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ABSTRACT

On The Optimality of Risk-Sharing in Growth Models: The Role of 'Education'*

While the 'risk amelioration' literature suggests that risk-sharing channels savings into risky but productive technologies and hence favours growth, models focused on precautionary savings reverse this conclusion. We solve, by means of numerical techniques, a model based on human capital accumulation through education and we find that the increase in precautionary savings makes labour more productive in the goods sector and draws resources from education, which is the 'growth-leading' activity. Hence, we establish a result favourable to financial integration, even in a model where precautionary savings play an important role.

JEL Classification: F40, O41
Keywords: endogenous growth, human capital, education, risk-sharing

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NON-TECHNICAL SUMMARY

During the last decade, a large body of literature has identified many different channels through which financial developments may favour growth. From the perspective of an analysis of the relation between risk-sharing and growth, a relevant channel is ‘risk amelioration’, which is modelled by assuming that each agent (or country) has at his disposal two different technologies. While one is safe, the return provided by the other is high, as it is its volatility. In this context, (international) financial integration funnels savings in the direction of high return technologies, since it reduces their risk, as perceived by each single investor. Hence, risk-pooling promotes growth.

This conclusion may be overturned in models focused on the role of precautionary savings. This happens when the productivity level of the safe technology is so low that in an ‘autarkic equilibrium’ all the agents (countries) adopt only the risky technique. Since agents use technologies that are characterized by the same expected return and differ only in their stochastic components, a reduction in risk can not involve any ‘substitution effect’ towards highly productive technologies. Hence, the contributions introducing such assumptions focus on the fact that equity markets and their international integration, allowing investors to diversify risk, attenuate the precautionary motive for savings: investment and therefore growth may be reduced through this channel.

The policy implications of these contributions are potentially far-reaching. Since international integration may be detrimental for growth, the political stance approving financial liberalisation might prove questionable whenever the presence of positive externalities makes the growth rate sub-optimal.

However, a reduction of the growth rate caused by a decrease in risk does not necessarily imply harmful consequences for risk-averse individuals. Thus, a deep analysis of the effects of uncertainty on growth and welfare is necessary.

Devereux and Smith (1994) raise the strongest point within this literature, since they present an endogenous growth model where, under appropriate conditions, a reduction in risk decreases not only the growth rate but also the welfare level. Devereux and Smith examine a framework populated by risk-averse individuals where the accumulation of knowledge is not the outcome of a conscious effort. Following Romer (1986), human capital is taken to be proportional to the stock of physical capital, due to a positive Marshallian externality. Welfare may be harmed by risk-sharing because we are in the presence of two distortions: the positive externality implies a sub-optimal growth rate and uncertainty is not diversified away as much as possible.

Hence, the possible negative impact on welfare of financial integration is a typical second best result.

While this result may be extended in various ways, in this Paper we argue that, once the possibility of human capital accumulation through education is taken into account, the picture significantly changes. Following Lucas (1988), we divide our economy into two sectors and we assume that one of them produces 'education', i.e. additions to the stock of human capital. The technology describing the growth of human capital is stochastic, as it is the production of goods. Since the stochastic component in the educational process can not be pooled on the market due to moral hazard, we focus on variations in the standard deviation of the technological disturbance, suggesting that its reduction may be interpreted as a way to stylize the effect of (international) financial integration.

To solve the model, we need to resort to numerical techniques but our result can be explained intuitively. The reduction in the technological disturbance reduces the need for precautionary savings; hence, the ratio between physical and human capital decreases and the use of labour in the goods sector becomes less productive. Therefore, labour is moved to the schooling sector and the welfare level increases not only because the risk-averse representative individual is exposed to a lower level of volatility but also because the shift in the allocation of labour reduces the growth rate of human capital. This exerts a negative influence on the already sub-optimal expected growth rate.

In this way, we identify a channel-linking risk reduction and growth that is different from the one characterizing the existing literature. In fact, many contributions suggest that 'risk amelioration' draws resources towards highly productive activities since it helps pooling their volatility; such a 'resource shift' towards projects with high risk and high return is favourable to growth. In our model, resources, specifically labour, move *away* from the sector where risk is reduced.

We test the robustness of our conclusions, running several simulations and we find that the reduction in welfare caused by an increase in the technological disturbance is larger, the risk aversion is higher and the external effect of human capital on production is stronger. We also consider the case of external effects provided in production by physical capital. Again, an increase in risk shifts resources away from education. This effect proves to be increasing with the externality, since labour becomes more productive in the goods sector when the steady-state ratio of human over physical capital decreases, due to the precautionary motive.

Therefore, in conclusion, we re-establish the ‘traditional result’, favourable to financial integration, in a model where precautionary savings play an important role: our analysis stresses that the direction of the effect of precautionary savings on growth depends on the structure of the model. If capital accumulation is the ‘engine of growth’, the relation will be positive; on the other hand, if growth is led by the accumulation of human capital, an increase in precautionary savings is detrimental to the expected growth rate. Accordingly, (international) financial integration is always welfare-improving.

I. Introduction

During the last ten years, a large and increasing number of contributions has analysed the relationships between financial development and growth.

As suggested by Pagano (1993) in his early survey, the renewed interest about this previously almost neglected issue can (at least partly) be ascribed to the success of the endogenous growth approach. In traditional growth theory, preferences, technological levels, market structures and institutions could influence the level of capital per worker but not the growth rate of income, since the latter was due to exogenous technical progress. According to the new approach, growth is self-sustaining and the growth rate is endogenously determined by elements such as the ones listed above. Therefore, also the degree of financial development and the efficiency of financial institutions gain a quantitatively larger importance for the growth process.

As documented by Levine (1997), this stream of literature has identified many different channels through which financial developments may favour growth. From the perspective of an analysis of the relation between risk-sharing and growth, the most relevant channel is "risk amelioration", which is modelled by assuming that each agent (or country) has at his disposal two different technologies. While one is safe, the return provided by the other is high, as it is its volatility. In this context, (international) financial integration funnels savings in direction of the high return technologies, since it reduces their risk, as perceived by each single investor. Hence, risk pooling promotes growth. For example, this mechanism drives the results in Obstfeld (1994), which is a paper that uses a modelling technology akin to the one we choose. A similar "substitution effect", conveying investment towards risky but highly productive projects, may be modelled by allowing financial institutions to pool idiosyncratic "liquidity" risk, as in Levine (1991) and Bencivenga and Smith (1991).

In these contributions, precautionary savings play either a secondary role or no one. Levine (1991), who embeds an idiosyncratic technology shock in his model, constrains overall savings to be equal to young agents' income. The same is true in the basic version of Bencivenga and Smith (1991), who however neglect technology shocks. Obstfeld (1994) carefully studies the savings behaviour in his linear stochastic model. Yet, in his framework, for any given level of wealth, consumption is reduced by an increase in

uncertainty. In fact, the shift towards the low risk - low productivity technology lowers the expected returns on savings and hence increases consumption. A similar mechanism is at work also in the version of Bencivenga and Smith's model with variable savings. They limit their analysis to the case of unit elasticity of intertemporal substitution, finding ambiguous results: since a reduction in the liquidity risk funnels savings to long-term assets, their higher productivity may well induce agents to reduce consumption.

The contributions focused on "risk amelioration" usually consider agents (or countries) of the same dimension and endowed with technologies that differ only for the realisation of their stochastic components. While this characterisation implies an increase in growth for all the participants in financial markets, the picture may change if each agent is endowed with a different technology. Devereux and Saito (1997) consider the growth and welfare implication of international asset trade in a two-country model, where the first economy faces a high risk-high returns technology, while the other is endowed with a safer but less productive technique. When the country with the less risky technology is small, its growth rate and welfare level may be higher in a regime of non-contingent assets trade than under complete assets markets. This happens because the small country can borrow at a safe rate that is close to the rate prevailing in the large country. Since the latter is characterised by a risky technology, such rate is low. Notice that the equilibrium characterised by incomplete asset markets can be favourable only to one country.

However, financial developments may involve also a reduction of growth for all the participants in the market. This happens when the productivity level of the safe technology is so low that in an "autarkic equilibrium" all the agents (countries) adopt only the risky technique. Since agents use technologies that are characterised by the same expected return and differ only in their stochastic components, a reduction in risk can not involve any "substitution effect" towards highly productive technologies.[1] Hence, the contributions introducing such assumption focus on the fact that equity markets, and their international integration, allowing investors to diversify risk, attenuate the precautionary motive for savings: investment and therefore growth may be reduced through this

[1] Obstfeld (1994) briefly considers this case in Section II.

channel.

The policy implications of these contributions are potentially far-reaching. Since international integration may be detrimental for growth, the political stance approving financial liberalisation might prove questionable whenever the presence of positive spillovers makes the growth rate sub-optimal.

However, a reduction of the growth rate caused by a decrease in risk does not necessarily imply harmful consequences for risk-averse individuals. Thus, a deep analysis of the effects of uncertainty on growth and welfare is necessary.

Devereux and Smith (1994) raise the strongest point within this literature, since they present an endogenous growth model where, under appropriate conditions, a reduction in risk decreases not only the growth rate but also the welfare level. Devereux and Smith examine a discrete time framework populated by agents with *CRRA* preferences; the returns to scale of the production function are constant in capital and human capital. The accumulation of knowledge is not the outcome of a conscious effort; rather, following Romer (1986), human capital is taken to be proportional to the stock of physical capital, due to a positive marshallian externality. Hence, the aggregate production function turns out to be linear in capital. In the tradition of discrete time models, Devereux and Smith assume that the shock is observed before current consumption in decided upon.

To consider the role of income risk pooling, Devereux and Smith assume the presence of a stochastic endowment, which plays the role of individual specific labour earnings. Formally, the endowment is affected by additive shocks, which are independent over time. These shocks are assumed to be proportional to the aggregate capital stock, since growth would make (asymptotically) negligible the effect of identically distributed disturbances. In such a stochastic endowment case, Devereux and Smith show that the growth rate is lessened by a reduction in aggregate risk (by a transition from financial market autarchy to international integration) and that welfare may be harmed.[2] The result concerning the growth rate is in the precautionary savings tradition: with idiosyncratic income risk, a positive third derivative of the utility function (which is always the case

[2] The parameter set for this to be true must be computed numerically. For an example, see Devereux and Smith, (1994), pp. 540-544.

with *CRRA* preferences), guarantees that a reduction in risk depresses savings.[3] Welfare may be lessened because we are in presence of two distortions: the positive externality implies a sub-optimal growth rate and uncertainty is not diversified away as much as possible. Hence, the possible negative impact on welfare of financial integration is a typical second best result.

These outcomes are significantly affected by the presence of multiplicative (Hicks neutral) technology shocks. Under this assumption, Devereux and Smith find that an increase in the variance of the disturbance enhances the growth rate only if the elasticity of intertemporal substitution is lower than one. They ascribe this result to the ambiguity of the response of saving to rate-of-return risk ((1994), p. 545). Mauro (1995) has considered an endogenous growth model where, again, physical capital is the source of the relevant externality; his model is populated by overlapping generations composed of "non-expected utility maximisers". Mauro reaches the same conclusion about the response of the growth rate to the introduction of the stock market. Jitsuchon and Saito (1995) confirm this result in a continuous time framework where risk aversion is distinct from the elasticity of intertemporal substitution and the production function is linear in capital, as in Rebelo (1991).

In this second specification of their model, Devereux and Smith obtain an unambiguous result about welfare: an increase in risk is always damaging. The economic intuition for this result is straightforward: with multiplicative shocks, the externality is less marked than in the case of endowment risk because the private return on capital reflects part of the shocks, and it covaries negatively with the marginal utility of future consumption. Therefore, growth is riskier than in the "stochastic endowment" case: an increase in the standard deviation of the disturbance has a stronger effect on the volatility of consumption.

In a previous version of the present paper, we have analysed a continuos time model whose productive structure is very similar to the ones considered by Devereux and Smith (1994) and Mauro (1995): physical capital provides the marshallian externality and the

[3] This result dates back to Sandmo (1970); for recent developments in this stream of literature see, e.g. Weil (1993) and van der Ploeg (1993).

source of risks is a multiplicative technology shock. The utility specification for our infinitely-lived individual was a standard *CRRA*. However, we have let consumption to be decided upon *before* the shock is observed. [4] This seemingly minor modification has allowed us to show that, with plausible parameterisations for the utility and the production functions, a reduction in risk may be harmful for welfare even with multiplicative technology shocks. The hypothesis about the timing of decisions has important consequences on the discount rate used to capitalise future wages. When consumption is decided upon *after* the realisation of the shock, labour income is known and human wealth is evaluated using the (observed) marginal productivity of capital. On the contrary, when consumption is chosen while current wages are uncertain, the (endogenous) discount rate for the stream of labour incomes increases, to take account of their riskiness. A mean preserving spread in the technological disturbance, therefore, by increasing the discount rate on wages, reduces human wealth and hence consumption, and fosters growth. This effect proves to be strong enough to involve the result mentioned above.[5]

However, once the possibility of human capital accumulation through education is taken into account, the picture significantly changes. In Section II, we build a continuos-time stochastic version of the well-known Lucas (1988) model, we solve it by means of numerical techniques, and we find that an increase in technological risk is welfare damaging. This happens because the production of goods is capital intensive, hence, the increase in precautionary savings makes labour more productive in that sector and draws resources from education, which is the "growth leading" activity. Therefore, we re-

[4] In discrete time models where the time span is long, as it is the case in overlapping generation models, this hypothesis is not appealing, since one may presume that consumption can be adjusted within the period, following variations in income. However, as the time interval gets short, it seems sensible to assume that such an adjustment becomes difficult. Moreover, real income, in decentralised economies, may be realised with a time lag, possibly due to difficulties in acquiring information about real prices. Actually, in most consumption-portfolio decisions models, formulated both in discrete and in continuous time, consumption decisions are taken before yields can be observed.

[5] To check the robustness of such a "perverse" result, we have used the generalised isoelastic preferences, proposed by Epstein and Zin (1989), Svensson (1989) and Weil (1990) to distinguish between elasticity of intertemporal substitution and risk aversion. Within this framework, we have considered the possibility of an endogenous labour/leisure choice and of a (limited) uncertainty about future preferences. We have analysed also the effect of an additional distributive shock. It turned out that none of these modifications could conclusively disrupt the "perverse" result.

establish the "traditional result", favourable to financial integration, even in a model where precautionary savings play an important role.

II. Human capital accumulation through education

The "learning by doing" model neglects the basic fact that skills must often be acquired through a period of formal training. The idea that the investment in education is an important source of growth has been corroborated by the cross-country regressions presented in Barro and Lee (1994) and in Barro and Sala-i-Martin (1995). Their results suggest that the educational attainment, measured in terms of years of schooling, is positively and significantly correlated with subsequent growth. [6] Barro and Sala-i-Martin include among their explanatory variables also the ratio between public spending on education and GDP. The estimated coefficient is, again, significantly positive, suggesting that an increase in the quality of schooling is important for growth. A similar conclusion can be drawn from Lee and Lee (1995), who find that economic growth is positively related to an index of "educational achievements". Hansen and Knowles (1998) estimate an aggregate production function for the OECD countries, detecting increasing returns to scale in physical and human capital. Their work also suggests that physical capital may exert relevant external effects.

Since the relation between education and growth, we now consider a framework where, as in Lucas (1988), the accumulation of human capital is not due to an externality but it requires some effort to the representative agent.

We will consider a single country model, but it is possible, in principle, to show that international risk pooling is equivalent to a reduction in technological uncertainty. This should be the case if the technology available to each country is characterised by the same expected return and technologies differ only in their stochastic components.[7]

Following Lucas and many authors, we divide our economy into two sectors and we

[6] One can argue, on the ground of the results in Barro and Lee (1994), that an additional year of male secondary education raises the average growth rate by not less than 1.34 percentage points. However, a puzzling (and recurrent) result in those growth regressions is that the female schooling entes with the wrong sign.

[7] A recent contribution analysing this problem in the linear-in-capital model (with externalities) is Ghosh and Pesenti (1994), section 2 in particular.

assume that one of them produces "education", i.e. additions to the stock of human capital.

We postulate a technology relating the growth of human capital (*dH)* to the level already attained, *H*, and to the labour time devoted to education:

$$dH = BH\,(1\text{-}L)\,(dt + \sigma_H dz_H) \qquad (1)$$

The shock dz_H is a standard Wiener process, σ_H is the instantaneous standard deviation; *B* is a parameter. The supply of labour is inelastic. Since we have normalised total labour time to unity, both at the individual and at the aggregate level, *L* is the (share of) labour time used in the goods sector. According to eq. (1), the production of human capital involves no physical capital, an important hypothesis for our results. While this assumption is debatable, according e.g. to Barro and Sala-i-Martin (1995), the case of a low capital intensity in education is empirically relevant. [8] While we take the non-stochastic version of the model as known, it is important to remark that the growth rate of the economy is determined by the share of labour devoted to education (see e.g. Lucas (1988) or Barro and Sala-i-Martin (1995)).

All the existing firms produce goods using the following stochastic Cobb-Douglas technology:

$$dY = AK^{\gamma}(HL)^{1-\gamma}\tilde{H}^{\phi}(dt + \sigma_z dz)$$

where *A*, γ and ϕ are parameters. *dY* is the total output flow, *K* is the stock of physical capital and $\tilde{H}$ is the average stock of human capital; hence $\tilde{H}^{\phi}$ represents the external effect of human capital. We assume that the Wiener process *dz* is independent from dz_H, to stylise the idiosyncrasy of shocks in education. The aggregate capital accumulation equation becomes:

[8] A specification encompassing the use of capital in the educational sector is desirable, but it would imply the presence of a further control variable, the share of capital devoted to production. Hence, the solution of the model would become considerably more complex. Notice also that we have assumed a common disturbance to human capital accumulation for all the individuals populating our economy. While this is an unsatisfactory hypothesis, we need to introduce it not only to allow for welfare comparisons, but also for technical reasons. An explicit consideration of the heterogeneity characterising agents involves the need to keep track of the *H/K* ratio at the individual level: the resulting model becomes too complex.

$$dK = AK^{\gamma}(HL)^{1-\gamma}\tilde{H}^{\phi}(dt + \sigma_z dz) - \delta K dt - C dt$$

where C is consumption and δ is the capital depreciation rate.

Our economy is populated by identical, infinitely lived, individuals with *CRRA* preferences, given by:

$$E_t\left(\int_{\tau=t}^{\infty}\frac{C(\tau)^{1-R}}{1-R}e^{-\rho(\tau-t)}dt\right)$$

where ρ is the instantaneous rate of time preference and $R\in[0,1)\cup(1,\infty)$ represents the reciprocal of the elasticity of intertemporal substitution and the degree of risk aversion. In accordance with our basic *CRRA* specification, we guess that the maximum value function for the Bellman equation solving the intertemporal problem for the representative agent takes the form: [9]

$$J(K,x,t) = \left[\frac{K^{1-R}}{(1-R)}\varphi(x)\right]e^{-\rho t} \qquad (2)$$

where $x=\left(\frac{H}{K}\right)^{1-\gamma}\tilde{H}^{\phi}$ and $\varphi(x)$ is an unknown function. We postulate that $\varphi(x)$ is twice continuously differentiable.

Exploiting our guess, we may formulate the Bellman equation as follows:

$$0 = \max_{C;L}\left\{\frac{C^{1-R}}{(1-R)}dt - \rho\frac{K^{1-R}}{(1-R)}\varphi(x)dt + K^{-R}\varphi(x)E(dK) + \frac{K^{1-R}}{(1-R)}\varphi'(x)E(dx)\right.$$

$$\left. - R\,K^{-(1+R)}\,\varphi(x)\frac{E(dK^2)}{2} + K^{-R}\varphi'(x)E(dKdx) + \frac{K^{1-R}}{(1-R)}\varphi''(x)\,\frac{E(dx^2)}{2}\right\} \qquad (3)$$

where:

$$\frac{E(dx)}{dt} = (1-\gamma)x\left[B(1-L) - AxL^{1-\gamma} + \delta + \frac{C}{K}\right] + \phi\, x g_H - \frac{\gamma(1-\gamma)}{2}xB^2(1-L)^2\sigma_H^2$$

[9] Clearly, our guess has been inspired by Mulligan and Sala-i-Martin (1993) who showed how the Lucas' model can be transformed into a simpler one using x as the state variable.

$$+ \phi(1-\gamma)xB(1-L)g_H\sigma_H^2 + \frac{(1-\gamma)(2-\gamma)}{2} x^3A^2L^{2(1-\gamma)}\sigma_K^2 + \frac{\phi(\phi-1)}{2} xg_H^2\sigma_H^2$$

$$\frac{E(dx^2)}{dt} =$$

$$=[(1-\gamma)xB(1-L)]^2\sigma_H^2 + [(1-\gamma)x^2AL^{1-\gamma}]^2\sigma_K^2 + [\phi\, xg_H]^2\sigma_H^2 + 2\phi(1-\gamma)x^2B(1-L)g_H\sigma_H^2$$

and $\frac{E(dxdK)}{dt} = - K(1-\gamma)x^3A^2L^{2(1-\gamma)}\sigma_K^2$

The first order condition for consumption allows to obtain the following expression:

$$C = K\left[\varphi(x) - \frac{(1-\gamma)}{(1-R)} x\varphi'(x)\right]^{-1/R} \qquad (4)$$

Some manipulations lead to the first order condition for the percentage of labour used to produce goods: [10]

$$A\left[\varphi(x) - \frac{(1-\gamma)}{(1-R)} x\varphi'(x)\right] - L^{\gamma}B\left[(1+\phi xg_H\sigma_H^2)\frac{\varphi'(x)}{(1-R)} + \phi xg_H\,\sigma_H^2\frac{\varphi''(x)}{(1-R)}\right] +$$

$$+ \frac{A^2xL^{1-\gamma}}{(1-R)}\{-R(1-R)\varphi(x)+(1-\gamma)x[(2-\gamma)\varphi'(x)+(1-\gamma)x\varphi''(x)-2(1-R)\varphi'(x)]\}\sigma_K^2$$

$$+ \frac{(1-L)L^{\gamma}B^2}{(1-R)}[\gamma\varphi'(x)-(1-\gamma)x\varphi''(x)]\sigma_H^2 = 0$$

This expression may be interpreted as an ordinary equation relating L to x through $\varphi(x)$ and its first and second derivatives. If we substitute (4) into the Bellman equation (3), we find that the resulting expression is homogeneous of degree (1-R) in K. Therefore, our guess (2) is verified and we are left with a system composed of a partial differential equation for $\varphi(x)$ and an ordinary equation for $L(x)$. This system can be solved using the

[10] The first order condition has been obtained by deriving with respect to L the Bellman equation, dividing the resulting equation by $K^{1-R}(1-\gamma)xL^{-\gamma}$ and rearranging.

"collocation technique" neatly expounded by Judd (1992).[11]

In our numerical exercises, we focus on variations in the standard deviation of the technological disturbance. The variance in the process of human capital accumulation has been fixed to 0.01 and then always left unchanged. Since the stochastic component in the educational process can not be pooled on the market due to a moral hazard problem, a change in σ_H^2 is not relevant in a framework stylising the effect of (international) financial integration. Our benchmark value for this variance might seem high, but it accomplishes the idiosyncrasy of shocks in the educational process; lower values for σ_H^2 do not affect our results.

Following the literature originated by Lucas (1988), we choose, to set γ=0.3, which is roughly compatible with the observed capital income share, and ϕ=0.4. Therefore, we incorporate a relevant spillover effect. *R* has been set to 3; *A* has been normalised to unity, since this parameter governs only a scale effect, which is not relevant. We have set *B* to the value implying a 2% per capita growth rate, given our constellation of parameters.

[Figure 1 about here]

Our main result concerns the effect of the decrease in the variance of the technological process (from 0.002 to 0). Even if obtained by use of numerical techniques, our result can be explained intuitively: the reduction in the technological disturbance reduces the need for precautionary savings; hence, the ratio between physical and human capital decreases and the use of labour in the goods sector becomes less productive. (Figure 1a shows the behaviour of the *C/K* ratio.) Therefore, labour is moved to the schooling sector (*L* diminishes, see Figure 1b). The welfare level increases (Figure 1c) not only because the risk-averse representative individual is exposed to a lower level of volatility but also because the shift in the allocation of labour reduces the growth rate of human capital (recall equation (1)). This exerts a negative influence on the (already sub-

[11] The routine is written in Gauss and is based on the NLSYS procedure. We set _nlfvtol equal to $10^{(-10)}$ and _nsltol=_nlmtol=$10^{(-20)}$. A personal computer with a P133 processor takes about twenty minutes to produce the results displayed in Figure 1.

optimal) expected growth rate. [12] Notice that we have identified a channel linking risk reduction and growth that is different from the one characterising the existing literature. As documented by Levine (1997), many contributions suggest that "risk amelioration" draws resources towards highly productive activities since it helps pooling their volatility; such "resource shift" towards projects with high risk and high return is favourable to growth. In our model resources, specifically labour, move *away* from the sector where risk is reduced. As already suggested, this effect is related to the reduction in precautionary savings and hence in the ratio between physical and human capital.

To test the robustness of our conclusions, we run several simulations, varying R from 1.05 to 8. In coherence with our intuitive explanations, we have found that the higher R, the larger the reduction in welfare caused by an increase in the technological disturbance: a high degree of risk aversion involves a more important effect on precautionary savings. We have also considered the possibility of stronger external effects, raising ϕ from 0 to 1. We have uncovered that a more relevant role for spillovers enforces our result, since the wedge between market and optimal expected growth rate is augmented, in our model, by an increase in risk.

Finally, we considered the case of external effects provided in production by physical capital:

$$dY = AK^{\gamma}(HL)^{1-\gamma}\tilde{K}^{\phi}(dt + \sigma_z dz)$$

where $\tilde{K}$ is per capital physical capital; $\tilde{K}^{\phi}$ represents the marshallian externality. Hansen and Knowles (1998) provide some empirical support for this specification of the aggregate production function. We run several simulations, for increasing values of ϕ up to 0.4, and we found that a reduction in technological risk has a positive effect on welfare. Again, a lowering in risk shifts resources towards education and hence it is favourable to growth. Moreover, this effect is increasing with ϕ: a larger externality makes labour less productive in the goods sector when the (steady state) ratio of human

[12] We have found support for the role of precautionary savings by simulating a model where the representative agent is not allowed to change her consumption to capital ratio. In such case, our (appropriately modified) routine shows that an increase in the volatility of production induces a *decrease* in the share of labour used to produce goods and hence an increase in the expected growth rate for human capital.

over physical capital increases, due to a reduction in precautionary savings. Our numerical exercises suggest that the effect on growth dominates the welfare-enhancing consequence of the increase in the sub-optimal stock of capital.

III. Concluding remarks

Several important contributions within the "risk amelioration" literature suggest that risk-pooling, conveying resources towards risky but highly productive activities, exerts a positive effect on growth. This conclusion is reversed in the frameworks where a reduction in uncertainty attenuates the precautionary motive for savings and therefore reduces investment. Moreover, when the growth rate is sub-optimal and physical capital generates positive spillovers, the decrease in capital accumulation caused by a reduction in risk can be welfare lessening, even if the decline in the level of uncertainty is beneficial for risk averse individuals.

The microfoundation of human capital accumulation proves to be an essential element to reconcile the implication of the precautionary savings approach with the literature focused on "risk amelioration". We have built a continuos-time stochastic version of the Lucas (1988) model, and, for realistic parameters values, we found that an increase in technological risk damages welfare.

This happens because an increase in risk enlarges the need for precautionary savings; hence, the long-run optimal ratio between physical and human capital increases: since the educational sector does not employ physical capital, the use of labour in the goods sector becomes more productive. Hence, labour is driven away from formal education, which is the "growth leading" sector. Notice that, as long as the use of physical capital is less intensive in schooling than in production, our result should hold: an increase in capital augments the productivity of labour more in the latter sector than in the former.

Notice, moreover, that if we could adopt time correlated technological disturbances, we would probably obtain stronger results, since shocks that are more persistent generate larger precautionary savings (e.g. Caballero (1990), Weil (1993)) and hence, in our framework, a more important effect on the allocation of resources.

In conclusion, our analysis is useful to stress that, while precautionary savings are important to determine the growth rate, the direction of their effect depends on the

structure of the model. If capital accumulation is the “engine of growth”, the relation will be positive; on the other hand, if growth is led by the accumulation of human capital, an increase in precautionary savings is detrimental for the expected growth rate. Accordingly, (international) financial integration is always welfare improving.

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Figure 1a. Consumption to capital ratio as a function of σ_z^2

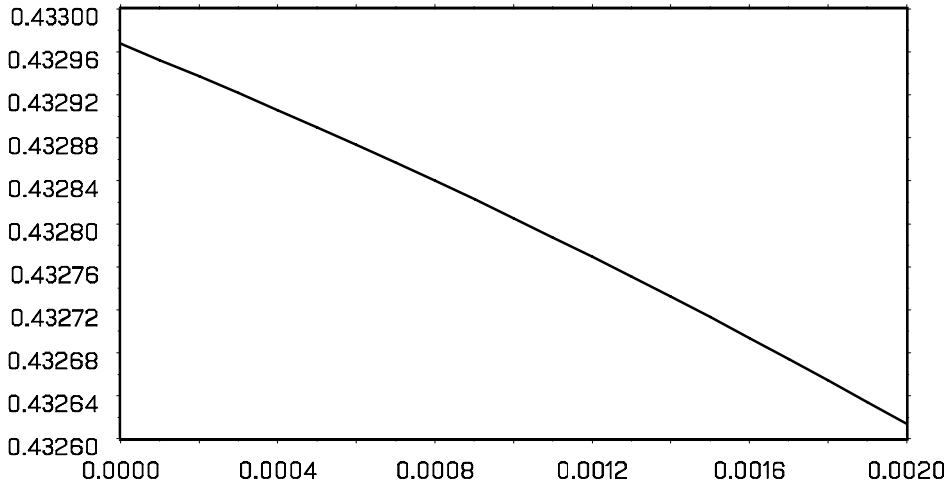

Figure 1b. Share of labour used in production as a function of σ_z^2

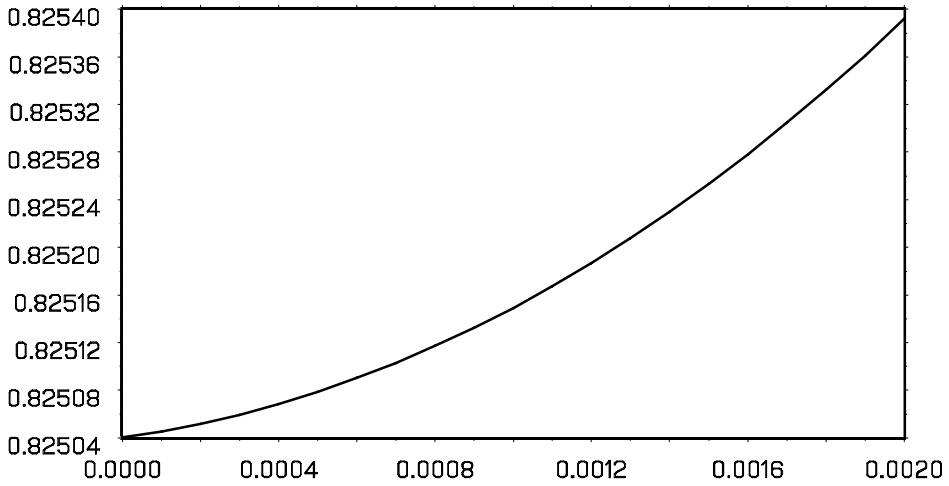

Figure 1c. Welfare as a function of σ_z^2