Natural volatility - Towards a first survey

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extremely preliminary - comments welcome

A new approach to jointly analysing short-run fluctuations and long-run growth is proposed by the natural volatility literature. This is a first attempt at providing a survey of this recent approach. Many references are still missing. The broad idea should already become clear, however.

1 Introduction

The expression 'natural volatility' represents a certain view about why almost any economic time series exhibits fluctuations. Natural volatility says that fluctuations are natural, they are intrinsic to any growing economy. An economy that grows is also an economy that fluctuates. Growth and fluctuations are "two sides of the same coin", they have the same origin: new technologies.

This is the first aspect on which the literature on 'natural volatility' agrees. Published papers in this literature are (to the best of the author's knowledge at this stage, in sequential and alphabetical order) Fan (1995), Bental and Peled (1996), Freeman, Hong and Peled (1999), Matsuyama (1999, 2001), Wälde (1999, 2002, 2005), Li (2001) Francois and Lloyd-Ellis (2003) and Maliar and Maliar (2004).[1] Papers not yet published include Phillips and Wrase (2005), Francois and Lloyd-Ellis (2004) and Posch and Wälde (2005).

The characteristics of this literature can be understood easily when contrasting it with other approaches. The most prominent one, the RBC approach, views the source of fluctuations to be coming from outside the economy. Total factor productivity follows an exogenously given process. In sunspot models, economies are generally characterized by multiple equilibria and jump between them due to some exogenous driving mechanism (the sunspots).

In this literature, economies fluctuate because of some mechanism that results from decisions of agents. In deterministic growth cycle models, the economy fluctuations because, as in Matsuyama (1999, 2001) agents invest either in R&D or capital accumulation, or, as in Francois and Lloyd-Ellis (2003), because firms find it profitable to delay implementation. In stochastic models like Bental and Peled (1996) or Wälde (2002, 2005), the investment

[1] Due to the explicit modelling of R&D processes, these models can be viewed to represent industrialized economies. Aghion, Banerjee and Piketty (1999) analyse an AK-type economy with borrowing constraints and investors and savers that are distinct agents. They find that when "the separation <between investors and savers> is large but not too large <...> we observe short-run instability" (p. 1375). If the separation is too large, there would be a permanent slump. Without separation, the economy converges to balanced growth. Hence, their intermediate case with growth and fluctuations seems to best describe developing countries.

decision of agents into R&D determines how often technology jumps occur and thereby how long the (expected) length of a cycle is. Technically speaking, stochastic natural volatility models can be seen as an extension of RBC models in the sense that the economy is not hit in every period by a shock but the probability with which an economy is hit by a shock depends on decisions of agents.

This literature provides predictions about the length and the amplitude of cycles, where "expected" needs to be added for stochastic variants.

2 Commonalities and differences in the literature

For a quick overview, the papers can be classified according to (i) the economic mechanism stressed why growth is intimately linked to fluctuations, (ii) the motivation why growth and fluctuations are jointly analysed and (iii) the modelling approach.

2.1 Why growth and fluctuations can not be separated

2.1.1 The basic idea

The second aspect on which the literature agrees (and this is probably a necessary property of any model that wants to explain both short-run fluctuations and long-run growth) is that labour or total factor productivity does not grow smoothly over time as in most models of exogenous or endogenous long-run growth but that productivity follows a step function.

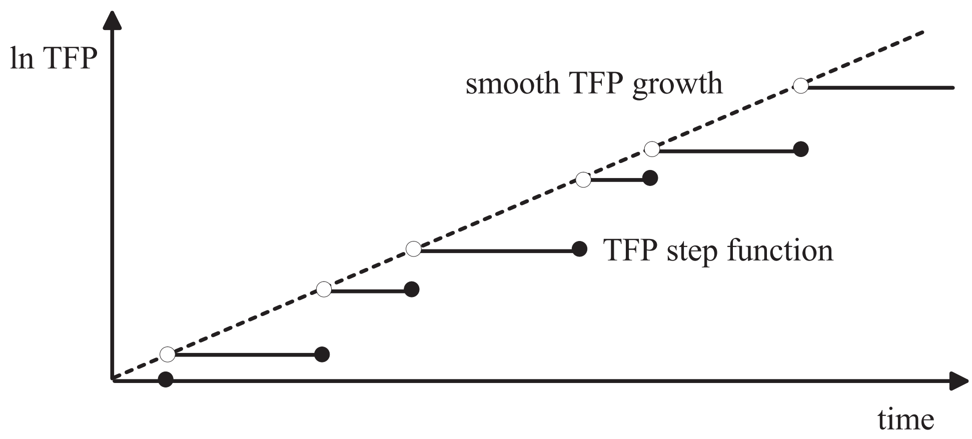

Figure 1 *Smooth TFP growth in balanced growth models (dashed line) and step-wise TFP growth in models of natural volatility*

With time on the horizontal and the log of TFP on the vertical axis, this figure shows as the dashed line a smooth TFP growth path. This is the smooth growth path that induces balanced growth. In models of natural volatility, the growth path of TFP has periods of no change at all and points in time of discrete jumps. After a discrete jump, returns to investment go up and an upward jump in growth rates results. Growth rates gradually fall over time as long as TFP remains constant. With the next jump, growth rates jump up again. While this step function for TFP implies long-run growth as TFP on average grows over time, it also implies short-run fluctuations.

The precise economic reasons given for this step function - which is not simply imposed but always follows from some deeper mechanisms - differ from one approach to the other. A crucial implication of this step-function is the implicit belief that economically relevant technological jumps take place once every 4-5 years. Each cycle of an economy and thereby also long-run growth go back to relatively rare events. Fluctuations in time series that are of higher frequency than these 4-5 years either go back to exogenous shocks, to measurement error or other disturbances of the economy.

2.1.2 Some discussion

Clearly, one should not build a theory on large aggregate shocks to TFP as those are not easily observable. This literature therefore needs to find answers to the question as well, how small changes in technology can have large effects. There are several approaches to this.

Francois and Lloyd-Ellis (2003), using Shleifer's (1986) idea of bunching of implementations even though innovation is continuous, argue that there are many industries in which R&D or improvement of production processes (through reorganization) takes place. These reorganizations are not implemented, however, unless many other industries or firms do this as well. In equilibrium, innovations take place all of the time, implementations take place only at discrete points in time. In this way, small improvements on the sectoral level translate into large jumps on the aggregate level.

Vintage capital models are another way out: Wälde (2005) and Posch and Wälde (2005) use a setup where technological improvements take place only for new vintages of capital. Labour productivity of older vintages do not change when a new technology enters the market. As a consequence, TFP does not jump instantaneously by a large discrete amount but only gradually as the new technology gets more widely used in the economy. In this sense, fig. 1 is only an illustration and models provide more realistic explanations of the evolution of TFP.

Even though not directly related to natural volatility models, the argument by Gabaix (2005) is very useful in this context: When some large firms dominate the economy, changes in TFP at the firm level has economy wide effects. A law of large numbers that is usually argued to prevent that sectoral shocks have aggregate effects does therefore not hold - at least not in the usual way.

2.2 The motivation for a joint analysis

Many papers, sometimes relatively directly, take as starting point a motivation that can be summarized by the following table.

	growth	volatility
exogenous	Solow	RBC, sunspots
endogenous	Romer, Lucas Aghion Howitt Grossman Helpman and others	to be done

Figure 2 *The literature gap on a joint analysis of growth and fluctuations*

The starting point of modern growth theory is usually taken to be the Solow growth model. Long-run growth of GDP per capita is explained by technological progress whose origins are not explicitly modelled. The literature on real business cycles is strongly inspired by the Solow growth model. It is therefore not surprising that fluctuations of an economy are explained by exogenous disturbances to TFP growth. Just as long-run growth is "explained" by exogenous factors in the Solow model, so are short-run fluctuations in the RBC literature. This is true also for models of the sunspot literature where some exogenous mechanism (the sunspots, or beliefs) push economies from one equilibrium path or point to another one. In both approaches, there would be no fluctuations without exogenous disturbances.

The 1980s and 1990s were then characterized by a strong renewed interest in growth theories, starting with the papers by Romer (1986) and Lucas (1988). Models of endogenous technological change were then developed by Romer (1990), Aghion and Howitt (1992), Grossman and Helpman (1991) and many others.

Given this shift in the interest of economists to understand the sources of long-run growth directly from within the model, i.e. given the change in beliefs that long-run growth is determined by economic incentives and not only technological factors, it is natural to ask: Can economic fluctuations also be argued to depend on economic circumstances? Are economic fluctuations just as endogenous as economic growth is?

The motivation of many of the natural volatility papers is therefore the "to be done" area in fig. 2. How can we jointly understand short-run fluctuations and long-run growth as phenomena that both depend on economic circumstances in a given country?

2.3 The modelling approach

A simple though useful way to classify various approaches in the literature is to look at the modelling approach. Some papers follow deterministic approaches like Matsuyama (1999, 2001) or Francois and Lloyd-Ellis (2003). Others take an explicit stochastic approach like Bental and Peled (1996) or Wälde (1999, 2002, 2005) and Posch and Wälde (2005). This is not only a modelling difference but also points to differences in the economic factors behind natural volatility that these various approaches want to stress.

Before we go into details, however, the next section will present a prototype model of the stochastic natural volatility approach. The subsequent section will then look at deterministic versions.

3 A simple stochastic model

This section presents the simplest possible model that allows to understand the difference between the stochastic natural volatility and the RBC approach.

3.1 Technologies

Let the technology be described by a Cobb-Douglas specification,

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha},$$

where A_t represents total factor productivity, K_t is the capital stock and L_t are hours worked. Capital can be accumulated according to

$$K_{t+1} = (1-\delta) K_t + I_t$$

The technological level follows

$$A_{t+1} = (1+q_t) A_t$$

where

$$q_t = \left\{ \begin{array}{c} 0 \\ 1 \end{array} \right\} \text{ with probability } \left\{ \begin{array}{c} p_t \\ 1-p_t \end{array} \right. . \quad (1)$$

The probability depends on resources R_t invested into R&D,

$$p_t = p(R_t).$$

Clearly, the function $p(R_t)$ in this discrete time setup must be such that $0 \leq p(R_t) \leq 1$.

The specification of technological progress in (1) is probably best suited to point out the differences to RBC type approaches: The probability that a new technology occurs is endogenous. This shows both the "new growth literature" tradition and the differences to endogenous growth type RBC models. In the latter approach, the growth rate is endogenous but shocks are still exogenously imposed. Here, the source of growth and of fluctuations all stem from one and the same source, the jumps in q_t in (1).

3.2 Optimal behaviour of households

The resource constraint the economy needs to obey in each period is given by

$$C_t + I_t + R_t = Y,$$

where C_t, I_t and R_t are aggregate consumption, investment and R&D expenditure, respectively. Assume that optimal behaviour of households implies consumption and investment into R&D amounting to

$$C_t = s_K Y_t, \quad R_t = s_R Y_t,$$

where s_K and s_R are two constant saving rates. This would be the outcome of a two-period maximization problem or an infinite horizon maximization problem with some parameter restriction similar to e.g. Benhabib and Rustichini (1994) or, in continuous time, Xie (1991,) or Wälde (2005). As the natural volatility literature has various papers where the saving rate is not constant (Matsuyama, 1999, assumes a constant saving rate, but see Matsuyama, 2001), it seems reasonable not to fully develop an optimal saving approach here as it is not central to the natural volatility view.

3.3 Equilibrium

Equilibrium is determined by

$$\begin{aligned} K_{t+1} &= (1-\delta) K_t + Y_t - R_t - C_t \\ &= (1-\delta) K_t + (1 - s_K - s_R) Y_t. \end{aligned}$$

plus the random realization of technology jumps, where the probability of a jump depends on investment in R&D,

$$p_t = p(s_R Y_t).$$

When we use as auxiliary variable capital per effective labour, $k_t \equiv K_t / (A_t L)$, we obtain with $\frac{K_{t+1}}{A_t L} = k_{t+1} \frac{A_{t+1}}{A_t} = k_{t+1}(1+q_t)$

$$k_{t+1} = \frac{(1-\delta) k_t + (1 - s_K - s_R) k_t^\alpha}{1+q_t}. \tag{2}$$

The convergence behaviour is illustrated in the following figure.

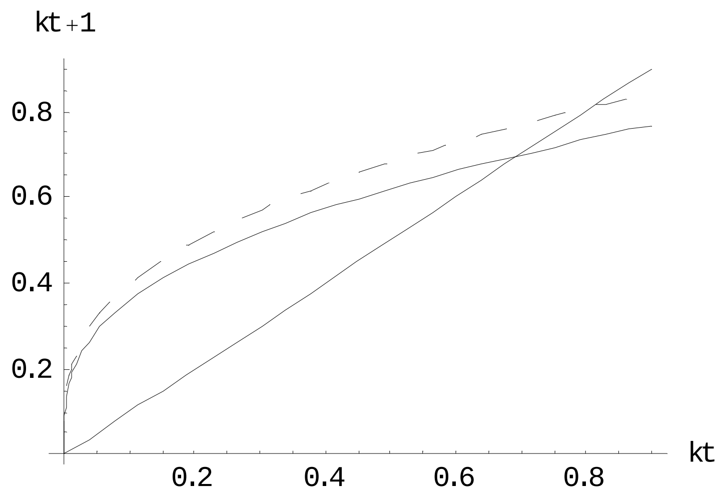

Figure 3 *The Sisyphus economy - convergence to a temporary steady state*

The figure plots the current capital stock per effective labour k_t on the horizontal and k_{t+1} on the vertical axis. As long as there is no technology jump, i.e. as long as $q_t = 0$, the capital stock k_t converges to its temporary steady state k_q^* just as in deterministic models. It follows by setting $k_{t+1} = k_t = k_q^*$ in (2) and is given by

$$\begin{aligned} k_q^* &= \frac{(1-\delta) k_q^* + (1 - s_K - s_R) \left(k_q^*\right)^\alpha}{1+q_t} \Leftrightarrow (q_t + \delta) k_q^* = (1 - s_K - s_R) \left(k_q^*\right)^\alpha \\ &\Leftrightarrow \; k_q^* = \left(\frac{1 - s_K - s_R}{q_t + \delta}\right)^{1/(1-\alpha)}. \end{aligned} \tag{3}$$

With a new technology, $k_t = K_t / (A_t L)$ decreases and the k_{t+1} line increases, as shown by the dashed line in fig. 3. As a consequence, as can also be seen in (3), the steady state increases. Subsequently, the economy approaches the steady state again. As growth is higher immediately after a new technology is introduced (growth is high when the economy is far away from its steady state), growth rates after the introduction of a new technology is high and then gradually falls. Cyclical growth is therefore characterized by a Sisyphus-type behaviour: k_t permanently approaches the steady state but eventually is thrown back due to the arrival of a new technology.

4 A deterministic model

coming soon ...

5 Empirical evidence

5.1 General aspects

When talking about empirical evidence, one needs to be precise about which type of evidence. Most of the time, theoretical models are written to highlight a specific aspect or relationship. They are not necessarily written to explain "the entire world". With respect to the natural volatility literature, this means that not all authors view all fluctuations in a real world economy to come from within an economy. There are definitely exogenous shocks to any real world economy. Hence, one would not necessarily have to take an either-or view about fluctuations. When confronting natural volatility models with data, it would therefore be useful to construct a model that combines endogenous with exogenous sources of volatility.

Some support for the natural volatility view comes from papers like Hall (1988) and subsequent work. As Burnside, Eichenbaum and Rebelo (1993) nicely write in their introduction, Hall (1988) has challenged the assumption of most RBC models that movements in the Solow residual represent exogenous technology shocks. As the Solow residual is correlated with military expenditures, various monetary aggregates and government consumption, the exogeneity of technology shocks could but questioned. While this debate so far is entirely about the validity of the exogeneity assumption in RBC models, it could be reinterpreted to provide empirical support for the view that fluctuations and growth are jointly endogenous. Jumps in the Solow residual in natural volatility models would by construction depend on e.g. military expenditure, monetary or fiscal policy.

5.2 The cyclical aspects of R&D expenditure

Early natural volatility models (e.g. Bental and Peled (1996), Matsuyama (1999, 2001) and Wälde (1999, 2002)) combine capital accumulation with R&D. Generally speaking, these model economies feature a growth path on which periods of high growth are followed by periods of low growth and vice versa. Similarly, periods of high innovative activity are followed by periods of low innovative activity. Whereas in Matsuyama's work, a temporary patent protection for innovators leads to a synchronization of innovative activity, it is relative returns for investors in Bental and Peled and Wälde's approach that coordinates investment decisions.

A common prediction of these models is a countercyclical allocation of resources to R&D.[2] In periods of high returns to capital (or no patent protection) and high growth of GDP, few resources are allocated to R&D. With low returns to capital (or temporary patent protection) and low growth, resource allocation to R&D is high. Empirically speaking, resource allocation to R&D should be negatively correlated with growth rates of GDP.

This prediction was tested by Wälde and Woitek (2004). They study G7 countries and use annual data for the period from 1973 - 2000. Five different filters are used to detrend GDP and R&D expenditure. Computing correlation coefficients, they find overall evidence for a procyclical nature of contemporaneous R&D expenditure. When looking at the correlation between gross fixed capital formation and R&D, it is even higher on average than the correlation between GDP and R&D. As the former is even closer to the theoretical prediction of natural volatility models, these findings contradict the mechanisms of these models.

Subsequent papers take this procyclical nature into account (Wälde, 2005; Posch and Wälde, 2005) and thereby show that natural volatility can be reconciled with procyclical R&D activities.

5.3 Calibration

Maliar and Maliar (2004)

Phillips and Wrase (2005)

5.4 Estimation

So far, Posch (2005) seems to be the only paper that explicitly tests some predictions of the natural volatility literature.

6 Other sections

6.1 Policy

Posch and Wälde (2005) analyse the effect of economic policy on fluctuations. They show analytically how differences in flat and constant tax rates across countries can explain cross-country differences in volatility. They also argue that changes in fiscal rules over time can imply a moderation of volatility as was observed e.g. for the US in 1983.

6.2 More to come

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[2]Francois and Lloyd-Ellis (2003) obtain this result in a multi-sector economy without capital accumulation.

7 Conclusion

The literature is quickly growing. Here is a list of current papers (known to me at this stage) that includes papers beyond those cited in the text. Whoever contributes to this type of approach is welcome to send an email with a short summary to NaturalVolatility@waelde.com. A reference will then be added or a summary included in the text.

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