschild and Stiglitz (1976) and in the next subsection, we will use this idea to refine the equilibrium concept to deal with the issue of inter-firm share trading.

Inefficiencies Under Alternative Market Structures and the "Reactive" Equilibrium

It could suspected that the failure of the decentralized mechanism to achieve efficiency can be related to our assumption of no inter-firm share trading. In this subsection, we will first establish that under very weak and plausible assumptions, there is no market structure that can support the efficient allocation as an equilibrium. And secondly, we will show that with a simple refinement of our equilibrium concept, even in the presence of inter-firm share trading, the equilibrium characterized in Proposition 1 is the unique equilibrium.

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[10] The important point of this equilibrium concept we offered as compared to Arrow-Debreu is not that there is no price for the non-traded securities but that this price is not the same as the price that an entrant contemplates to receive if it enters. In our context, there are well-defined prices conditional on entry and an entrant would enter in case it would make positive profits at those prices. There are also prices that would induce the consumers to choose zero demands. However, because of the non-convexity, the marginal entrant is never a "small" player and these two set of prices are not equal to each other.

First, note that if we allow firms to buy the shares of other firms, a giant "superintermediary" may emerge and buy up all of the industrial sector. If further competition were absent, the superintermediary would be able to offer non-linear prices to consumers. In particular, it could issue a bond which replicates the structure of returns required by the optimal allocation, and this would destroy our previous equilibrium since agents prefer a portfolio consisting entirely of this bond to the previous equilibrium portfolio. However, this is <u>not sufficient</u> to lead to efficiency and no decentralized equilibrium can achieve the first-best (without intervention). Thus,

Corollary 3: Suppose intermediary firms can costlessly trade shares and there is free-entry into the intermediate sector. Then the Pareto optimal allocation cannot be sustained as a decentralized equilibrium.

The intuition for this corollary can be given as follows. In the Pareto optimal allocation, shown in Figure 5, each individual needs to hold a "unbalanced" portfolio. But we know that if an individual faces equal prices, he would like to have a balanced portfolio. Thus, it is possible for an entrant to enter the no-minimum-size sectors, charge a price sufficiently close to 1 and sell to the representative individual, hence making positive profits. Therefore with free-entry, the Pareto optimal allocation cannot be sustained. Hence, despite the fact that our model is quite similar to a convex model, there are serious inefficiencies associated with the interaction of the endogenous commodity space and the indivisibilities; and these inefficiencies cannot be avoided by any market structure.

We can now establish the stronger result that even when the "ad hoc" assumption of no inter-firm share trading is relaxed, the equilibrium characterized in Proposition 1 remains the unique equilibrium, provided that we refine the equilibrium concept along the lines of Riley's idea of *reactive* equilibrium, originally suggested as a refinement of Rothschild and Stiglitz (1976)'s equilibrium concept. According to Riley (1979) to destroy a proposed equilibrium, it must be possible to introduce a contract that (i) is profitable and (ii) does not become unprofitable when yet more contracts are added by a new entrant *a posteriori*. The intuitive appeal of this equilibrium concept in our model is clear: on the whole, it seems implausible that a firm or intermediary will buy up the whole or a large part of the industrial sector, if it knows that there is no equilibrium at which it can enjoy a profit. In fact, this equilibrium concept can be more formally justified with small costs of making contract offers. Also note that using the same argument of the proof of corollary 3, it can be shown that with our original equilibrium concept and interfirm share-trading, there exists no equilibrium and this suggests that as in the Rothschild-Stiglitz insurance market, the strategy spaces of agents are too large and a tighter equilibrium concept is required.

To state our idea more formally, let $\pi(C \mid C \cup C')$ denote the total profit made from a set of contracts C when consumers have access to these contracts and an additional set C'. Then;

Definition 2 (Reactive Equilibrium): Consider the vector $(n_t^*, \{C_t\})_{t\geq 0}$ where n_t^* denotes the number of open sectors at time t and C_t is the set of contracts being offered to consumers by the financial intermediaries. This vector is an equilibrium iff

(i) $ed_t^j(n_t^*, C_t^*) = 0$ for all $j \leq n_t^*$ (given the set of contracts, supply of security j is equal to demand in all the open (n_t^*) sectors);

(ii) $\nexists$ C' based on a feasible production plan such that $\pi(C' | C^* \cup C') > 0$ and $\forall C'' : \pi(C'' \mid C^* \bigcup C' \bigcup C'') > 0, \quad \pi(C' \mid C^* \bigcup C' \bigcup C'') \geq 0$, and that conditional on C'', C' remains feasible in the sense of $ed_t^j(n_t^*, \{C^* \cup C' \cup C''\}) \leq 0$ for all securities j offered by the set of contracts $C \cup C \cup C''$.

Proposition 3: Suppose intermediary firms can costlessly trade in shares. Then, the equilibrium characterized in Proposition 1 is the unique Reactive Equilibrium.

Since we have demonstrated that there is a potentially important source of market failure and that no decentralized market mechanism can solve this problem, government policy may be required. The necessary government policy is easy to characterize and can be seen to take the form of direct subsidies or regulation that would support high indivisibility projects. It is interesting to note that this type of policy is in fact not too different from the pattern of industrial policy we observe at early stages of development in some countries (for instance in Germany, with state intervention, there was a large amount of capital invested in heavy industries at the expense of light industries, Gerschenkron (1962, p. 15), see also Cameron (1972)).

5) Attitudes Towards Risk and Underdevelopment Traps

Our results so far have been derived using logarithmic preferences. This has proved to be a very convenient functional form as it induces a constant savings rate. However, these preferences are very special as they imply that intra-temporal preferences are also logarithmic and thus the rate of relative risk-aversion is constant and equal to one. And yet, risk-aversion plays a key role in our analysis and it is instructive to investigate the implications of more general preferences. We turn to this issue in this section. Most of our results will hold with more general preferences, the only exception is Çorollary 2 which proved the ergodicity the equilibrium stochastic process. We show that when agents have a rate of relative risk-aversion greater than 1, we may end-up with an equilibrium (stochastic) process that is non-ergodic. That is, underdevelopment traps are possible. An economy that receives a series of unlucky draws may reach a level of capital stock that is sufficiently low that only a limited number of the risky sectors can be opened. In response, the risk-averse consumers of this economy decide to invest only a small proportion of their wealth in risky assets, and the productivity of the capital stock is endogenously low, and therefore growth is prevented.

To illustrate these features, we consider the following preferences

$$\log c_t + \beta \log\left(\int c_{t+1}(j)^{1-\theta} dj\right)^{\frac{1}{1-\theta}} \tag{24}$$

where $\theta > 0$. Note that these preferences are not von-Neumann-Morgenstern but of the Kreps-Porteus variety (see Kreps and Porteus (1978)). They are adopted so as to enable us to separate the impact of attitudes towards risk from intertemporal substitution. The form we have adopted still gives rate of intertemporal substitution equal to one, thus a constant savings rate[11] but the rate of relative risk-aversion need no longer equal 1, but is given by θ which can take any positive value.

It can also be noted that Lemma 1 still applies as it was derived only relying on competition among intermediaries and the form of the technology. After some simple algebra, the optimal portfolio can be characterized as

$$\max_{\{F_t, \phi_t\}} n_t \frac{(r\phi_t + RF_t)^{1-\theta}}{1-\theta} + (1-n_t)\frac{(r\phi_t)^{1-\theta}}{1-\theta} \tag{25}$$

subject to $n_t F_t + \phi_t = s_t$ where n_t is again taken as given by the representative consumer. Then;

$$\phi_t = \frac{R(R-rn_t)^{-\frac{1}{\theta}} s_t}{(R-rn_t)^{\frac{\theta-1}{\theta}} + rn_t((1-n_t)r)^{-\frac{1}{\theta}}} \tag{26}$$

$$F_t = \frac{[(r(1-n_t))^{-\frac{1}{\theta}} - (R-rn_t)^{-\frac{1}{\theta}}] rs_t}{(R-rn_t)^{\frac{\theta-1}{\theta}} + rn_t((1-n_t)r)^{-\frac{1}{\theta}}} \tag{27}$$

Notice that when $\theta \to 1$, the solution is identical to that obtained in section 3. Yet, in general, it is not possible to find a closed form expression analogous to (15) for the proportion of open sectors. Also, in this case static multiple equilibria may arise when we use our original equilibrium concept, that is there exist alternative equilibrium configurations with different numbers of open sectors for a given state of the system. Proposition 4 shows that this can only occur when the relative rate of risk aversion, θ, is greater than one and the economy has a sufficiently high amount of savings to open all sectors and more importantly, that the multiplicity of equilibria disappears when we allow inter-firm share trading and use the reactive equilibrium.

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[11] Generalizing the preferences to allow for other forms of intertemporal substitution would also be interesting, although somewhat cumbersome. If there are precautionary savings, for instance, these will fall as more diversification becomes possible.

Proposition 4: (a) Suppose no inter-firm share trading is allowed and use the concept of equilibrium of Definition 1, then;

(i) An equilibrium exists for all $\theta>0$.

(ii) If $\theta>1$, $\exists\ \bar{s}>D$ such that, if $s_t<D$, then the equilibrium exists and is unique; if $D\geq s_t\geq\bar{s}$, then there exist two equilibria with n_t^*, n_t^{**} sectors open such that $n_t^*<n_t^{**}=1$; and if $s_t\geq\bar{s}$, then there exists a unique equilibrium with $n_t^*=1$.

(iii) If $\theta<1$ and assumption (A) is satisfied, the equilibrium is unique for all $s_t\geq D$.

(b) Suppose interfirm share-trading is allowed, then for all values of θ, there is a unique Reactive equilibrium with a proportion n_t^* of the sectors open where $n_t^*=\max\{n_t^*(i)\}$ and $n_t^*(i)$'s denote the static equilibria as characterized in (a) above.

Let us start with part (a) and go back to Figure 3. Since $F(n=1)=s_t$ and $M(n=1)=D$, then $F(n)$ is always vertically below $M(n)$ when $s_t<D$. This, together with the fact that $F(n)$ is strictly convex when $\theta\geq 1$, rules out the possibility of multiple crossings when the stock of savings is not sufficient to open all sectors. Proposition 1 established that, under assumption (A), in the logarithmic case the equilibrium was also unique when $s_t=D$; the geometric intuition is that $M(n)$ is steeper than $F(n)$ at $n=1$. But this is no longer true for larger levels of risk aversion, and we prove that in such cases, $F(n)$ intersects $M(n)$ from below at $n=1$. Since $F(0)>0$, this implies that $F(n)$ must also intersect $M(n)$ at some lower level of n, and therefore, we have static multiple equilibria. The economic intuition is that if all agents invest a lot in the risky assets, all sectors can be opened and, because all risks are diversified, the representative agent wants to invest a high proportion of his savings (in our case, all of it) in risky assets. But there is also an equilibrium at which agents invest less in risky assets, and still no profit opportunities are left to individual entrants (unless they can coordinate their decisions). Note that if assumption (A) did not hold, a similar multiplicity would also apply to the logarithmic case of section 3.

However, part (b) of Proposition 4 shows that, although interesting per se, this multiplicity of equilibria only has limited relevance because it can be shown that if we allow interfirm share trading and apply the concept of Reactive Equilibrium as in Proposition 3, the multiplicity will disappear and the economy will always choose the Pareto preferred equilibrium which is the one with the highest number of open sectors. Whenever we are in a Pareto inferior equilibrium, a firm can enter, buy a sufficient proportion of sectors and offer a larger portfolio. The only difference from our baseline analysis is that the function $n^*(K_t)$ will have a discontinuity at $s_t=D$, so that take-off will be more abrupt than before.

Despite the fact that the static multiplicity associated with a high degree of risk-aversion is of limited interest, we will now show that there is an issue of "dynamic multiplicity" or *underdevelopment traps*, which is more interesting and robust. The stochastic process associated with equilibrium will be unique but will posses more than one ergodic set. To analyze this issue, consider the law of motion for the capital stock. After some algebra, this can be written as;

$$K_{t+1}=\begin{cases}\left[\dfrac{Rr((1-n_t)r)^{\frac{1}{\theta}}}{(R-rn_t)((1-n_t)r)^{\frac{1}{\theta}}+rn_t(R-rn_t)^{\frac{1}{\theta}}}\right]\Gamma K_t^{\alpha}\equiv\sigma_B(n^*(K_t),r,R,\theta)\Gamma K_t^{\alpha} & \text{with prob } 1-n_t\\ \left[\dfrac{Rr(R-n_t r)^{\frac{1}{\theta}}}{(R-rn_t)((1-n_t)r)^{\frac{1}{\theta}}+rn_t(R-rn_t)^{\frac{1}{\theta}}}\right]\Gamma K_t^{\alpha}\equiv\sigma_G(n^*(K_t),r,R,\theta)\Gamma K_t^{\alpha} & \text{with prob } n_t\end{cases} \tag{27}$$

where Γ is the same constant which appeared in (16). The term $\sigma_G(n^*(K_t),R,r,\theta)$ measures the productivity of the capital stock conditional on good news and it can be recalled that in the case of logarithmic preferences, it turned out to be a constant. In this case we can state;

Lemma 2: $\theta>(<)1 \Rightarrow \dfrac{\partial\sigma_G}{\partial n}>(<)\ 0$.

Lemma 2 implies that with high risk-aversion as the number of open sectors increases, the productivity of the investment rises. On the other hand, the neoclassical technology implies decreasing marginal product of capital, thus we have two counteracting effects. Under some parameter configurations, the net effect is such that the marginal product of capital is locally increasing in the level of capital. It is then possible to find a region from where the economy will not be able to escape; in other words, an underdevelopment trap: once the capital stock is low enough, even in the presence of only good shocks, the economy will not grow beyond a certain point. Also note that in models where the aggregate technology is linear in capital, as in the endogenous growth case discussed above, the marginal product of capital will be everywhere increasing, thus such traps will be more common.

Proposition 5: Suppose (19) is satisfied, and $\theta>1$. Then, for a generic subset of parameter values $(\alpha,A,\beta,\gamma,R,r,D)$; $\exists[K^{+},K^{++}],\ K^{+}<K^{++}<K^{SS},\ s.t.\ K_t\in(K^{+},K^{++}) \Rightarrow K_{t+i}\in(K^{+},K^{++})\ ,\ \forall i\geq 0$.

Expressed differently, if the rate of relative risk aversion is greater than 1, there exists a non-trivial set of economies characterized by a non-ergodic equilibrium stochastic process. The technical intuition of this proposition can be obtained by noting that the growth rate of this economy conditional on receiving good news is given as $APK(K_t)\equiv\sigma_G(n^*(K_t),R,r,\theta)\Gamma K_t^{\alpha-1}$. If APK(K) is locally increasing with K_t, which can be when $\theta>1$, we can have multiple values of the capital stock for which APK = 1 (multiple quasi-steady-states conditional on good news). The corresponding dynamics are described by Figure 7. At K^{++} the average productivity of capital is one and is increasing with K. For K_t in the right neighborhood of K^{++}, the growth rate of the economy, even when it receives only good shocks, is negative. Thus the economy cannot grow beyond K^{++}. A similar argument using σ_B, the productivity of the capital stock in the presence of bad shocks, establishes the presence of a certain level of capital, K^{+} below which the economy cannot fall. As a result, $[K^{+},K^{++}]$ will be an ergodic set or in other words, an underdevelopment trap. This possibility of underdevelopment trap is different from a static multiplicity, and captures the possibility of dynamic lock-in in the context of development which were pointed out by David (1985) and Arthur (1989) in different contexts.

FIGURE 7 HERE

It should also be emphasized that the nature of this underdevelopment trap is different from others in the development literature or elsewhere also for the underlying economic intuition (e.g. Azariadis and Drazen (1990), Boldrin (1992), Matsuyama (1991)). Underdevelopment traps are usually driven by increasing returns. Yet, in our model, at earlier stages of development agents have access to technologies which are as productive as those available to advanced countries. However, the scarcity of capital leads to a lack of diversification opportunities, making the adoption of high productivity technologies risky, and in response to this, agents choose an aggregate technology that is relatively less productive, hence making the state of underdevelopment permanent. Thus, in our model micro level non-convexities only play a role in conjunction with risk aversion. For this reason, when risk aversion is not high enough underdevelopment traps can be ruled out. This is stated in the following proposition (note that corollary 1 above is a special case);

Proposition 6: Suppose (19) is satisfied, and $\theta \leq 1$, then $plim_{t\to\infty}(K_t)=K^{SS}$.

This proposition establishes that with low levels of risk-aversion, underdevelopment traps are not possible, thus makes it clear the role that risk-aversion plays in the existence of these traps.

6) International Capital Flows and Development

We have so far dealt with a closed economy and abstracted from the possibility of capital flows. This can be an important omission. For instance, in the process of industrialization of Western Europe, capital flows were important. The areas that emerged as industrial centers were often attached to (or were themselves) financial centers that attracted capital from other regions and towns and also subsequently provided capital to them (Braudel (1979,1984), Neal (1990)). These observations point out to the importance of analyzing the role of diversification and capital scarcity in the context of a model where inter-country capital flows are possible. Such an analysis will also give us an indication of the importance of the mechanisms we have developed in this paper for the development problems today in the presence of relatively more important international capital flows. A further consideration is that the dynamics of capital flows in the development process of Western Europe are not easily explained by the standard theories. Models based on a decreasing returns technology predict strong flows to poor countries whereas models with increasing returns imply the opposite. In practice, the picture is more complicated. While in the eighteenth century there were strong net flows from continental Europe towards London (the more developed center), in the nineteenth century, the direction of net flows was reversed (see Neal (1990) chapter 11). Encouragingly, this is the same as the basic prediction of our analysis in the next subsection.

Before we move to the analysis, we can note that if the country we are dealing with is a small open economy and capital can flow in and out without any transaction costs or enforceability problems, then all our results disappear. This is of course natural; our main mechanism is derived from capital shortages and the small open economy with perfect capital mobility assumes capital shortages away. This characterization of events does not however seem to accord well with the experience of developing countries today. Many of those try to attract foreign capital but often are not very successful and also they and even frequently try to limit the extent to which domestic capital is allowed to go abroad. Further, as we mentioned in the introduction, capital shortages are often mentioned as an important problem in the context of development. The findings of very imperfect consumption insurance across countries is another indication that the presence of frictions to international capital mobility. In the rest of this section, we will analyze a two-country world with free capital flows and then a small open economy with enforcement problems.

a) A two-country model. Neoclassical technology

Suppose that there are two countries with identical technologies as described in section 3. That is, both countries have the same production function and access to the same set of investment opportunities. Therefore if the state of nature is j, project j pays a rate of return equal to R in both countries and also the minimum size requirement of this project is M(j) in both countries as given by equation (1)[12]. We further assume that capital flows between the two countries are free. Also, as in the previous sections, intermediaries compete a la Bertrand in the financial market but the assets sold by these intermediaries can be bought by consumers of both countries. Further, since the investors naturally do not care whether the assets they are investing are domestic or foreign.

Let us denote the amount of risky investment in sector j of country 1 by F_1^j and the amount of risky investment in sector j of country 2 by $F_2^{j'}$. Similarly, let ϕ_1 be the investment in the safe asset of country 1 and ϕ_2 the investment level in the safe asset of country 2. These variables should

[12] It is of course possible to allow the minimum size requirements to vary between the two countries in which case there will be additional gains from capital flows than the ones emphasized. But in this section we prefer to abstract from these in order to maintain the analysis as tractable as possible.

have time-subscripts but these are dropped in this section not to complicate the notation since most of this section will deal with the static problem of fund allocation between the two countries. A final point to note before we move on is that with perfect capital mobility and one period lives for capital, the identity of the two countries is indeterminate. To avoid these problems, we will call the larger economy country 2.

Lemma 3: All risky assets that are traded in equilibrium have the same price.

This result mirrors the one we had in the closed economy case. The prices of traded securities are determined by the technology because of the constant returns aspect. This implies that we can characterize the individual consumer's decision in a simple form.

$$\max \int_0^{n_1} \log[\rho_1^j(r\phi_1+RF_1^j)+\rho_2^j(r\phi_2+RF_2^j)]dj + \int_{n_1}^{n_1+n_2} \log[\rho_1^j(r\phi_1)+\rho_2^j(RF_2^j+r\phi_2)]dj$$
$$+\int_{n_1+n_2}^{1} \log[\rho_1^j(r\phi_1)+\rho_2^j(r\phi_2)]dj \tag{28}$$

by choosing $\{F_1^j\}$, $\{F_2^j\}$, ϕ_1, ϕ_2 and subject to the constraint

$$\int_0^{n_1} F_1^j dj + \int_0^{n_1+n_2} F_2^j dj + \phi_1 + \phi_2 = S \tag{29}$$

where ρ_i^j is the marginal product of capital in country i in state j. We also adopt the convention that n_1 sectors open in country 1 and $n_1 + n_2$ sectors open in country 2 and as before all the states are equi-probable. Note that the consumer is taking the number of sectors that are open in the two countries as given and as in the closed economy, he is treating the marginal products of capital in the different states as parameters. Further, although it is not important for the consumer's maximization problem which sectors will be open, as in the closed economy, sectors with smaller minimum size requirements will open first and we have already incorporated this into the problem.

We can now characterize the solution to the individual maximization problem more closely;

Lemma 4: $(i)\ \forall\ (j,j')\ s.t.\ j<j'<n \Rightarrow F_1^j = F_1^{j'}\ ,\ F_2^j = F_2^{j'}$

$(ii)\ \forall\ (j,j')\ s.t.\ n_1<j<j' \Rightarrow F_2^j = F_2^{j'}$

The intuition of these results is straightforward. If two sectors j and j' are open in both countries and they trade at the same price, then consumers will never be happy to purchase different amounts of these assets. Similarly, if two sectors are only open in one country, the same will again hold. Using Lemma 4 we can then write this problem as

subject to

$$\max_{F_1,F_2,G,\phi_1,\phi_2} n_1\log[\rho_1(1)(r\phi_1+RF_1)+\rho_2(1)(r\phi_2+RF_2)]+n_2\log[\rho_1(2)(r\phi_1)+\rho_2(2)(r\phi_2+RG)] \\ +(1-n_1-n_2)\log[\rho_1(3)((r\phi_1)+\rho_2(3)(r\phi_2))] \tag{30}$$

$$n_1(F_1+nF_2)+n_2G+\phi_1+\phi_2=s \tag{31}$$

where $\rho_i(q)$ denotes the marginal product in country i in state q where $q=1$ denotes $j\leq n_1$, $q=2$ denotes $n_1<j\leq n_1+n_2$ and $q=3$ denotes $j>n_1+n_2$. Therefore

$$\rho_i(1)=\alpha A(r\phi_i+RF_i)^{\alpha-1} \qquad \rho_1(2)=\rho_1(3)=\alpha A(r\phi_1)^{\alpha-1} \qquad \rho_2(2)=\alpha A(r\phi_2+RG)^{\alpha-1} \tag{32}$$

Next, using the first-order conditions of this maximization problem and substituting for the marginal product of capital, we can establish;

Lemma 5: **(i)** $RF_1 + r\phi_1 = RF_2 + r\phi_2$. **(ii)** $F_2 > F_1$ and $\phi_1 > \phi_2$. **(iii)** $G > F_1$.

The first part of the lemma follows directly as if it were not true the marginal product of capital would be higher in one country and by changing, F_1 and F_2, total output in the all states $j\leq n_1$ could be increased. An informal intuition for second part of the lemma is that since G is received in country 2, the insurance role of safe investments in this country is less important, thus $\phi_1 > \phi_2$. Finally, the last part is due to the fact that in the states $j \in (n_1,n_1+n_2)$, there is lower return in country 1 than in the states $j\leq n_1$ and for insurance reasons, it is beneficial to increase G above F_1. The general form of equilibrium that is implied by this Lemma is also shown in Figure 8.

FIGURE 8 HERE

Lemma 6: (i) If $n_1+n_2 \rightarrow 1$, then $n_1 \rightarrow 1$. **(ii)** If $n_1<1$, then $n_2>0$.

In words, one of the countries cannot reach full-diversification before the other. The intuition of this lemma is that when one of the countries is near full diversification, the effect that leads to concentration becomes small relative to the difference between the marginal products of capital in the two countries and the additional value of a dollar is relatively more in the country that has fewer sectors open. Therefore, consumers will always want to invest more in the smaller country and as a result, the two countries will reach diversification at exactly the same time.

Now combining all these lemmas we can summarize the main findings of this section as;

Proposition 7: The equilibrium of the two-country model always takes the following form;

If $s < 2D$; (i) One of the countries always attracts more of the capital and open more sectors; $n_2 > 0$.

(ii) No country opens all projects; $n_1 + n_2 < 1$.

(iii) As s approaches 2D, both countries reach full diversification simultaneously.

If $s \geq 2D$, both countries open all their projects and each project receives the same amount of capital.

Our analysis so far has characterized the equilibrium of the static problem of fund allocation, taking the amount of savings, s_t, as given. To obtain the full dynamic equilibrium, we need to determine the amount of savings and also provide the transition equations as in the closed economy case. Because of the logarithmic preferences, the aggregate amount of savings will still be a fixed proportion of wage income and the dynamic transition equations of our economy can simply be obtained by determining wage income. However, this extreme simplicity of the two-period overlapping generation structure leads to some artificial results. Consider the world economy starting from a point of capital scarcity and equal wealth in the two countries. Then, the first part of Proposition 7 (or Lemma 6) implies that more capital will go to one of the countries and thus we can claim that capital flows create forces that work in the direction of divergence. However, if a state $j \leq n_1$ occurs, because $r\phi_1 + RF_1 = r\phi_2 + RF_2$, the two countries will have exactly the same output level and the workers will have exactly the same income, hence there will not be any income inequality left in the following period. Then in the subsequent period, again more funds will be invested in one of the countries, thus the capital stocks will not be equalized, but it is still an unattractive feature of our model that for all states $j \leq n_1$, the young in the richer country will have the same income level as those in the poorer one. However, many extensions of the model that take it towards a more realistic direction will avoid this problem. In particular, if there are more intertemporal linkages than allowed here, this problem will not arise. Here we sketch a simple way of allowing for this without complicating our analysis, which is to introduce bequest motives for our agents. More precisely, the utility function (2) can be changed to

$$U(c_t,c_{t+1},b_t)=\log(c_t)+\beta E[\log(c_{t+1})+\mu\log(b_{t+1})] \tag{33}$$

where b_{t+1} is the bequest that generation t agents leave to their off-springs and μ is a parameter that captures the strength of this impure altruism. In this case, the saving decision changes to

$$s_t=\frac{\beta(1+\mu)}{1+\beta(1+\mu)}w_t \tag{34}$$

but since it is still constant and independent of the rate of return expected between t and t+1, all our analysis applies. And, if countries have different income levels at time t, even a state $j \leq n_{1t}$ does not lead to equalization of incomes, since the young of the richer country will have received more bequests than those of their poorer neighbor.

With this formulation, the general dynamics of the world economy are straightforward to obtain from Proposition 7. First of all, if there does not exist enough capital in the world for both countries to reach full diversification, neither country will have all of its sectors open. Thus bad news will affect both countries, but, in general, not symmetrically. To make another observation let us consider a situation where both countries have initial endowments that are small and also quite close to each other. In this case, the possibility of foreign capital flows first leads to divergence across countries; one of the countries (in our case, country 2), attracts capital from country 1. However, as the world economy receives a series of good shocks, n_1+n_2 and n_1 both approach 1; n_2 becomes arbitrarily small, and the two countries start converging. Therefore, in line with the historical evidence from the industrialization of Western Europe, our two-country model predicts that at the early stages of development, capital flows slow down development in one of the countries while enhancing it in the other. And at later stages, the relatively backward country receives capital imports from the advanced economy, consequently capital flows contribute to fast (but of course, not immediate) convergence.

(b) A two-country model. Constant returns to capital.

In the presence of endogenous growth a la Romer (i.e. the version of the model we analyzed at the end of section 3), the rate of return on capital is constant and capital flows will not influence the productivity of the remaining capital. The implication of this is straightforward: all the capital of the world will go to country 2. This is obviously unrealistic but is also instructive of a set of effects that arise in this type of economy. In the case of constant returns to capital, all the capital of the poor country flowing to the rich country is beneficial for the current old (rentier) generation of both countries and the young of country 2, but as a result of this, there is no capital invested in country 1 and the young of this country are impoverished. Therefore, although capital flows are welfare improving from the viewpoint of the current generation, they lead to important intertemporal inefficiencies and as a result, future generations who are assumed to remain in this country pay a very high price. In our analysis so far, we have not concentrated on the intertemporal aspects of efficiency, nevertheless this case shows that these considerations become very important in the presence of open economies and from the viewpoint of intertemporal efficiency, capital flows can be quite harmful.

(c) Small Open Economy with Enforcement Problems.

Now briefly consider the case of a small open economy. In the absence of transaction costs associated with foreign capital flows and enforceability problems, it is obvious that all the sectors will immediately open. However, it was argued above that this is not an interesting case and does not accord well with the existing observations concerning the experience of developing countries. Instead, suppose that there are enforceability problems. In particular, if the country that we are considering is sovereign, it has the right to repudiate on the debt and often it will choose to do so[13]. To give the main ideas of this case, simply assume that the foreign investment that comes into a country will not be paid back. Naturally, in this case, there will be no capital inflows. However, the small open economy is still of interest because of the capital outflows. Domestic investors can always put their money in foreign assets and get a fixed rate of return (since the country is small). An interesting implication is that as the productivity of investments abroad increases ϕ_t and F_t will (normally) diminish, therefore, the rate of industrialization will fall. This is the static effect of capital flows out of the country which improves the welfare of the current generation. However, the dynamic effects are more harmful to development. As capital flows out of the country, the wages fall and there is even less capital to be invested in the following period. Assuming that enforcement constraints are still limiting the amount of foreign capital that can come in, this process will quickly take the wages in the country to a very low level and future generations will be impoverished and industrialization will be prevented.

How serious the consequences of this process will be depends obviously on how strict the enforcement constraints are. As in the other case of harmful capital flows, this extension points out that even in the presence of capital scarcities, the possibility of international capital movements may have adverse effects when other market failures are also present.

7) Conclusion

Indivisibilities and non-convexities are often recognized as important factors in the process of development. We argue that the interactions between diversification and indivisible projects will crucially influence the development experience of a country. In the presence of non-convexities, an economy with limited resources will not be able to invest simultaneously in many sectors, and to the extent that these sectors have imperfectly correlated returns, it will not be able to benefit from diversification. This lack of diversification will often bias the portfolio towards safe but low return projects and will therefore slow down the process of accumulation. However, as the economy grows it will have more resources, because more projects are undertaken, the composition of investment will change towards riskier and more productive projects. This will eventually bring the economy to a take-off stage. Take-off and the associated financial deepening will finally result in steady

[13] Because of the two-period overlapping generations aspect, the old generation will always want to repudiate completely on the debt. It is possible to incorporate these type of enforcement constraints in models with more forward looking behavior and obtain strictly positive but limited foreign direct investment into developing countries (e.g. Bulow and Rogoff (1989)).

industrial growth. In this process random events are very important. Since at the early stages of development, the economy only invests in a few sectors, it can easily be unsuccessful and spend too long in the primitive accumulation stage. We also show that when agents in this economy are sufficiently risk-averse, a series of bad draws can condemn a society to permanent "underdevelopment"; at a certain level of the capital stock, the economy will never invest enough in risky projects to take-off from primitive accumulation.

In our model, an interesting inefficiency also arises. Due to sectoral non-convexities, the Arrow-Debreu equilibrium fails to exist and in all equilibria with competition and price-taking, there is inefficiency in the form of too few sectors being open and as a result the economy on average spends too long in primitive accumulation. We show that this source of inefficiency is robust across different market structures and government intervention is necessary to deal with it. The form of required government policy is to subsidize large projects as we observe in the development experience of many economies.

Although we argue that the investigation of the interactions between risk and indivisibilities will be important in understanding the process of development, a number of issues require further thought and research. First, our model allows perfect risk-pooling and yet, indivisibilities may also limit the access of individual agents to financial instruments and may prevent risk-pooling across agents; it will be interesting to investigate how this interacts with the evolution of diversification and income distribution at the aggregate level. Second, our model does not grant a role to financial intermediation, and implicitly assumes that the process of intermediation is costless and efficient at all stages of development. In the light of the findings of the recent literature, one could try to consider explicitly the role of credit and stock markets (a step that we are taking in on-going work). Third, though we show in section 6 that international capital flows do not necessarily undo our mechanism, one would like to assess empirically to what extent underdeveloped countries today suffer from capital shortages induced by undiversified risks. A related issue is to investigate whether part of the high variability of growth rates of poor countries can be reduced by diversification. Finally, the most pressing and probably fruitful extension is to incorporate enforcement problems explicitly in such a model and attempt to determine the size of an accumulation unit together with the degree of indivisibilities that will influence such a unit. Such an extension would enable us to reach a much better assessment of the empirical importance of this mechanism in the context of current development problems.

APPENDIX A

Proof of Lemma 1: Free-entry implies that in all equilibria $P_t^j = P_t^{j'} = 1$, $\forall\, j, j' \in J(t)$ (if $P_t^j > 1$ the positive profits would lead to further entry; if $P_t^j < 1$ then the firm in question makes a loss). All states of nature j are equally likely and all securities have the same price, thus $F_t^j = F_t^{j'}$, $\forall\, j, j' \in J(t)$. QED

Proof of Proposition 1: Consider the allocation characterized by $(n = n_t^*, \{P_t^j = 1\}_{0 \le j \le n_t^*})$ where n_t^* is given by (15), and asset holdings are given by (13) and (14). Conditional on n_t^*, both consumers and incumbent firms are optimizing. Thus we only need to check whether all opportunities for profitable entry are exploited. First, observe that the entry cannot be profitable unless $P_t^v > 1$, where v indexes the potential entrant. Next note that

$$F'(n_t^*) = \frac{r(R-r)}{(R-rn_t^*)^2} > 0 \ , \quad F''(n_t^*) = -2\frac{r(R-r)}{(R-rn_t^*)^3} < 0 \tag{A1}$$

Under assumption (A), we have $F'(1) = r/(R-r) < D/(1-\gamma)$ which implies $F'(n_t^*) < D/(1-\gamma),\ \forall n_t^*$. Geometrically, the slope of F(.) in Figure 3 is always less than the slope of the M(.) function. Thus when an additional sector opens, the increase in the investment in the risky asset is not sufficient to cover the minimum size requirement of an additional sector. Therefore, no additional firm can come in with $P^v(.) \ge 1$. This proves that the characterized allocation is an equilibrium.

For uniqueness note that all equilibria have to be characterized by the intersection of F(n) and M(n) or by

$$n_t^* = \frac{(R+r\gamma) \pm \sqrt{(R+r\gamma)^2 - 4r\left[\frac{(R-r)(1-\gamma)}{D}s_t + \gamma R\right]}}{2r} \tag{A2}$$

as long as $n_t^* \in [0,1]$. Also when $s_t \ge D$, $n_t^* = 1$ and s_t is given by equations (4) and (11) in the text.

Denote the solutions to (A2) by n_1 and n_2 with $n_1 > n_2$. When assumption (A) is satisfied, $n_1 > 1$ for all values of $s < D$. But in this case $n = 1$ cannot be an equilibrium since all sectors cannot be opened. Thus when $s < D$, there is a unique equilibrium given by n_t^* as in (15) given by the smaller root of (A2). Next note that when assumption (A) is satisfied, the smaller root n_2 is greater than or equal to 1, for all $s \ge D$. Thus when $s \ge D$, there is only a unique equilibrium with $n^* = 1$. This establishes uniqueness. QED

Proof of Corollary 1: The law of motion (16) implies that for $0 < K_t < K^{SS} \Rightarrow K_{t+1} > K_t$ conditional on favorable realizations. Also, (16) implies that for any K_0 there exists a sequence of good realizations such that K_t reaches K^* in finite time, where K^* is such that $n^*(K^*)=1$. Once this capital level is reached, (16) and (20) ensure that the economy converges deterministically to K^{SS}. Furthermore, K^{SS} is the only absorbing set of the system. Since any finite sequence of "good" realizations occur with positive probability, then convergence to K^{SS} is guaranteed almost surely. QED

Proof of Corollary 2: The calculation of V_n follows straightforwardly from the definition of $\sigma(n(K),r,R)$ and from (16). Then:

$$\begin{aligned} Sign\{\frac{\partial V_n}{\partial n^*}\} &= Sign\{(1-n^*)(R-rn^*)-n^*(R-rn^*)+2r(1-n^*)n^* \\ &= Sign\{R-2n^*R+rn^*\} \end{aligned} \tag{A3}$$

Thus if $n^* > \frac{R}{2R-r}$, the variance is decreasing in $n^*(K)$. We also know that $n^*>\gamma$; therefore, if

$\gamma > \frac{R}{2R-r}$, then the variance is always decreasing in n^*. Otherwise, it will be non-monotonic

(inverse U-shaped, with a maximum at $n^* = \frac{R}{2R-r}$). Since n^* as determined by equation (15) is a

monotonic function of the capital stock K, the rest of the proof follows. QED.

Proof of Proposition 2: By substituting constraint (9) into the utility of the individual, let us define

$$V(n_t,\{F_t^j\},\phi_t) = \int_0^{n_t} \log(RF_t^j+r\phi_t)dj+(1-n_t)\log(r\phi_t) \tag{A4}$$

Evaluating V(.) at the decentralized equilibrium - i.e. at $n_t=n^*$, $F_t^j=F_t^*$ for all $j \leq n_t$ and substituting for ϕ_t from the budget constraint, we obtain

$$\frac{\partial V(n_t^*,F_t^*)}{F_t^j} = 0 \quad \forall j \leq n_t^* \tag{A5}$$

and

$$\begin{aligned} \frac{\partial V(n_t^*,F_t^*)}{\partial n} &= \log(RF_t^* + r(s_t - n_t^* F_t^*)) - \log(r(s_t-n_t^*F_t^*)) \\ &+ \frac{F_t^*(r(s_t-n_t^*F_t^*)+RF_t^*(1-n_t^*))}{(RF_t^*+r(s_t-n_t^*F_t^*))(s_t-n_t^*F_t^*)} > 0 \end{aligned} \tag{A6}$$

Since we can reduce F_t^j for some intra-marginal sector and increase n_t, V(.) can go up, thus the decentralized equilibrium is not Pareto Optimal.

To characterize the first-best, construct the Lagrangean

$$L(n_t,\{F_t^j\}) = \int_0^{n_t} \log(RF_t^j + r\phi_t)dj + (1-n_t)\log(r\phi_t)$$
$$+\lambda_t(s_t - \int_0^{n_t} F_t^j dj - \phi_t) + \mu_t^j(F_t^j - M(j)) \qquad \textbf{(A7)}$$

and differentiate with respect to F_t^j, we obtain the following first order conditions

$$\frac{R}{RF_t^j + r\phi_t} - \lambda_t - \mu_t^j = 0 \qquad \textbf{(A8)}$$

Now for all sectors j that *do not* have a binding minimum size requirement, i.e. $F_t^j > M(j)$, the corresponding Lagrangean multiplier is zero, thus $F_t^j = F_t$ for all such j. It is straightforward to see that all sectors with $M(j)=0$ fall in this category since, by its concavity, V cannot be maximized when no investment is put in these sectors. But for the rest of the sectors (i.e. those with a positive multiplier), $F_t^j = M(j)$ must hold. Thus the form in Proposition 2 follows. We only need to show that j^* is strictly smaller than n_t^{FB}. Were this not the case, an equal amount would be invested in all sectors and we would get the decentralized equilibrium which is suboptimal as shown above. QED

Proof of Corollary 3: Suppose there exists a market structure with free-entry that implements the Pareto optimal allocation. Take a sector j that does not have a minimum size requirement. Then, by Proposition 2, $F^j < F^n$ (where F^n is the optimal holding of the asset with the largest minimum size among those in which the social planner would invest). This implies that the shadow price that the representative agent is facing for the marginal unit of j, MP^j, is strictly greater than the price he is facing for the marginal unit of n and the seller of these securities has to make non-negative profits, $MP^j > 1$. But then because there is no minimum size requirement for j, an additional firm can come in, set a price below MP^j but still above 1. If this price is sufficiently near 1, the representative consumer will want to buy further units of this security, thus the firm will make positive profits. QED

Proof of Proposition 3: We need to show (i) the equilibrium of Proposition 1 is a reactive equilibrium; (ii) there is no other allocation that can be supported as a reactive equilibrium. For this proof, let us also denote by MP^j the maximum price that a consumer would be willing to pay for a marginal unit of security j.

(i) Let C be the set of contracts that maintains the allocation of Proposition 1 as an equilibrium. We need to show that for every C′ that disturbs C, ∃ C″ such that, $\pi(C'' \mid C \cup C' \cup C'')>0$ and $\pi(C' \mid C \cup C' \cup C'')<0$. But by definition, the equilibrium of proposition 1 cannot be disturbed by a balanced portfolio that has $MP^j = MP$ ∀j. Then consider an unbalanced portfolio to disturb C, but for $\pi(C' \mid C \cup C')>0$, some consumers must be attracted to C′ thus some of the prices must be lower than 1, denote the set of these securities by the set J. Then for C′ to make positive profit, some prices must be greater than 1, thus ∀j' such that $MP^{j'} > 1$, denote the set of these securities by J'. Now we have to allow for two possibilities; (a) different securities in C′ can be bought separately; (b) there is only one combined security in C′ (other hybrid cases can be handled similarly). Also denote by n_C the number of sectors open with the set of contracts C (i.e. the number of open sectors in the equilibrium of Proposition 1) and $n_{C'}$ the set of sectors open to support the set of contracts C'. For C' to disturb C and make positive profit we know that $n_{C'}$ must be strictly greater than n_C (since no balanced portfolio can disturb C and if $n_{C'} \leq n_C$, the consumers will hold a balance portfolio).

(a) Consider C'' such that in all $j' \in J'$, a unit of security is sold at the price $1+\epsilon$. This implies that, the firm offering the set C' will not sell any of the securities in J' and since at least some of the other securities in J are sold at a price below 1, it will make a loss.

(b) Let the combined security that constitutes C' have a price P and by definition of the profitability of C', $P > 1$. Then, consider C'' such that $P^{j'} = 1+\epsilon < P$ for all $j' \in J'$. The consumer will want to have $F^{j'} \geq F^{j}$ for all $j \in J$ and $j' \in J'$, whereas by construction C' offers more of security J than J'. Thus consumers will reduce their purchase of the combined security in C' to a level no greater than $F(n_{C'})$. But by definition of the equilibrium of Proposition 1, we know that $F(n_C)$ is not sufficient to cover the minimum size requirements of sectors $n_{C'}$-n_C, therefore the supply of these securities is equal to zero whereas the demand is strictly positive, thus C' violates feasibility and C' is not a valid disturbance to C.

(ii) Now consider an allocation supported by a set of contracts that is different from the equilibrium of Proposition 1. By definition, MP^j is not constant (otherwise we end up with the allocation of Proposition 1). Then at least for some j, $MP^j > 1$. Then, there exists C' which in this case is just a Basic Arrow Security j that will sell at $1+\epsilon$ and for small enough ϵ, it would make positive profits. Now we show that for all profitable reactions C'', C' remains feasible and does not make negative profits. First, since C' consists of Basic Arrow Securities, if C'' undercuts C', then no units of C' are sold and hence, it makes zero profits. Next, since C'' is undercutting C', more units of Basic Arrow Security j mst be demanded, therefore feasibility will not be violated. Thus, for all other allocations other than that of the Proposition 1, a valid disturbance C' can be found. QED

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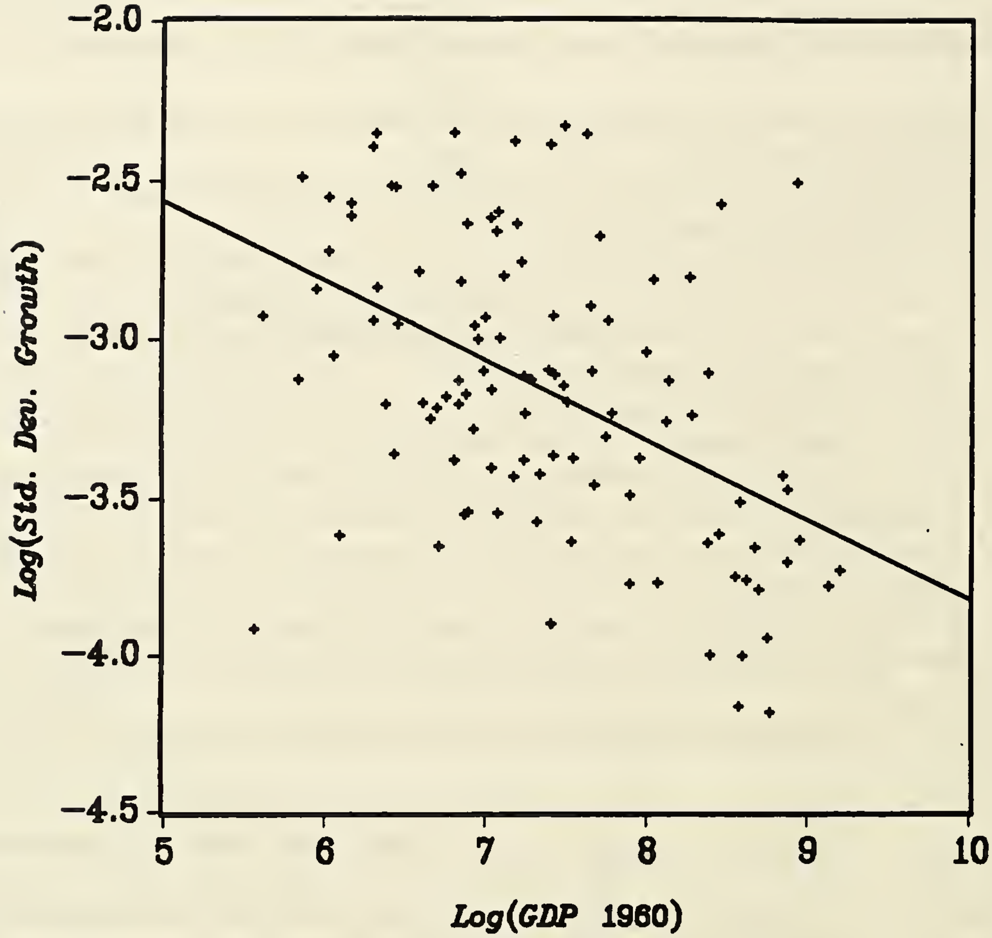
Figure 1



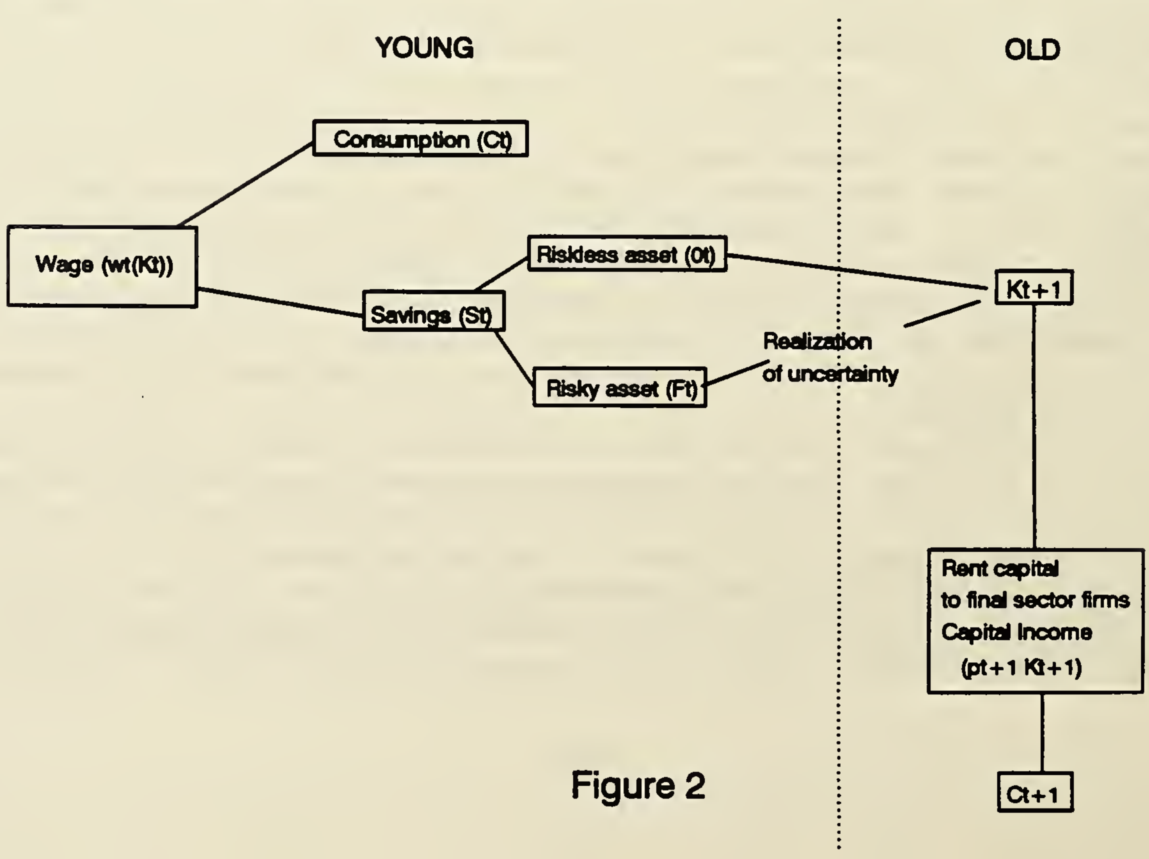
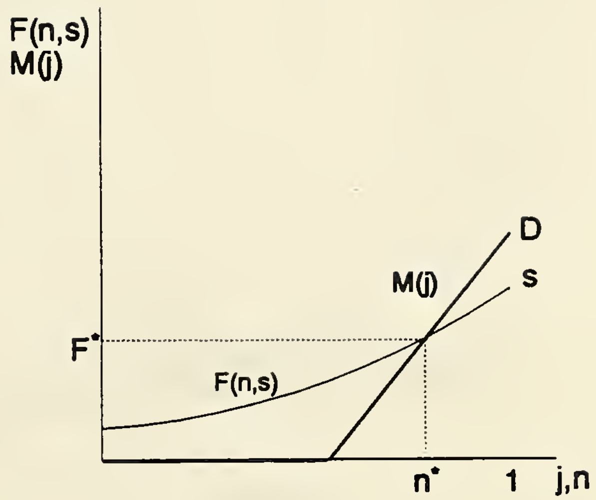


Figure 2



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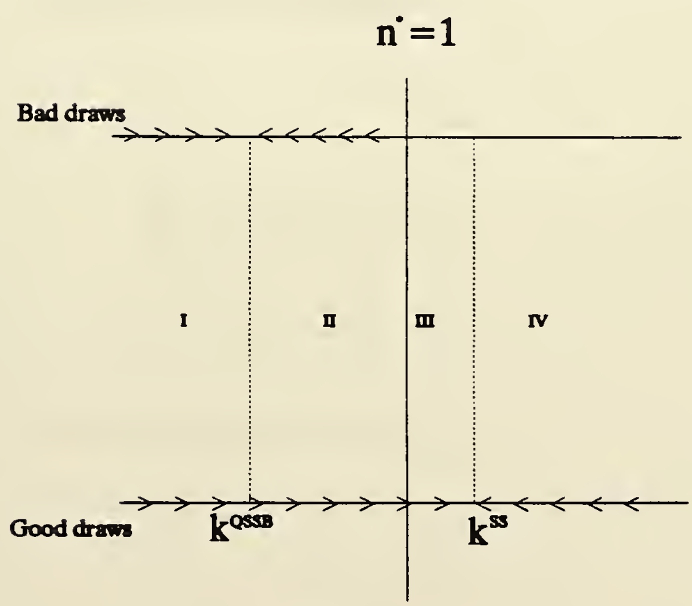

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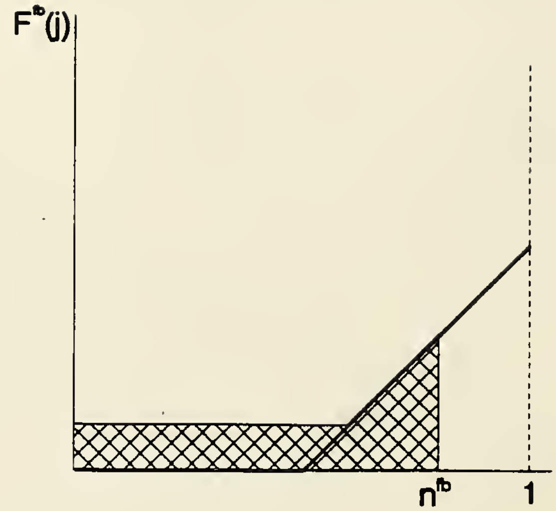

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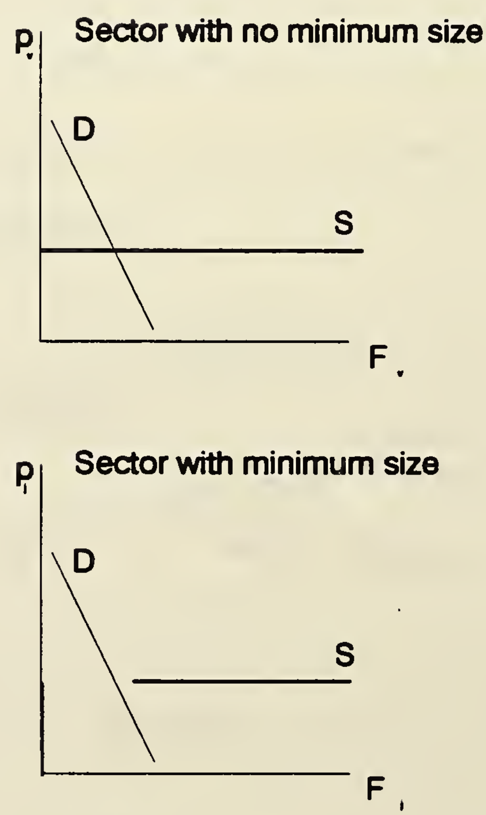

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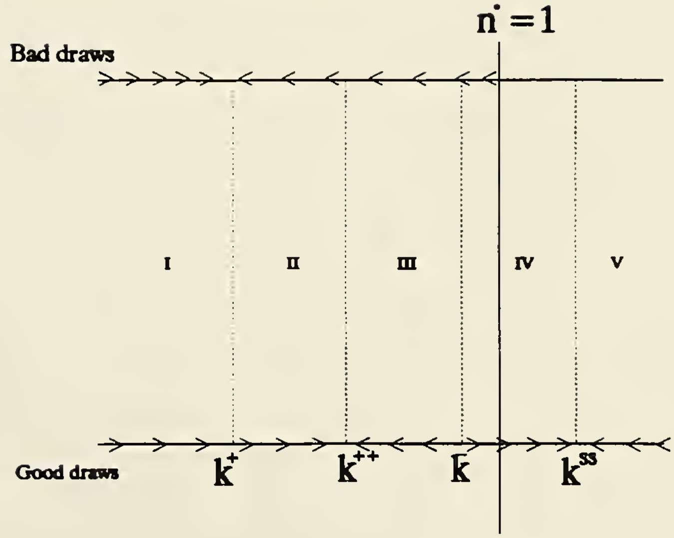

Figure 7

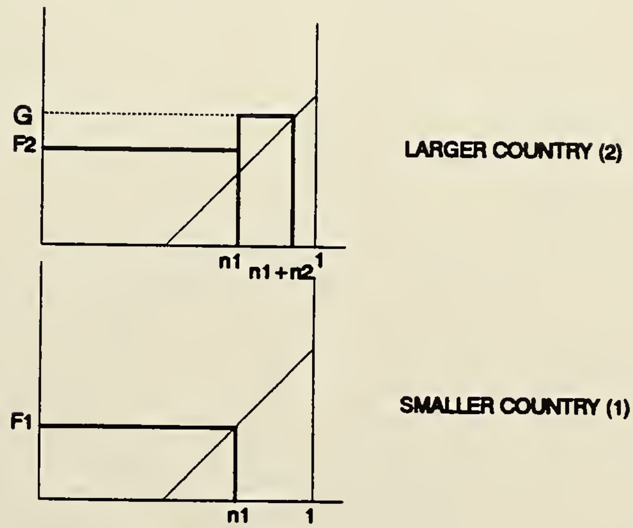

Figure 8