A Note on Uncertainty and Growth with Recursive Preferences*

Barbara Annicchiarico† Alessandra Pelloni ‡ Fabrizio Valenti§

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Abstract

There is cross-country and time-series evidence that volatility is associated with slower growth. Yet, matching this evidence has proven to be a challenge for growth models without market failures, as they tend to predict the opposite for values of risk aversion greater than unity. This note studies the relationship between uncertainty and long-term growth in a complete markets economy with Epstein-Zin preferences and where the accumulation of human and physical capital drives unbounded growth. With these preferences, risk aversion and intertemporal elasticity of substitution are allowed to be independent of one another. When both are relatively high, the relationship between volatility and growth turns out to be negative.

JEL classification: D92; E22; E32; O49.

Keywords: *Growth and Uncertainty; Epstein-Zin Preferences; Intertemporal Elasticity of Substitution; Risk Aversion.*

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†Dipartimento di Economia e Finanza, Università degli studi di Roma Tor Vergata; e-mail: barbara.annicchiarico@uniroma2.it.

‡*Corresponding Author*: Dipartimento di Economia e Finanza, Università degli studi di Roma Tor Vergata, Via Columbia 2, 00133, Roma, Italy; e-mail: alessandra.pelloni@uniroma2.it

§KSAR Consulting Group; e-mail: fabrizio.valenti@ksar.co

1 Introduction

Can increased uncertainty about the future cause a contraction in long-term growth?[1] Most of the evidence offered by a wide empirical literature points to a negative effect of volatility on growth, from the seminal paper of Ramey and Ramey (1995) to the recent one by Jovanovic and Ma (2022), even if estimates varied considerably across empirical studies.[2] The question has gained further relevance in light of the unprecedented shocks that have harmed the economy since the end of the Great Moderation. If we look at the data for the US, we see that there is a negative relationship between the frequency and the amplitude of the business cycle and the long-term growth time series, as shown in Figure 1.

However, the theoretical literature on endogenous growth has experienced difficulties in generating a negative relationship between volatility and growth. In fact, in the standard expected utility framework, given plausible degrees of risk aversion, uncertainty causes an increase in precautionary investment, which is conducive to an increase in long-run growth (see De Hek 1999, Canton 2002 and Jones et al. 2005).[3] Then explanations hinging on various market and state failures have been proposed for the negative association between mean growth and the amplitude and duration of fluctuations that the data seem to suggest: credit constraints making it impossible to exploit the reduced opportunity cost of innovating during slumps (Aghion et al. 2010), new Keynesian features (e.g. wage and price setting) because of which negative demand shocks cause a fall in real activity and reduced accumulation of material or immaterial capital, not compensated by the increased accumulation during booms (Blackburn and Pelloni 2004, Blackburn and Pelloni 2005 and Annicchiarico and Pelloni 2014). Other explanations go from intergenerational complementarities in education (Palivos and Varvarigos 2013) and countercyclical mark-ups leading to extrinsic uncertainty (Wang and Wen 2011) to bad institutions and undisciplined governments (Loayza and Hnatkovska 2004, Varvarigos 2010,

[1]Frank Knight distinguished between risk, arising where choices have to be made where the distribution over a set of relevant events is known, and uncertainty, where the distribution is not known. Today, economists tend to define the latter situation as giving rise to 'ambiguity' and to use uncertainty to refer to situations where distributions are known.

[2]See the meta-analysis by Bakas et al. (2019), to which we refer the interested reader for other original contributions.

[3]This is also the case in the presence of idiosyncratic uninsurable risk, as shown by Krebs (2003).

Fatás and Mihov 2013).[4] The incorporation of real and nominal rigidities in endogenous growth models, as in Comin and Gertler (2006), has also been used in the years following the Great Recession of 2008–2009 to explain the deterioration of growth prospects in the US and many developed countries (e.g. Benigno and Fornaro 2018, Anzoategui et al. 2019, Bianchi et al. 2019 and Cozzi et al. 2021 among others). Annicchiarico and Pelloni (2021) and Garga and Singh (2021) study optimal monetary policy in related setups.[5]

The recent literature has shown the usefulness of Epstein-Zin (EZ) preferences (see Epstein and Zin 1989) in explaining standard asset pricing puzzles.[6] A key feature of these preferences is that the relationship between aversion to risk (RA) and intertemporal elasticity of substitution (IES) is not restricted to be reciprocal, as is the case with standard CRRA preferences. This degree of flexibility is attractive because it is unclear why individuals' willingness to substitute consumption across random states of nature should be so tightly linked to their willingness to substitute consumption deterministically over time.[7]

As in modern economic theory, asset prices are evaluated using marginal utilities, the empirical evidence from asset markets can potentially provide guidance for the choice of preferences in macroeconomic analysis. EZ preferences have then been incorporated into DSGE models to match basic asset pricing observations while maintaining good business cycle properties. A seminal paper in this stream of research is Tallarini (2000). More recent contributions are Van Binsbergen et al. (2012), Croce et al. (2012) and Kung and Schmid (2015).

In this note, we show that EZ preferences can also be useful in investigating the relationship between uncertainty and growth. With EZ preferences, the relationship can take a negative sign even in a model without market or institutional failures and, in fact, featuring none of the mechanisms suggested in the literature as possible explanations. More specifically, we introduce EZ preferences into the standard framework by Jones et al. (2005), in which the accumulation of human and physical capital drives unbounded growth and the source of volatility

[4]For a comprehensive survey of the literature, see Priesmeier and Stähler (2011).

[5]A complementary body of works have developed on uncertainty shocks and business cycles. However, in these works, these shocks and long-run growth are not related. See the overview in Fernández-Villaverde and Guerrón-Quintana (2020).

[6]A leading contribution is Bansal and Yaron (2004).

[7]With EZ preferences a high risk aversion, consistent with a large risk premium, can then coexist with a small aversion to intertemporal inequality (inverse of IES) as consistent with a small risk free interest rate.

is a productivity shock. We will see that the relationship between volatility and growth in the model depends on the interplay between the elasticity of intertemporal substitution, the coefficient of risk aversion, and the Frisch elasticity of labor supply. In particular, a negative effect of volatility on growth is obtained when the IES and RA are both high enough, i.e. under preference parameterizations widely used for calibration purposes and empirically supported. Intuitively, with volatility, agents can work more when the realization of the productivity shock is higher. The expected return to savings will then be increasing in the variance of the shock. However, the certainty equivalent of the return will be reduced by risk aversion. If RA is high enough, more volatility will decrease rather than increase the certainty equivalent of the return to savings. However, this will reduce savings and growth only if the IES is above one, so that the substitution effect prevails on the income effect in choosing current consumption.

Epaulard and Pommeret (2003), like us, analyze the effect of volatility on growth in a model with EZ preferences. Using a simple AK model, they show that the sign of the effect of uncertainty on growth is exclusively governed by intertemporal elasticity of substitution, while risk aversion only influences the size of such an effect. Our work, instead, shows that the sign of the relationship between volatility and growth crucially depends on both risk aversion and the intertemporal elasticity of substitution. We demonstrate that this substantial difference in results is due to the assumption in their paper that only capital and not labor is needed for producing. We drop this restrictive assumption and show that labor supply plays an important role in determining how uncertainty influences growth and how risk aversion and intertemporal elasticity of substitution affect that influence.

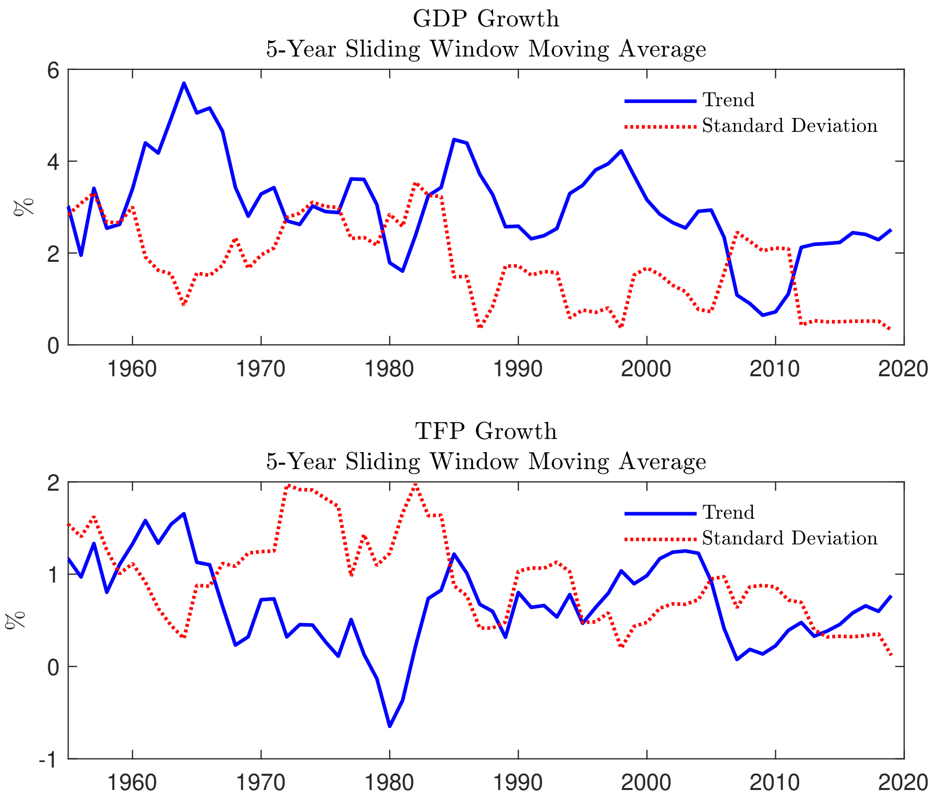
The remainder of this note is structured as follows. Section 2 introduces the model, Section 3 presents our results, and Section 4 concludes.

2 The Model

As in Jones et al. (2005), the economy is characterized by the following production function:

$$Y_t = As_t K_t^{\alpha} \left(n_t H_t\right)^{1-\alpha}, \; 0 < \alpha < 1, \tag{1}$$

Figure 1: Volatility and Growth in the U.S.



Source: Our elaborations on yearly data for the period 1954-2019 from the US Bureau of Economic Analysis (Real Gross Domestic Product) and University of Groningen and University of California, Davis (total factor productivity - TFP). The top graph shows the average GDP growth and its standard deviation, while the bottom one shows the average TFP growth and its standard deviation. The time series plotted are obtained from computation over five-year rolling windows.

where H is human capital, K is physical capital, n is the fraction of time spent working for the market, A is a technological constant, while s_t introduces innovation into the model and is such that

$$s_t = \exp\left(\zeta_t - \frac{\sigma^2}{2\left(1-\varphi^2\right)}\right), \quad (2)$$

$$\zeta_t = \varphi\zeta_{t-1} + \varepsilon_t, \;\; \varphi \in (0,1) \quad (3)$$

with $\varepsilon \sim N\left(0, \;\sigma^2\right)$. This parameterization implies that changes in σ^2 do not affect the expected value of s_t. The two types of capital accumulate according to the following functions:

$$K_{t+1} = \left(1-\delta_k\right) K_t + I_{k,t}, \quad (4)$$

$$H_{t+1} = \left(1-\delta_h\right) H_t + I_{h,t}, \quad (5)$$

where I_k (I_h) is investment in physical (human) capital and the parameters δ_k and δ_h measure the rate of capital depreciation. For simplicity, we assume that physical capital depreciates at the same rate as human capital $(\delta_h = \delta_k = \delta)$.

The representative household has the following Kreps-Porteus preferences in their EZ specification:

$$U\left(C_t, L_t\right) = \left(1-\beta\right) u(C_t, L_t) + \beta\left(\mathbb{E}_t U(C_{t+1}, L_{t+1})^{\frac{1-\gamma}{1-\rho}}\right)^{\frac{1-\rho}{1-\gamma}}, \; 0<\rho<1, \quad (6)$$

or alternatively:

$$U\left(C_t, L_t\right) = \left(1-\beta\right) u(C_t, L_t) - \beta\left[\mathbb{E}_t\left(-U(C_{t+1}, L_{t+1})\right)^{\frac{1-\gamma}{1-\rho}}\right]^{\frac{1-\rho}{1-\gamma}}, \; \rho>1 \quad (7)$$

where $\beta \in (0,1)$ is the discount factor, $u(C_t, L_t)$ is the period utility function with arguments consumption C_t and leisure $L_t = 1 - n_t$, ρ is the inverse of the intertemporal elasticity of substitution, say ψ (i.e., $\rho = \psi^{-1}$), and γ is the coefficient of relative risk aversion (see Swanson 2012, 2018 for the derivation of RA in dynamic models with EZ preferences and flexible labor margin). Standard Von Neumann-Morgenstern preferences constrain the risk aversion to be the inverse of the intertemporal elasticity of substitution (in our context, this would mean $\gamma = \rho$), while with EZ preferences, these two parameters are allowed to take any positive value. Note that to express preferences we have started from the formulation of Swanson (2018). Usually, EZ preferences are expressed as

$$\tilde{U}_t\left(C_t, L_t\right) = \left[(1-\beta)\,\tilde{u}(C_t, L_t)^{1-\rho} + \beta\left(\mathbb{E}_t \tilde{U}(C_{t+1}, L_{t+1})^{1-\gamma}\right)^{\frac{1-\rho}{1-\gamma}}\right]^{\frac{1}{1-\rho}}. \tag{8}$$

It can be seen that by setting $U = \tilde{U}^{1-\rho}$ and $u = \tilde{u}^{1-\rho}$ for $0 < \rho < 1$ and $U = -\tilde{U}^{1-\rho}$ and $u = -\tilde{u}^{1-\rho}$ for $\rho > 1$, (8) correspond to (6) and (7).

We assume that preferences are multiplicatively separable between consumption and leisure, and consider the following period utility function:

$$u(C_t, L_t) = \frac{C_t^{1-\rho}\left[1-\chi(1-\rho)(1-L_t)^{1+\frac{1}{\eta}}\right]^{\rho}}{1-\rho}, \tag{9}$$

where $1-\chi(1-\rho)(1-L_t)^{1+\frac{1}{\eta}} > 0$ for concavity, $\eta > 0$ is the Frisch elasticity of labor supply and $\chi > 0$ is a scaling parameter weighting the disutility from labor.[8] For non-recursive preferences, this specification of the period utility function was first proposed by Trabandt and Uhlig (2011) and is consistent with long-term growth. We adopt it because it is easier in sensitivity exercises to isolate the role of the Frisch elasticity when it is captured by just one parameter, rather than changing with the level of consumption or labor supply. Note that if $0 < \rho < 1$, labor disutility is decreasing in consumption, while the opposite is true if $\rho > 1$.

As the economy is Walrasian, we can just consider the social planner problem:

$$V_t = \max_{\{n_t,\; K_{t+1}, H_{t+1}\}} U_t \tag{10}$$

subject to the constraints in (1)-(5), given (9), as well as the following resource constraint

$$Y_t = C_t + I_{k,t} + I_{h,t}. \tag{11}$$

[8] The restriction $1-\chi(1-\rho)(1-L_t)^{1+\frac{1}{\eta}} > 0$ must hold, otherwise the marginal utility of consumption could be negative for low values of leisure. For a proof of the strict concavity in C_t and L_t of the periodic utility function in (9), see Annicchiarico et al. (2022).

Epstein and Zin (1991) prove the existence and uniqueness of V_t when there is a single consumption good and no labor, which also applies if consumption and leisure form an aggregate good, as in the specification we adopt. Assuming that an interior and a unique solution exists, optimality conditions are then found to be:

$$C_t = \frac{1-\alpha}{\rho\chi\left(1+\frac{1}{\eta}\right)n_t^{\frac{1}{\eta}}}\left[1-\chi(1-\rho)n_t^{1+\frac{1}{\eta}}\right]As_t\left(\frac{K_t}{n_t}\right)^{\alpha}H_t^{1-\alpha}, \tag{12}$$

$$1 = \mathbb{E}_t\left\{M_{t+1}\left[1-\delta+\alpha As_{t+1}\left(\frac{n_{t+1}H_{t+1}}{K_{t+1}}\right)^{1-\alpha}\right]\right\}, \tag{13}$$

$$1 = \mathbb{E}_t\left\{M_{t+1}\left[1-\delta+(1-\alpha)As_{t+1}\left(\frac{H_{t+1}}{K_{t+1}}\right)^{-\alpha}{n_{t+1}}^{1-\alpha}\right]\right\}, \tag{14}$$

where M_{t+1}, the stochastic discount factor in our economy, is given by:

$$M_{t+1} = \beta\left[\frac{\left[\left(\mathbb{E}_t V_{t+1}^{\frac{1-\gamma}{1-\rho}}\right)\right]^{\frac{1-\rho}{1-\gamma}}}{V_{t+1}}\right]^{\frac{\gamma-\rho}{1-\rho}}\left[\frac{1-\chi(1-\rho)n_{t+1}^{1+\frac{1}{\eta}}}{1-\chi(1-\rho)n_t^{1+\frac{1}{\eta}}}\right]^{\rho}\left(\frac{C_t}{C_{t+1}}\right)^{\rho},\ 0<\rho<1 \tag{15}$$

or by:

$$M_{t+1} = \beta\left\{\frac{\left[\mathbb{E}_t\left(-V_{t+1}\right)^{\frac{1-\gamma}{1-\rho}}\right]^{\frac{1-\rho}{1-\gamma}}}{-V_{t+1}}\right\}^{\frac{\gamma-\rho}{1-\rho}}\left[\frac{1-\chi(1-\rho)n_{t+1}^{1+\frac{1}{\eta}}}{1-\chi(1-\rho)n_t^{1+\frac{1}{\eta}}}\right]^{\rho}\left(\frac{C_t}{C_{t+1}}\right)^{\rho},\ \rho>1. \tag{16}$$

3 Uncertainty and Growth

We are now ready to investigate how risk aversion and intertemporal elasticity of substitution influence the relationship between uncertainty and economic growth. We first calibrate the model and then solve it using a second-order perturbation method, as in Van Binsbergen et al. (2012). We then present and comment on the results for our baseline calibration. Finally, we perform some sensitivity analysis to check the robustness of our results and to deepen our understanding of the interaction between the degree of risk aversion and the intertemporal elasticity of substitution in conditioning the impact of volatility on growth.

3.1 Calibration

To compute the desired simulations, we calibrate the model as follows. We set the individual discount rate, β, equal to 0.95, which means that the duration of a period is equal to one year. For our benchmark simulation, we will set the elasticity of intertemporal substitution, $\psi = \rho^{-1}$, equal to 1.73, as estimated by Van Binsbergen et al. (2012). This value is an intermediate value between the one adopted by Bansal and Yaron (2004) and the one used in Croce et al. (2012) and Kung and Schmid (2015). As far as it concerns the parameter measuring risk aversion, γ, we fix it at 20, which is an intermediate value between the standard value in the literature dealing with EZ preferences (e.g., Bansal and Yaron 2004, Croce et al. 2012 and Kung and Schmid 2015 who set it to 10 and the estimated value found in Van Binsbergen et al. 2012, which is around 66).[9] Finally, the Frisch elasticity, η, is set equal to one, which is an intermediate value in the range of macro and micro data estimates.

Turning to the production side of the economy, we set the capital share, α, to 0.33 and the common depreciation rate of physical and human capital to $\delta = 0.075$, as suggested by Jones et al. (2005). This is an intermediate value, higher than those estimated for the depreciation of human capital (usually between 1 and 4%) but smaller than that of physical capital. In our benchmark case, we want to achieve a steady-state growth rate for output, say g^Y, equal to 2%, a labor supply, n, equal to 0.17. Note that g^Y is close to the annual growth rate of GDP per capita observed in US data for the period 1960-2019, which is 1.97%, according to World Bank data.[10] To match these desired values we set A equal to 0.86 and χ equal to 35.51. Finally, we assume that the standard deviation of the shock is equal to $\sigma = 0.011$ and its persistence equal to $\varphi = 0.9$. With these values, we are able to match the annual standard deviation of GDP

[9] For other recent estimates of the parameters with EZ preferences, see, e.g. Chen et al. (2013), Bollerslev et al. (2015), Schorfheide et al. (2018) and Pohl et al. (2021).

[10] World Bank, Constant GDP per capita for the United States [NYGDPPCAPKDUSA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/NYGDPPCAPKDUSA, October 23, 2022.

per capita growth for the US in the period 1960-2019, which is around 1.94%. The calibration is summarized in Table 1.

Table 1: Benchmark Calibration

Fixed Parameters		
α	Share of capital	0.33
β	Discount factor	0.95
γ	Risk aversion	20
δ	Capital depreciation rate	0.075
η	Frisch elasticity	1
$\psi = \rho^{-1}$	Intertemporal elasticity of substitution	1.73
σ	Standard deviation of the shock	0.011
φ	Persistence of the shock	0.90
Implied Parameters		
A	Technological constant	0.86
χ	Leisure scaling parameter	35.51

3.2 Results

Given the optimal decision rules, to analyze the impact of uncertainty on growth, we look at the unconditional mean of output growth $E(g^Y)$. All we have to do is compare the steady-state value of the growth rate of the output with its first moment. If the latter is smaller (larger) than the former, volatility has a negative (positive) effect on output growth.

In our benchmark simulation, we observe that the expected growth rate of the output is 1.78%, that is 22 basis points lower than its deterministic counterpart. This is a remarkable result, since traditional expected utility models with no distortions show a positive relationship between volatility and growth.

Our findings are represented in Figure 2, where we plot the unconditional mean of output growth for different values of the standard deviation of the productivity shock σ and its autoregressive coefficient φ. As can be seen, the loss of economic growth can be significant in a highly perturbed economy with persistent shocks. This is a particularly important finding, given that economies have recently been subjected to significant disruptions.

To interpret our findings, we can reason as follows. Introducing uncertainty through multiplicative productivity shocks raises average output. In fact, a favorable realization of the shock makes output increase one-for-one, given the inputs. In addition, if agents adjust the labor supply intertemporally, working more when it is more productive to do so, output can increase further. Hence, an increase in productivity will raise output more than proportionally: the reduced-form (equilibrium) production function and its first derivatives are convex with respect to the shock. In particular, through Jensen's inequality, the expected return to savings is increasing in the volatility of the shock. We call this the mean effect.

However, risk aversion means that the certainty equivalent of a gamble of a given expected value is lower, the higher the variance of the payoffs across states. If offered two possible consumption streams, one which is constant and the other which has the same mean but moves around the mean, risk-averse consumers would always prefer the former. We call this the risk aversion effect.[11]

As long as the risk aversion effect prevails over the mean effect, the certainty equivalent of returns to savings will decrease with volatility, reducing both welfare and the relative price between current and future consumption. The substitution effect then pushes current consumption up, while the income effect pushes it down. When the IES is greater than one, the substitution effect prevails, so that consumption goes up and savings down: on average, growth is reduced.

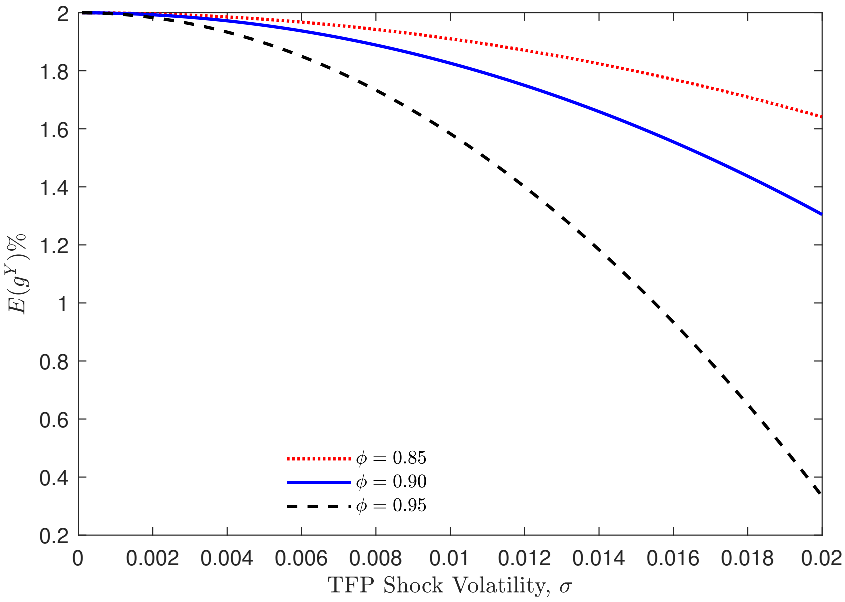
In the next section, we perform some sensitivity analysis to check the robustness of our result and to better understand the interplay between the degree of risk aversion and the intertemporal elasticity of substitution.

3.3 Sensitivity

Our first sensitivity exercise consists of making the risk aversion γ take different values (ranging from 0.5 to 35), for three different values of the elasticity of substitution ψ higher than 1. The results of these simulations are presented in Table 2, where we report the unconditional means for output growth, $E(g^Y)$ and labor, $E(n)$ under different parameterizations. The parameters

[11] Cho et al. (2015), whose terminology we have followed, consider the mean and fluctuations effects to study the welfare cost of business cycles. If the mean effect prevails, the indirect utility function will be convex in shocks, and uncertainty raises welfare.

Figure 2: Volatility and Growth



A and χ are adjusted so that the steady-state growth rate remains equal to 2% and the labor supply equal to 0.17.[12]

From Table 2 we see that, given an IES larger than one, to obtain a negative effect of volatility on growth, we need a high enough RA. This can be intuitively understood as follows. If RA is low, the mean effect will prevail over the risk aversion effect, so that the certainty equivalent return to savings will increase with volatility and individuals will be better off. The income effect will push toward more consumption, but the substitution effect, which prevails, given IES above unity, will make for more savings and growth.

Next, we replicate the same experiment, as in Table 2 for three values of the intertemporal elasticity of substitution, 0.1, 0.5 and 0.7. Table 3 shows that when the IES is less than one, the effect of more volatility on growth is positive across all the values of RA we look at, with the magnitude of the effect increasing in risk aversion.[13] An intuitive explanation is that the

[12]Other experiments can be considered, such as anchoring all the scale parameters to their baseline values and letting the steady state values of growth and labor to change consistently with different values of the intertemporal elasticity of substitution. The results, however, do not change qualitatively with this alternative approach. These findings are available on request.

[13]Note that for $\psi = 0.5$ and $\gamma = 2$, Table 3 reproduces the result of the standard Von Neumann-Morgenstern preferences in which risk aversion and intertemporal elasticity of substitution are the inverse of each other. In this case, the effect of uncertainty on average growth is clearly positive.

Table 2: Expected Growth and Labor - High Intertemporal Elasticity of Substitution

	$\psi = 1.5$		$\psi = 1.73$		$\psi = 2$	
	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$
$\gamma = 0.5$	2.0422	0.1702	2.0578	0.1703	2.0819	0.1704
$\gamma = 2$	2.0291	0.1701	2.0366	0.1701	2.0494	0.1702
$\gamma = 5$	2.0030	0.1698	1.9941	0.1698	1.9844	0.1697
$\gamma = 10$	1.9595	0.1695	1.9234	0.1692	1.8761	0.1690
$\gamma = 20$	1.8725	0.1688	1.7820	0.1681	1.6594	0.1674
$\gamma = 30$	1.7855	0.1680	1.6405	0.1671	1.4427	0.1659
$\gamma = 35$	1.7421	0.1677	1.5698	0.1665	1.3344	0.1652

Note: The table reports the unconditional means for output growth and labor for different values of the risk aversion γ and of the intertemporal elasticity of substitution ψ.

multiplicative separability of leisure and consumption in the period utility function, necessary for the function to be consistent with long-term growth (with the exception of the knife-edge case of logarithmic utility), more volatility in labor will imply more volatility in consumption. A lower intertemporal elasticity of substitution in consumption will then weaken the mean effect, so that the risk aversion effect will always prevail. This implies that agents will always be worse off with more uncertainty, which will also reduce the certainty equivalent of the return to savings. However, with an IES lower than one, the income effect will prevail over the substitution effect, so that consumption will be reduced and growth increased.

The results obtained confirm the intuition of Jones et al. (2005), that the parameters that govern the curvature of the utility function are crucial in determining the sign of the relationship between volatility and growth. In particular, the above results seem to suggest that the relationship between volatility and growth depends on the absolute values of RA and IES and on the ratio between the two values.

Finally, to understand the role of labor flexibility in driving our results, we vary the Frisch elasticity of labor supply, η, and compute the unconditional means of output growth and labor for different values of risk aversion, leaving the intertemporal elasticity of substitution at its baseline value, $\psi = 1.73$ in Table 4, and setting it to 0.7 in Table 5.

Table 3: Expected Growth and Labor - Low Intertemporal Elasticity of Substitution

	$\psi = 0.1$		$\psi = 0.5$		$\psi = 0.7$	
	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$
$\gamma = 0.5$	2.0046	0.1700	2.0074	0.1699	2.0126	0.1700
$\gamma = 2$	2.0134	0.1700	2.0159	0.1700	2.0174	0.1700
$\gamma = 5$	2.0309	0.1701	2.0293	0.1702	2.0268	0.1701
$\gamma = 10$	2.0601	0.1702	2.0516	0.1704	2.0426	0.1703
$\gamma = 20$	2.1184	0.1705	2.0962	0.1709	2.0742	0.1706
$\gamma = 30$	2.1768	0.1708	2.1408	0.1714	2.1057	0.1710
$\gamma = 35$	2.2060	0.1709	2.1631	0.1716	2.1215	0.1711

Note: The table reports the unconditional means for output growth and labor for different values of the risk aversion γ and of the intertemporal elasticity of substitution ψ.

Table 4: Expected Growth and Labor, and the Frisch Elasticity - High Intertemporal Elasticity of Substitution

	$\eta = 0.5$		$\eta = 1$		$\eta = 1.5$	
	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$
$\gamma = 0.5$	2.0377	0.1701	2.0578	0.1703	2.0746	0.1704
$\gamma = 2$	2.0225	0.1700	2.0366	0.1701	2.0491	0.1702
$\gamma = 5$	1.9920	0.1698	1.9941	0.1698	1.9980	0.1698
$\gamma = 10$	1.9413	0.1695	1.9234	0.1692	1.9129	0.1691
$\gamma = 20$	1.8397	0.1689	1.7820	0.1681	1.7427	0.1677
$\gamma = 30$	1.7382	0.1682	1.6405	0.1671	1.5726	0.1663
$\gamma = 35$	1.6875	0.1679	1.5698	0.1665	1.4875	0.1656

Note: The table reports the unconditional means for output growth and labor for different values of the risk aversion γ and of the Firsch elasticity of labor supply η for an intertemporal elasticity of substitution ψ equal to 1.73

Table 5: Expected Growth and Labor, and the Frisch Elasticity - Low Intertemporal Elasticity of Substitution

	$\eta = 0.5$		$\eta = 1$		$\eta = 1.5$	
	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$	$E(g^Y)$	$E(n)$
$\gamma = 0.5$	2.0108	0.1700	2.0126	0.1700	2.0141	0.1699
$\gamma = 2$	2.0146	0.1700	2.0174	0.1700	2.0195	0.1700
$\gamma = 5$	2.0224	0.1701	2.0268	0.1701	2.0303	0.1701
$\gamma = 10$	2.0352	0.1702	2.0426	0.1703	2.0483	0.1704
$\gamma = 20$	2.0610	0.1704	2.0742	0.1706	2.0842	0.1708
$\gamma = 30$	2.0867	0.1706	2.1057	0.1710	2.1201	0.1713
$\gamma = 35$	2.0996	0.1707	2.1215	0.1711	2.1381	0.1715

Note: The table reports the unconditional means for output growth and labor for different values of the risk aversion γ and of the Firsch elasticity of labor supply η for an intertemporal elasticity of substitution ψ equal to 0.7.

A higher value of the Frisch elasticity clearly makes for a stronger mean effect and, therefore, for a stronger positive impact of volatility on the expected return to investing. The impact on mean growth of changes in the degree of risk aversion tends to be higher. In other words, as labor supply becomes more flexible, the impact of volatility on growth, whether positive or negative, is amplified.

4 Conclusion

There is convincing evidence that greater volatility is related to lower long-term growth. The theoretical literature has been able to reproduce this evidence by relying on various kinds of institutional or market failures. However, this paper demonstrates that this stylized fact can be easily replicated in a frictionless endogenous growth model, where agents have Epstein-Zin preferences.

Our simulations agree with the conclusion in Jones et al. (2005) that the relationship between uncertainty and growth can be positive or negative, depending on the concavity of the utility function. However, adopting Von Neumann-Morgenstern preferences means constraining risk aversion and intertemporal elasticity of substitution to be the inverse of each other. As the former parameter is generally assumed to be above unity, this characterization of preferences may bias the results toward finding that, due to precautionary savings, more uncertainty is good for growth. We have found that when risk aversion and elasticity of intertemporal substitution are disentangled and allowed to be both relatively high, the relationship between volatility and growth is negative, whereas otherwise it is positive. We show that when reasonable parameter values are employed, the model yields a negative relationship between uncertainty and growth.

From this perspective, our results uncover a further potential channel for the observed negative relationship between uncertainty and growth, in addition to the various market failures already explored in the literature. In future work, we plan to further investigate the link between growth and volatility by considering the interaction of multiple mechanisms that may be at work.

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