



IMF Working Paper

The Volatility Trap: Precautionary Saving, Investment, and Aggregate Risk

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Abstract

We study the effects of permanent and temporary income shocks on precautionary saving and investment in a “store-or-sow” model of growth. High volatility of permanent shocks results in high precautionary saving in the safe asset and low investment, or a “volatility trap.” Namely, big savers invest relatively little. In contrast, low volatility of permanent shocks leads to low precautionary saving and high or low investment, depending on the volatility of temporary shocks. Empirical evidence shows a nonlinear relationship between investment and saving and that investment is a hump-shaped function of the volatility of permanent shocks, as predicted by the model.

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INTRODUCTION

Studying the effect of aggregate risk on investment and saving is important to understand how economies work. In contrast to idiosyncratic risk, aggregate risk affects the whole economy and is not insurable on a country level. Although hedging instruments flourished since the 1990s, their use at the macro-level remains marginal.¹ Meanwhile, the liberalization of trade and capital flows may have amplified the effects of external shocks on the economy. It is quite possible that aggregate risk plays a central role in the investment-saving dynamics at the macroeconomic level. Low aggregate risk could explain why the saving-investment balance (or current account balance) in advanced economies tends to be smaller than that in emerging nations. Among other factors, an increase in aggregate risk could explain the build-up in current account surpluses and international reserves in Asian countries, following the 1997-98 financial crisis.² In this paper, we explore the effect of aggregate income risk on investment and saving.

We analyze the impact of permanent/persistent and temporary income shocks in a stylized model of precautionary saving and optimal investment under uncertainty. The model is related to the precautionary saving model of Carroll (2001).³ We study aggregate rather than household dynamics and introduce investment. Our representative agent model thus features two assets: a safe asset and risky capital. The investment rate affects output/income growth, resembling the production function in Barlevy (2004). Output is perturbed by permanent and temporary shocks.

We identify four regions of volatility of permanent and temporary income shocks with distinct precautionary saving-investment behavior. High volatility of permanent income shocks leads to high precautionary saving and low investment, or a “volatility trap.” Low volatility of permanent shocks leads to low precautionary saving and high or low investment, depending on the volatility of temporary income shocks. We find that the relationship between the investment rate and the variance of permanent income shocks has a hump-shaped pattern. An increase in variance implies not only a higher saving rate but also a change in the portfolio allocation of saving between risky capital and a safe asset.⁴ In the region of low permanent shocks, the tradeoff between investment and the safe asset is in favor of allocating the additional saving into capital to increase the expected return (despite

¹ See Borensztein et al. (2009) and Zhang et al. (2011) for studies exploring the effects of hedging aggregate risk.

² Such factors as mercantilist policies, capital controls and non-flexible exchange rates in some surplus countries in the region, and possibly over-accommodative macroeconomic policies in some deficit advanced countries, could also have contributed to the reserve accumulation in the region.

³ We define precautionary saving as the amount saved in a safe asset. Carroll (2001) defines precautionary saving as the difference of saving rates in a safe asset between the perfect foresight model and the model with uncertainty. In our model, we have two types of assets: a safe asset and risky capital. Under perfect foresight, capital with higher return will dominate the safe asset, so our definition of precautionary saving is conceptually similar to Carroll's.

⁴ See Levhari and Srinivasan (1969) and Rothschild and Stiglitz (1971) for a detailed treatment of the problem with serially uncorrelated returns.

increased risk) rather than into the safe asset to help weather potential negative shocks. Yet when the critical point is reached, not only the additional saving is allocated into the safe asset, but also the investment rate is cut to reduce the heightened persistent risk. As a result, precautionary saving in the safe asset surges. In contrast, there is no threshold effect as the volatility of temporary income shocks changes. Rather, the investment rate declines and precautionary saving gradually rises as volatility increases. Gourio (forthcoming) also emphasizes the relationship between risk and return. He finds that an increase in disaster risk lowers investment and increases the expected return on risky assets. In addition, Bloom (2009), using temporary aggregate and idiosyncratic shocks in a model of the firm, shows that uncertainty shocks decrease investment and output.

The empirical evidence indicates a nonlinear relationship between investment and saving and between investment and the volatility of permanent shocks, as predicted by the model. The theory we suggest does not explicitly differentiate between domestic and external shocks. In the empirical analysis we focus on the volatility of exports as a proxy for tradable income. We find a strong negative relationship between the investment-saving ratio and the saving rate for a large cross-section of countries.⁵ Big savers invest relatively little, and income volatility seems to be an important driver of the investment and saving dynamics. High volatility of permanent income shocks corresponds to countries that save a lot and invest relatively little. Panel fixed effects regressions suggest that the effect of volatility on investment differs, depending on the nature of income shocks. As a function of the volatility of permanent shocks, investment resembles an inverted U-curve. The volatility of temporary shocks does not have a statistically significant effect, also in line with our model that shows a less stark effect of the volatility of temporary shocks on investment.

A large literature studies the welfare cost of volatility and the effect of volatility on growth. In a survey, Loayza et al. (2007) present explanations as to why the welfare cost of macroeconomic volatility in developing countries might be sizeable, in contrast to the finding by Lucas (2003) for advanced countries, and discuss how to manage it. Ramey and Ramey (1995) show empirically that there exists a significant and negative relationship between output volatility and growth in both OECD and non-OECD countries. Aizenman and Marion (1999) find a negative link between different measures of volatility and private investment in a sample of 40 developing economies. In a recent study, Aghion et al. (2009) show empirically that countries with low financial development have a negative relationship between real exchange rate volatility and growth. Barlevy (2004) presents a model where volatility (in productivity or policy) reflected in volatile investment has a direct and sizeable welfare cost. This result holds even if the average investment rate is kept constant. Our model studies the effect of volatility not only on investment but also on precautionary saving.

Our paper is related to the recent literature that explores precautionary saving in the open economy setting.⁶ In particular, Fogli and Perri (2008) provide empirical evidence of a

⁵ Feldstein and Horioka (1980) indicated that there was a positive correlation between investment and saving rates (see surveys by Obstfeld and Rogoff, 1996, and Coakley et al., 1998). A closer look at the data, however, suggests that this relationship is nonlinear.

⁶ See, for example, Borensztein et. al. (2009) and Durdu et. al. (2009).

positive relationship between macroeconomic volatility and changes in the net external position in OECD economies. This pattern is explained using a two-country business cycle model where changes in the volatility of productivity lead to changes in precautionary saving. In our paper, we study the impact of persistent and transitory income shocks on both precautionary saving and investment. Aguiar and Gopinath (2007) suggest that the main source of fluctuations in emerging markets stems from shocks to trend growth instead of transitory shocks around a stable trend. Kraay and Ventura (2002) analyze how additional saving is allocated between domestic and foreign assets in the presence of temporary income shocks. They argue that it is optimal to invest additional saving so as to maintain the portfolio composition, implying that fluctuations in saving lead to fluctuations in current account. Empirically, they find support to their rule in a cross-section of countries. However, Perri (2002) stresses the importance of distinguishing between permanent and temporary shocks in studying the dynamics of current account.

Other papers have examined the effect of idiosyncratic risk on investment and saving. Our paper complements Aiyagari (1994) as we study the effects of uninsured aggregate risks (in the absence of liquidity constraints) on saving and investment, while he studies the link between idiosyncratic endowment (or labor income) risks and aggregate saving under liquidity constraints. Angeletos (2007) and Angeletos and Panousi (2010) analyze uninsured idiosyncratic investment (or capital income) risk and its implications on saving and investment. Angeletos (2007) shows that this risk results in a tradeoff between higher precautionary saving and lower demand for investment in a closed economy setting. With a large enough intertemporal elasticity of substitution, higher risk reduces aggregate saving, capital stock, and income. Angeletos and Panousi (2010) further show that in the open economy setting, financial integration results in lower capital and output in the short run but higher capital and output in the long run. As wealth is accumulated, a developing country reallocates saving from safe but low-return investment to risky high-return investment, and capital stock increases.

Our contribution to the literature is to study the effects of aggregate income risk in the presence of a precautionary saving motive on investment and saving while explicitly accounting for both the persistent and temporary nature of income shocks. By disentangling the effects of permanent and temporary shocks on investment and precautionary saving, we find the threshold effect of the volatility of permanent shocks, which is supported by empirical evidence. A return-risk tradeoff is the main driver of optimal decisions in allocating income between the safe asset (precautionary saving) and risky investment.

The paper is organized as follows. Section II presents a stylized “store-or-sow” model, and section III discusses its implications. Section IV explores an empirical relationship among investment, saving, and volatility, and section V concludes.

II. A “STORE-OR-SOW” MODEL OF PRECAUTIONARY SAVING AND INVESTMENT

The model presented builds on the household/micro version of the model in Carroll (2001). It has one good—wheat—and in each period, a farmer chooses an amount of grain to store in a safe silo to get through winter (or mitigate against potential negative weather shocks), and an

amount of grain to sow for the next harvest, which is irreversible. In essence, the farmer chooses between a safe and liquid asset and a risky illiquid one.⁷ We simplify the problem by assuming that the investment rate, i.e. the share of output left for sowing, is constant and calculate the optimal investment rate, or “golden rule.” We implicitly assume that the farmer’s supply of labor is inelastic. Assuming a separable utility function and using the market clearing condition that nontradable output must equal nontradable consumption, we abstract from the nontradable sector in our model.⁸ More importantly, it is the tradable output and its volatility that matter for aggregate investment and saving dynamics.

Preferences

In period t , a farmer has the following expected utility over T periods:

$$E_t[\sum_{s=1}^T \beta^{s-t} u(C_s)] \quad (1)$$

where C_s represents consumption in period s and β is a discount factor. The utility function is of a constant relative risk aversion (CRRA) form:

$$u(C) = \frac{C^{1-\rho}}{1-\rho} \quad (2)$$

where ρ is the relative risk aversion coefficient.

Production

Given a quantity K_s of grain sowed, the farmer harvests a quantity Y_s in period s such that:

$$Y_s = f_{\xi}(K_s, V_s)N_s \quad (3)$$

where N_s is a unit mean i.i.d. temporary shock due to, for instance, bad weather conditions (e.g. freeze), and V_s is a unit mean i.i.d. “permanent” shock due to, for example, a damage done by migrating birds flying over the field year after year. Alternatively, one can think of the permanent shock as productivity changes (e.g. sustained injury) or persistent weather patterns (e.g. climate impact). In each period, the farmer can process wheat harvest into seeds at no cost. The process is assumed to be irreversible. We assume that the share of harvest used to be transformed into seeds each period is constant:

$$K_s = \xi f_{\xi}(K_{s-1}, V_{s-1}) \quad (4)$$

⁷ The setup with two assets is analogous to monetary growth models, in which money and capital coexist despite higher expected returns on capital. In our model, safe assets are not channeled into investment via financial intermediation, and there is no government borrowing that could crowd out private investment.

⁸ The assumption that tradable and nontradable goods are not perfect substitutes is not unreasonable, and we use a separable utility to simplify the numerical problem. A simple extension of the model with a nontradable sector can be found in Cherif and Hasanov (2012).

where ξ is the investment rate applied to the permanent production function $f_\xi(K_{s-1}, V_{s-1})$ at the previous period, i.e. the share of permanent output re-invested. Investment is thus risky. We define the production function as:

$$f_\xi(K_s, V_s) = \left(\varepsilon + \frac{1}{\xi}\right) K_s V_s \quad (5)$$

where ε lies in $[0,1]$ and can be interpreted as a productivity parameter. Therefore, permanent output follows a geometric random walk. Substituting (4) into (5), we get:

$$f_\xi(K_s, V_s) = \xi \left(\varepsilon + \frac{1}{\xi}\right) f_\xi(K_{s-1}, V_{s-1}) V_s = (1 + \xi\varepsilon) f_\xi(K_{s-1}, V_{s-1}) V_s \quad (6)$$

This functional form has the following features. The greater the investment rate ξ is, the smaller the marginal product of capital is. At the same time, given the investment rate ξ , the production function is linear in capital, thus resembling the AK model and substantially simplifying the numerical problem. In essence, the average growth rate is set to be equal to a fixed part (ε) of the investment rate (ξ) while the trend of average output is perturbed by both permanent and temporary shocks. The law of motion of output is somewhat reminiscent of Barlevy (2004) and is a macro version of Carroll (2001).

In the presence of a safe asset in the form of a silo, for a strictly positive investment rate, the harvest at the end of the year has to yield, on average, at least as much grain as was sowed, which holds if $\varepsilon > 0$.

Budget constraint

The quantity sowed K_s in each period is assumed to disappear after the harvest, which is equivalent to assuming a 100 percent depreciation rate.⁹ At period $s+1$, the farmer possesses an amount of “wheat-on-hand” equal to the sum of the quantity of grain stored in the previous period, W_s , and the harvest left after the sowing (i.e. investment), $Y_s - \xi f_\xi(K_s, V_s)$. The budget constraint in any period s is:

$$W_{s+1} = W_s + Y_s - \xi f_\xi(K_s, V_s) - C_s \quad (7)$$

We assume that in a given period t the farmer has an initial quantity of grain stored in the previous period.

Solution

In every period, the farmer chooses its consumption and the quantity of grain to save in a silo after the amount of grains to be sowed has been put aside. The maximization problem is similar to that in Carroll (2001), where he shows that it can be normalized to depend on a

⁹ In a general setting, the assumption of 100 percent depreciation is not necessary. However, it will add another state variable, capital stock, to the model.

unique state variable in the following Bellman equation (variables in small letters are normalized by permanent output [equation 5]):¹⁰

$$v_t(w_t) = \max_{c_t} \{u(c_t) + \beta E_t[(1 + \xi\varepsilon)^{1-\rho} v_{t+1}(w_{t+1})]\} \quad (8)$$

We use the endogenous grid points solution method introduced by Carroll (2006) to solve the problem numerically.

The equilibrium is defined as follows: Given an investment rate ξ and an initial quantity of grain W_t , the equilibrium is a quantity C_t and an amount W_{t+1} such that the expected utility is maximized subject to the law of motion of output and the budget constraint for every s in $[t, T-1]$ and such that W_T , “wheat-on-hand,” is fully consumed and K_T , capital, is not.¹¹ We then use a grid search to find ξ^* , the “golden rule” investment rate, or the investment rate maximizing U_t over ξ in $(0,1)$.

Calibration

Preferences: Following Carroll (2001), the coefficient of risk aversion ρ is set to 2, the lower end of the range generally used in the literature. The discount rate is set to the standard value of 4 percent.

Technology: We choose ε to be equal to 0.1, implying that a country with the investment rate of 20 percent would grow on average at 2 percent per year, broadly in line with what we observe for advanced countries. It is also consistent with a pooled regression of growth rates on investment rates over 1970-2000.

Shocks: Permanent (V) and temporary (N) shocks are assumed to be unit-mean log-normal. We also assume a probability of 1.7 percent of a temporary 30 percent drop in production following Barro’s (2008) rare disaster analysis.¹² Standard deviations (σ_V, σ_N) vary in $[0.01, 0.3]$ range.¹³ This range corresponds to the range of standard deviation of shocks observed for tradable income.¹⁴

Initial conditions: We assume that initial wealth is equal to zero and normalize initial income to 1. Results should be interpreted in percentage of initial income. We also assume a time horizon of 50 years.

¹⁰ The return on wealth, r , is assumed to be zero without a loss of generality and is consistent with the average after-tax real return on Treasury bills in the second half of the 20th century (Dacy and Hasanov, 2011).

¹¹ K_T could be considered as a bequest for the next generation.

¹² This is in fact equivalent to Carroll’s unemployment probability in the household version of the model.

¹³ At very low volatility, there is a possibility that the farmer would want to borrow an infinite amount to invest. We do not find this outcome in the range chosen.

¹⁴ Standard deviations of permanent and temporary shocks of exports (in constant USD) proxied for tradable output are estimated using the Kalman filter over the period 1970-2008. Data are from the World Bank’s World Development Indicators database.

III. RESULTS AND IMPLICATIONS

The patterns of the optimal investment rate and precautionary saving in the safe asset depend substantially on the nature and magnitude of income shocks. Figure 1 shows the optimal, or golden rule, investment rate ξ^* and the precautionary saving rate (in the safe asset) for every value of volatility of permanent and temporary income shocks, (σ_V, σ_N) , in $[0.01, 0.3]$ range in the initial time period. The total saving rate is the sum of investment and precautionary saving rates shown in Figure 1. In an open economy setting, precautionary saving in the safe asset can be interpreted as the current account balance or net acquisitions of foreign safe assets. In a closed economy setting, precautionary saving in the safe asset can be thought of as inventory (or silo) investment.

Figure 1: Precautionary Saving and the “Golden Rule” Investment Rate in the Initial Period

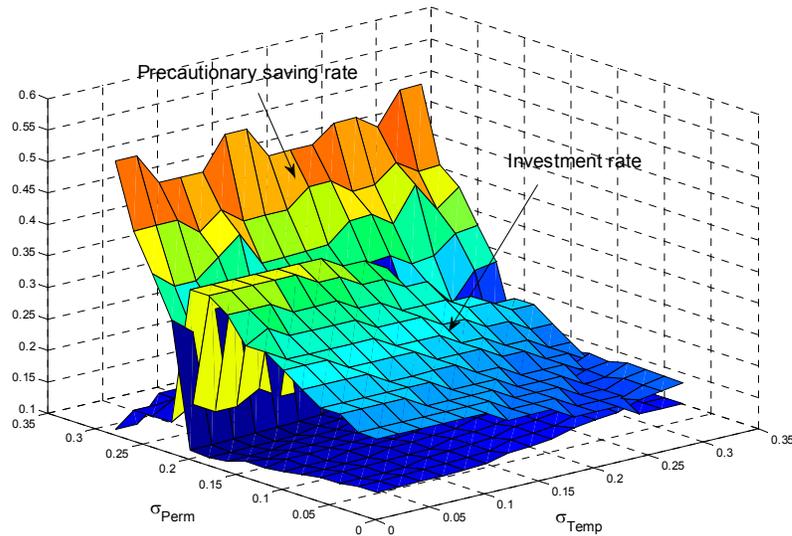
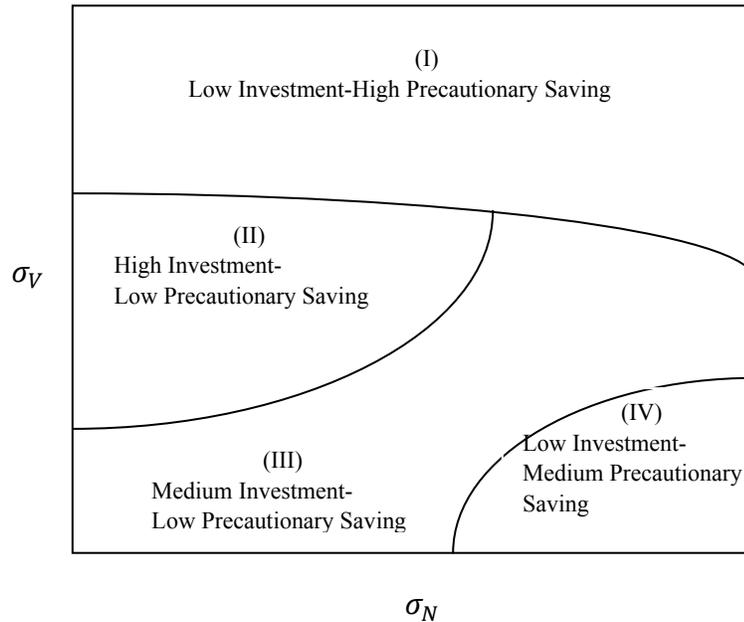


Figure 2. A Phase Diagram of Precautionary Saving and Investment Rates in the Space of Volatility of Permanent (σ_V) and Temporary (σ_N) Income Shocks



There are four regions or phases in the space of volatility of permanent and temporary income shocks that illustrate the relationship between investment/saving and volatility (Figure 2). In the first region of high volatility of permanent shocks (above the standard deviation of 0.2, see Figure 1), investment is relatively low (10-15 percent of income) while precautionary saving is high (25-50 percent of income). In the second region of medium volatility of permanent shocks (below the threshold) and low/medium volatility of temporary shocks, the investment rate is high (25-30 percent of income) while precautionary saving is low (10 percent of income). In the third region that corresponds to medium volatility of permanent shocks and high volatility of temporary shocks, or low volatility of both permanent and temporary shocks, the investment rate falls to 15-20 percent of income with still relatively low precautionary saving rate (10-15 percent of income). Lastly, in the fourth region of low volatility of permanent shocks and high volatility of temporary shocks, investment falls further to the level in phase I (10-15 percent of income), whereas precautionary saving increases slightly from phase III level to about 15 percent of income.

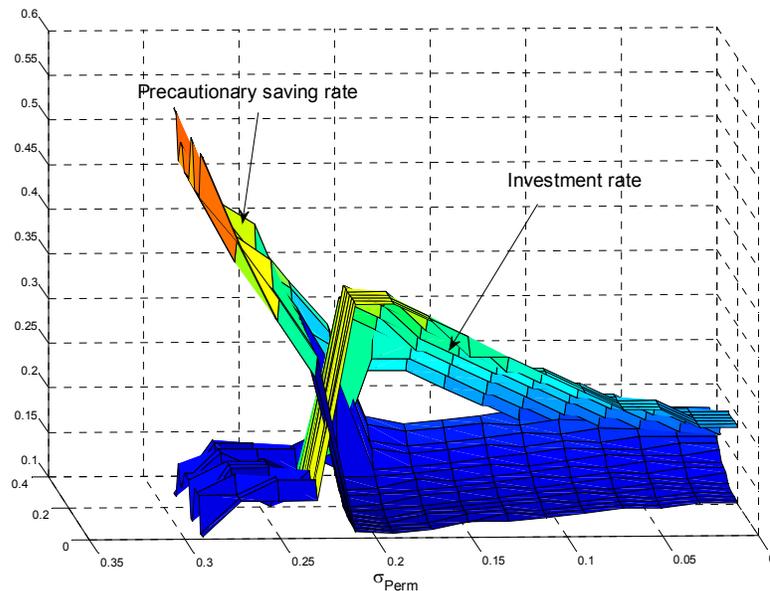
These phases describe rather well overall macroeconomic environment of many countries. Phase I, for instance, corresponds to commodity exporters, especially oil producers. With high volatility of permanent income shocks from commodity income, commodity exporters are likely to run sizeable current account surpluses.¹⁵ Phase II can be associated with emerging economies. The investment share is very high while precautionary saving is relatively low. The diagram suggests that a small increase in the volatility of permanent shocks, especially those countries that have relatively large volatility, can lead to a transition from phase II to phase I. Our model yields another explanation to the current account

¹⁵ See Cherif and Hasanov (2012) for a more detailed treatment of oil-exporting countries.

reversals seen in the Asian emerging economies after the 1997-98 crises.¹⁶ The Asian countries went from current account deficits (or small surpluses) to large surpluses. The severity of the crisis could have led economic agents to revise upward their estimate of the volatility of permanent shocks. If these countries were close to the threshold between phase I and phase II (or if the increase in volatility was large enough), they might have transitioned to the threshold or further beyond the threshold into phase I, witnessing higher precautionary saving and lower investment. Phases III and IV can describe the advanced economies with their relatively low investment and precautionary saving rates.

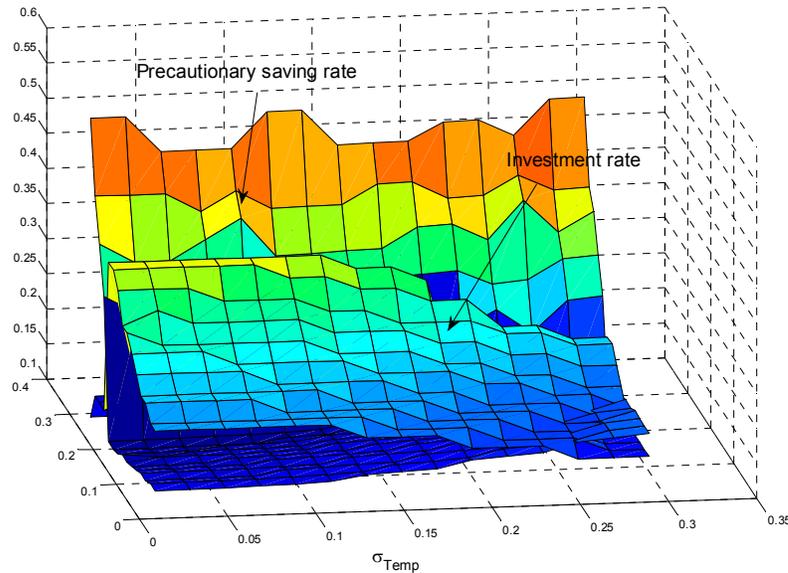
There is nonlinearity in the relationship between investment/precautionary saving and income volatility of permanent shocks, as opposed to the relationship of these aggregates with the volatility of temporary shocks. An increase in the volatility of permanent shocks results in an increase of the investment rate and a slightly decreasing precautionary saving rate until a certain threshold after which investment collapses and precautionary saving in the safe asset surges (Figure 3). The threshold occurs around the standard deviation of a little above 0.2, beyond which the investment rate falls rapidly to stabilize at around 10-15 percent of income while the precautionary saving rate grows from 20 percent of income at the standard deviation of 0.2 to 50 percent at the standard deviation of about 0.3. In contrast, an increase in the volatility of temporary shocks leads to a gradual increase in the precautionary saving rate and a decrease in the investment rate (Figure 4). The total saving rate is slightly decreasing.

Figure 3. Precautionary Saving and Investment Rates vs. Volatility of Permanent Shocks



¹⁶ See Park and Shin (2009) for stylized facts and a study of the reversal, which, however, does not incorporate the impact of a change in volatility.

Figure 4. Precautionary Saving and Investment Rates vs. Volatility of Temporary Shocks



The observed relationship between investment/precautionary saving and income volatility stems from the tradeoff between volatility and expected return. As the volatility of permanent shocks goes up, we first observe that the investment rate increases while the precautionary saving rate slightly declines until a certain threshold level of volatility (Figure 1). The increase in the investment rate and a decrease in precautionary saving in the safe asset with higher volatility may seem puzzling. However, with the higher investment rate, both the expected growth rate of income and total income volatility (the variance of total income) are also higher (see equation 6). As the investment rate increases, the benefit from an increase in the expected income return initially outweighs the cost of an increase in total income volatility. Thus, the farmer compensates higher volatility of permanent shocks, despite increasing total income volatility, with higher expected return—investment increases and precautionary saving declines.

Above the threshold, however, the farmer does not want to bear extra volatility that extra investment would bring. Volatility emanating from permanent shocks is already high enough. The farmer switches his portfolio from risky investment to the safe asset. Interestingly, the switch is relatively abrupt since lower investment rate decreases total income volatility, and even though expected growth also falls with lower investment, higher precautionary saving would protect against any large negative persistent shocks. In summary, when volatility is low, the marginal utility of an increase in the expected return of investment outweighs the marginal disutility of higher volatility. On the contrary, when the variance of the permanent

shock is high, an increase in the expected return of investment does not compensate for higher volatility.¹⁷

The tradeoff between expected return and volatility of temporary shocks is more straightforward. We find that with higher volatility, total saving and investment decline while precautionary saving increases. This result is in line with the findings of Levhari and Srinivasan (1969) in their study of a portfolio-savings problem with serially uncorrelated returns. Similar to our set up, with a CRRA greater than one and log-normally distributed returns, they show that an increase in the variance of one asset leads to a decrease in the saving rate and a portfolio reallocation toward the less risky asset. Essentially, with higher temporary risk, the farmer has less incentive to save even though higher saving would help sustain higher level of consumption in the future. The farmer reduces investment to lower total volatility and increases precautionary saving but by a lesser amount. The farmer's response is starkly different from the situation when the farmer is faced with persistent risk.

IV. AN EMPIRICAL RELATIONSHIP AMONG INVESTMENT, SAVING, AND VOLATILITY

Descriptive Statistics

The cross-country data for 75 countries over the 1970-2008 period show that, on average, both the investment and savings rates are about 23 percent of GDP (Table 1).¹⁸ Yet there is much more dispersion in saving rates than in investment rates. Similarly to the finding of Feldstein and Horioka (1980), the correlation between investment and saving rates is high (Figure 5).

Table 1. Saving, Investment, and Volatility: Descriptive Statistics

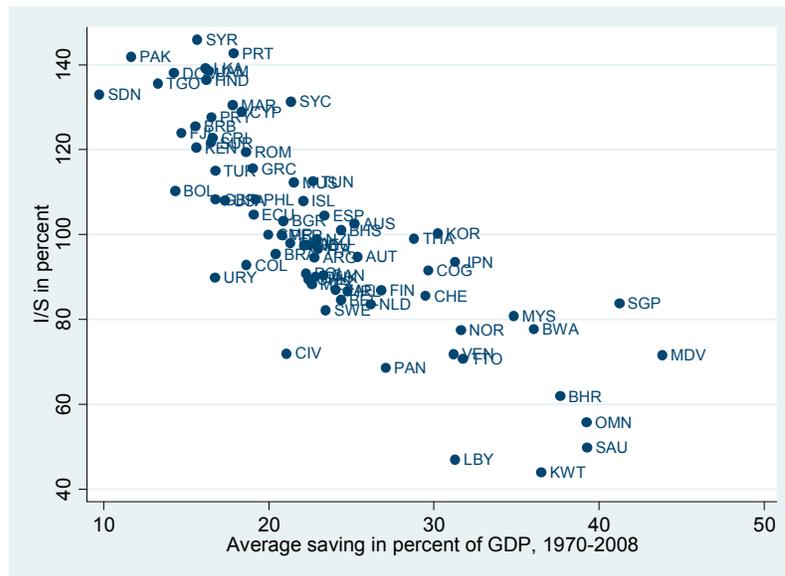
	Mean	Std-dev	Min	Max
Saving	23.2	7.3	9.7	43.8
Investment	23.2	4.1	15.6	35.8
Volatility	0.14	0.05	0.07	0.31

Notes: Saving and investment are in percent of GDP.

Volatility is standard deviation of exports' growth rates in constant USD.

¹⁷ Rothschild and Stiglitz (1971) provide a mathematical explanation of the tradeoff between return and risk. Let $V(\theta, \xi)$ be the indirect utility of the representative agent, where θ is a random variable and ξ is the control variable (the risky asset or investment in our case). They showed that an increase in the variance of θ would lead to an increase in the optimal value of the control variable ξ^* if the second derivative of V_ξ is always positive. In our case, this would imply that V_ξ changes its convexity when the variance of θ is bigger than a certain threshold level of volatility.

¹⁸ All data are taken from the World Bank's World Development Indicators (WDI) database. Investment is gross fixed capital formation and saving is gross domestic saving. Volatility is measured as standard deviation of exports' annual growth rates in constant dollars. See the Appendix Table for the list of countries and average investment and saving rates and volatility.

Figure 6. Saving vs. Investment-Saving Ratio

Panel Fixed Effects Regressions

We use average cross-country data, for which long series are available, in a panel over the three periods, 1980-1990, 1991-2000, and 2001-2008. As a measure of volatility, we compute the standard deviation of the annual growth rate of exports of goods and services.²⁰ We focus on the volatility of exports as a proxy for the volatility of the tradable goods production, which is relevant for the study of investment and saving based on the model discussed in the previous section. The choice of the standard deviation of growth rates stems from our model, in which permanent income follows a geometric random walk. The volatility of persistent and transitory shocks has different effects in the model, which we also explore in the regressions. We use the Kalman filter to disentangle the persistent and transitory components of the logarithm of the exports of goods and services and compute associated standard deviations.

We find nonlinearity in the relationship between investment and saving and investment and volatility of permanent shocks. First, the relationship between investment and saving is nonlinear rather than linear in all specifications (Table 2), confirming the scatter plot in Figure 6. Second, the relationship between “total” volatility and investment is not statistically significant (Table 2, column 1). Including volatility of both temporary and persistent shocks in the regression (column 2) shows that only the volatility of permanent shocks is statistically significant. We find that investment is a nonlinear function of volatility of permanent/persistent shocks with an inverted U-shaped curve, reaching the maximum at the

²⁰ The data are deflated by the US CPI obtained from the WDI database.

standard deviation of about 0.1.²¹ These results are in line with the nonlinearity observed in the model.

Table 2. Panel Fixed Effects Regressions

Variables	Investment			
	(1)	(2)	(3)	(4)
Transitory Volatility		-10.81		
		[-0.0416]		
(Transitory Volatility) ²		214.8		
		[0.106]		
Permanent volatility		59.42**	61.45**	68.50***
		[2.076]	[2.361]	[3.155]
(Permanent volatility) ²		-320.6**	-328.5***	-350.9***
		[-2.593]	[-2.984]	[-3.783]
1990 dummy	1.922**	1.762*	1.741*	
	[2.435]	[1.824]	[1.918]	
2000 dummy	1.164*	1.186*	1.172*	
	[1.975]	[1.933]	[1.922]	
Log GDP per capita	0.367	0.753	0.799	-2.223
	[0.166]	[0.349]	[0.374]	[-1.504]
Saving	1.091***	1.348***	1.359***	1.384***
	[3.137]	[4.851]	[4.680]	[4.831]
(Saving) ²	-0.0147**	-0.0203***	-0.0206***	-0.0212***
	[-2.410]	[-4.712]	[-4.555]	[-4.774]
Volatility	-35.26			
	[-1.265]			
(Volatility) ²	110.6			
	[1.096]			
Constant	1.869	-9.198	-9.927	21.96
	[0.0772]	[-0.404]	[-0.448]	[1.377]
Observations	147	147	147	147
Number of countries	50	50	50	50

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

V. CONCLUDING REMARKS

We build a “store-or-sow” model of precautionary saving and investment to analyze the effects of the volatility of permanent and temporary income shocks. Our results suggest that with higher volatility of permanent shocks, investment and precautionary saving (in the safe asset) increase until a certain threshold after which investment drops while precautionary saving surges. In contrast, with higher volatility of temporary shocks, investment falls and precautionary saving gradually increases.

²¹ Regressing the investment-saving ratio on saving and volatility confirms the scatter of Figure 6 and shows an inverted U-curve relationship between the investment-saving ratio and the volatility of permanent shocks.

The model has implications for high volatility countries, in particular commodity exporters. With high volatility of permanent shocks, the model and the data indicate that precautionary saving (e.g. sovereign wealth funds invested in safe assets, e.g. U.S. Treasury bills) is large while investment is relatively low, thus explaining why high savers invest relatively little. Lowering volatility of permanent shocks would reduce the need to save in the safe asset and would stimulate investment. Our theory could also explain the change that occurred in some Asian economies after the 1997-98 crisis. These economies switched from low saving and high investment (current account deficits) to high saving and low investment (current account surpluses). If the crisis increased the expected volatility of permanent shocks, our model can explain such a change in the investment-saving behavior.

Our paper sheds a new light on Feldstein and Horioka's (1980) puzzle.²² The empirical evidence rejects the linear investment-saving relationship in favor of a nonlinear relationship. The literature studies a linear relationship and finds that investment-saving correlation is quite robust. The coefficient of the saving rate in the investment regression seems to have fallen in OECD countries in recent samples, and is substantially smaller for non-OECD countries. Obstfeld and Rogoff (2006) note that existing theoretical explanations of the puzzle are not supported by the empirical evidence. Our paper suggests a possible answer. The volatility of permanent shocks explains part of the nonlinear relationship between investment and saving observed in the data. Future research would benefit from studying further the theoretical and empirical relationships among investment, saving, and volatility.

Finally, our results have implications on the global imbalances debate. Global imbalances could be the product of heightened uncertainties and volatilities that countries face. It could be optimal for a country to accumulate large precautionary saving if faced with high volatility of permanent income shocks, which we observe for commodity exporters. It could also explain why some emerging markets started piling up foreign reserves and lowered investment, following the crises of the 1990s. Were commodity prices, or more generally exports, more stable, the current account surpluses of these countries would most likely significantly decrease. Policies decreasing income volatility would thus support the goal of reducing global imbalances. For instance, a commitment by oil importers to some oil price floor would most likely lead to a substantial decline of the current account surpluses of oil exporters.

²² In theory, with free capital flows, domestic investment and saving should be unrelated. In contrast, Feldstein and Horioka (1980) found a significant positive correlation between investment and saving rates for a group of OECD countries.

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Appendix Table. Average Investment, Saving, and Volatility (1970-2008)

Country	Code	Investment (% of GDP)	Saving (% of GDP)	Volatility (Std. Dev. of annual exports' growth)
Argentina	ARG	20.67	22.76	0.13
Australia	AUS	26.21	25.18	0.10
Austria	AUT	25.04	25.38	0.10
Belgium	BEL	22.38	24.36	0.10
Bulgaria	BGR	25.44	20.88	0.19
Bahrain	BHR	25.13	37.64	0.22
Bahamas, The	BHS	26.22	24.37	0.17
Bolivia	BOL	16.64	14.32	0.14
Brazil	BRA	20.06	20.41	0.11
Barbados	BRB	19.62	15.56	0.09
Botswana	BWA	34.60	36.06	0.17
Canada	CAN	21.43	23.30	0.07
Switzerland	CHE	26.03	29.51	0.10
Chile	CHL	20.80	22.39	0.14
Cote d'Ivoire	CIV	15.63	21.09	0.13
Cameroon	CMR	19.63	19.98	0.13
Congo, Rep.	COG	27.85	29.66	0.21
Colombia	COL	19.59	18.65	0.12
Costa Rica	CRI	21.13	16.59	0.10
Cyprus	CYP	25.76	18.34	0.10
Germany	DEU	22.33	22.46	0.10
Denmark	DNK	21.22	22.85	0.10
Dominican Republic	DOM	20.80	14.26	0.18
Ecuador	ECU	20.81	19.07	0.12
Spain	ESP	25.10	23.37	0.09
Finland	FIN	24.21	26.82	0.10
Fiji	FJI	20.17	14.70	0.11
France	FRA	21.44	21.29	0.09
United Kingdom	GBR	17.75	16.76	0.09
Greece	GRC	28.29	19.03	0.11
Honduras	HND	24.49	16.23	0.13
India	IND	23.52	22.13	0.09
Ireland	IRL	22.25	24.78	0.12
Iceland	ISL	24.08	22.08	0.15
Italy	ITA	22.43	22.99	0.09
Jamaica	JAM	24.07	16.39	0.08
Japan	JPN	29.84	31.28	0.09
Kenya	KEN	20.64	15.62	0.17
Korea, Rep	KOR	31.03	30.24	0.10
Kuwait	KWT	17.00	36.50	0.25
Libya	LBY	15.62	31.30	0.25
Sri Lanka	LKA	23.39	16.15	0.09
Morocco	MAR	24.50	17.81	0.10
Maldives	MDV	32.21	43.85	0.22
Mexico	MEX	22.90	22.61	0.09
Mauritius	MUS	26.06	21.51	0.11
Malaysia	MYS	27.76	34.84	0.12
Netherlands	NLD	21.97	26.18	0.10
Norway	NOR	25.90	31.63	0.09
New Zealand	NZL	23.52	22.93	0.09
Oman	OMN	22.55	39.25	0.18
Pakistan	PAK	18.06	11.67	0.09
Panama	PAN	20.94	27.09	0.22
Peru	PER	21.79	20.80	0.15
Philippines	PHL	22.17	19.18	0.10
Poland	POL	23.14	22.26	0.14
Portugal	PRT	26.02	17.86	0.11
Paraguay	PRY	22.69	16.52	0.19
Romania	ROM	25.37	18.62	0.17
Saudi Arabia	SAU	20.94	39.29	0.31
Sudan	SDN	16.22	9.73	0.28
Singapore	SGP	35.79	41.24	0.12
Suriname	SUR	22.81	16.50	0.23
Sweden	SWE	19.93	23.46	0.11
Seychelles	SYC	28.75	21.34	0.11
Syrian Arab Republic	SYR	22.39	15.67	0.18
Togo	TGO	20.86	13.28	0.18
Thailand	THA	29.56	28.81	0.09
Trinidad and Tobago	TTO	22.94	31.75	0.17
Tunisia	TUN	26.74	22.67	0.12
Turkey	TUR	19.84	16.76	0.12
Uruguay	URY	16.81	16.74	0.13
United States	USA	19.21	17.33	0.08
Venezuela, RB	VEN	24.99	31.19	0.23
South Africa	ZAF	21.61	24.05	0.13

Source: World Development Indicators, World Bank