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Is the Investment-Uncertainty Link Really Elusive? The Harmful Effects of Inflation Uncertainty in Brazil*

Tito Nícias Teixeira da Silva Filho**

Abstract

After being one the fastest growing countries in the world during the 1940-80 period, with an average growth rate of 6.8%, Brazil has experienced a severe growth slowdown since the 1980s, which coincided with the steep rise in inflation as of 1980. At the same time, real investment rates have plunged, shrinking around nine percentage points just in the 1980s. Moreover, they were unable to recover their 1989 level afterwards. This is unexpected as several pro-growth reforms took place since 1990, such as trade liberalisation, privatisation and economic stabilisation. More strikingly, in the ten years following the stabilisation of the economy, real investment rates have being at their lowest levels for, at least, fifty years. One major factor that could help explaining this dismal behaviour is inflation uncertainty, which have remained high despite much lower inflation since 1994. Indeed, inflation uncertainty is at the root as many types of uncertainties faced by firms. For example, it also means uncertainty about future interest rates and demand. This work aims both at uncovering the main determinants that have driven M&E investment in Brazil since 1980 and testing the link between inflation uncertainty and investment. The evidence strongly suggests that inflation uncertainty has been an important investment deterrent in Brazil, both in the short and long runs. Moreover, its effects were found to be asymmetric. Also, despite the limited role played by price variables in empirical studies of investment, the real interest rate, itself importantly affected by inflation uncertainty and inflation risk premium, seems to be another key factor in explaining low investment rates in Brazil.

Keywords: investment, uncertainty, inflation, inflation uncertainty, relative price of capital, user cost of capital, neoclassical model, real options approach.

JEL Classification: C22, C51, D81, D92, E22, E31.

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"Thus, low inflation may stimulate investment by reducing risk premia. As a result, low inflation makes it easier for firms to finance entrepreneurial projects. For example, low inflation is correlated with a narrow spread between high-risk securities and U.S. Treasury Bonds. (…) The low inflation that we have seen in this expansion, for example, has been associated with less inflation volatility than in earlier, higher inflation periods. The associated reduction in inflation uncertainty has surely been a positive factor for investment in plant and equipment."

Thomas. M. Hoenig (1998), FRB of Kansas City President

1. Introduction

Perhaps no other subject is so representative of the degree of theoretical dissent that is so pervasive in economics than the relation between investment and uncertainty. Moreover, perhaps no other subject has historically shown such a large dichotomy between what economists have to say and what most people's intuition take for granted. Despite the recent convergence provided by the real options approach to investment, which highlights the harmful effects of uncertainty when investment is at least partially irreversible and can be postponed, the issue remains largely unsettled with much of the economic theory producing ambiguous results. Against the above backdrop it possibly does not come as a surprise to find out that economists have still been unable to produce satisfactory theoretical models of investment behaviour. This is unfortunate since investment is a key variable in explaining both the short and long run economic performance.

Even playing such a prominent role, the behaviour of business fixed investment has for a long time been puzzling to economists. For example, the empirical evidence suggests that investment is much less sensitive to price variables such as the interest rate than models and most people usually assume. This "excess smoothness" to the interest rate, which is a key determinant of investment in the widely known neoclassical model through the user cost of capital, should be confronted with the "excess sensitivity" of investment to quantity variables, such as demand [see Chirinko (1993) and Caballero (1997)]. Moreover, it has also been found that entrepreneurs usually require rates of return several times as high as the cost of capital in order to finally decide to undertake an investment project. Bond and Jenkinson (2000) report evidence that U.K. firms required minimum rates of return as high as twenty percent in order to invest, which meant hurdle rates as high as four times the cost of capital. Pindyck and Solimano (1993) also noticed that "expected returns on projects are typically three or four times the cost of capital."[1]

Despite the early recognition that the neoclassical model has some serious limitations, that our understanding on the determinants of investment has advanced a great deal since then, and its limited success in explaining actual investment behaviour, the neoclassical model continues to be very popular, and most people and policymakers still give the interest rate (and taxes) a leading role as a determinant of investment decisions.[2] This has translated directly into policy disappointments, with policymakers often making overly optimistic predictions about the effectiveness of interest rate and tax policy changes as tools to foster investment.

In sharp contrast, the also very popular q-theory of investment [see Tobin (1969) and Hayashi (1982)] links investment decisions to the stock market, which is supposed to properly take into account all factors that affect the expected profitability of an investment project when valuing a firm. However, despite its theoretical appeal, q-models of investment have proven to be empirical failures [see Abel (1990) and Chirinko (1993)]. This is not surprising given that asset values and real variables have very different velocities of adjustment. Moreover, these models rely on a set of stringent assumptions that are not likely to hold. These range from simple ones such as perfect competition to sacred ones such as rationality and market efficiency. However, even ignoring those problems the q-theory simply "passes the buck" when dealing with several crucial issues on investment decisions. For example, it does not uncover how agents actually form their expectations about firms' future profitability, and what the market structure behind those projections is. Also, it does not deal with the crucial question of how uncertainty affects investment decisions.

One obvious reason on why economists have historically encountered so many difficulties in understanding investment behaviour is that investment decisions are the outcome of a very complex analytical process, which is unlikely to be successfully summarised by the NPV rule alone (even taking the option of waiting into account). For example, strategic reasons can be of paramount importance, so that in order to prevent other firms from entering the market or to steal a rival's market share, a firm may decide to invest

[1] This evidence is less puzzling, however, when one does consider the user cost of capital concept, which besides the interest rate also takes into account depreciation, capital gains, and other variables that affect the opportunity cost of holding one unit of capital. Abel (1990) provides simple examples of how the inclusion of depreciation implies a much smaller theoretical response of investment to interest rates. He also points out that the responsiveness of investment depends on the elasticity of substitution between capital and labour.

[2] For example, the assumption that undoing investment is costless and the fact that expectations play only a minor role in the model. See Chirinko (1993) for others criticism on the neoclassical model.

even when the expected return seems too low. Moreover, as Pindyck and Solimano (1993) notice, understanding investment behaviour is not only about understanding how firms *exercise* their investment opportunities, but also about how they *obtain* those opportunities in the first place. A major difficulty in modelling investment empirically is that firms' expectations on relevant variables such as prices, demand and costs are not observed. In addition, as mentioned above, the q-theory of investment, which was thought to circumvent these difficulties, has not paid off.

A less noble reason lies in the use of inadequate assumptions, such as the strong implications of the Modigliani-Miller (M&M) theorem, which implies that internal and external finance are perfect substitutes. As a consequence, the investment literature has for a long time underestimated the role of credit on investment, despite much evidence that credit constraints and liquidity are important factors behind investment decisions. For example, in surveys carried out by the Confederation of British Industry (CBI), managers consistently referred to shortage of internal finance as an important reason limiting investment (see Bond and Jenkinson, 2000). Indeed, Corbett and Jenkinson (1997) show that in the U.S., U.K., Germany and Japan, investment comes largely from internal finance, although there are important differences on the relative weight of this type of finance among them. Fazzari *et al.* (1988) estimated q-models of investment for U.S. firms and found that the inclusion of cash-flow variables improved significantly the fit of the models, especially for small firms, which are the most likely to suffer from shortage of internal finance.

A crucial step into the intricacies of investment behaviour was taken when economists began to explicitly recognise that investment expenditures are usually largely irreversible and can be postponed. In such a world uncertainty is likely to be a powerful investment deterrent, since any investment decision will compete with itself postponed. The reason is that by postponing the investment the firm will be able to take the decision with a better information set at hands, and this has important implications. For example, the possibility of investing "now" or "later" creates an option value of waiting that usually has a positive value and should be taken into account when investment decisions are being taken. The option approach to investment can be understood as another version of the famous saying "time is money", but here money could be made by staying put and taking the decision later on with more information, since any forgone revenue is dominated by the risk of a loss should events turn out to be worse than expected.[3] This is the peculiar bad news principle [see Bernanke (1983) and Dixit and Pindyck (1994)], which states that only one tail of the distribution of future outcomes matters when deciding to invest: the one with the negative outcomes.

The option approach helps to understand why firms require high hurdle rates to undertake investment projects: whenever the option has a positive value the firm should invest only if the NPV is higher than the option value. Moreover, the higher the uncertainty, the more valuable the option is and the higher the required rate of return. Hence, firms face a range of inaction, in which only sizeable changes in the interest rate are likely to affect investment decisions.[4] This option value is not just a theoretical curiosity, and can be large. For example, McDonald and Siegel (1986) show that for reasonable parameter values uncertainty can double the required rate of return to investment. More strikingly, even if future cash flows are known with certainty there can still be an option value involved. Ingersoll and Ross (1992) analysed the effect of interest rate uncertainty when the firm is *certain* about its returns, and show that the effect is equivalent to the case when cash flows are uncertain due to, for example, price uncertainty. More importantly, they show that even if interest rates are falling, if uncertainty about future rates increases the result could be a *reduction* in investment.

Note that behind the recognition that credit matters and that there is an option value in waiting for more information, lies a crucial variable: uncertainty. This finding should not come as a surprise, since the world is to a large extent unpredictable and investment expenditures bear a large degree of irreversibility. Note also that besides the "option channel", uncertainty helps to explain high hurdles rates through a second channel, the "risk channel". For example, given risk aversion, uncertainty means that firms will add a risk premium to interest rates. Therefore, higher discount rates will be used to assess investment opportunities, which mean higher required returns – hence uncertainty affects credit not only by restricting the amount of credit available at given interest rate, due to asymmetric information, but also by increasing the equilibrium interest rate. Thus, the option approach, together with risk aversion not only helps to understand the high hurdles rates observed empirically, but also

[3] See Dixit and Pindyck (1994) for a thorough treatment on the real option approach to investment, or Servén (1997) for a very good summary.

[4] This is true mainly at the micro level, in the aggregate, however, while some firms are far from the threshold point that triggers investment other might be close. In this case small changes in the interest rates can make much difference for those firms.

shed light on the smoothness of investment to changes in interest rate.[5]

It is widely known that firms face uncertainty over many dimensions. For example, there is uncertainty about firms' output prices, demand and costs, uncertainty about wages, interest rates and exchange rates, not to mention uncertainty about competitors' strategies and the success of newly created products, which is a pivotal characteristic of entrepreneurship. Even though some types of uncertainties are likely to be more relevant to some firms than to others (e.g. the exchange rate to importers and exporters) and firm specific uncertainty (e.g. uncertainty about the firm's demand) plays a major role in investment decisions, notice that uncertainty about inflation is at the root of many uncertainties. For example, one of the most important costs of inflation stem from its perverse interaction with the tax system, since it is not perfectly indexed, which means that, even if anticipated, inflation increases effective tax rates and lowers depreciation allowances, causing important distortions (see Feldstein, 1982). Hence, inflation uncertainty also means uncertainty about effective tax rates and depreciation allowances. For a given nominal interest rate, inflation uncertainty means uncertainty about the real interest rate. Moreover, under inflation uncertainty risk averse agents require a risk premium to buy nominal bonds, which raises the cost of capital and depresses investment.[6] Inflation uncertainty also implies uncertainty about other key variables to the firm, such as real wages. More importantly, inflation uncertainty implies uncertainty about the future stance of monetary policy, which in its turn implies uncertainty about future demand and prices. Hence, it is not surprising that inflation rate releases and Fed's assessments on future inflation prospects are so eagerly expected, and can produce big impacts on financial variables. Finally, inflation is a key variable partially because it summarizes how well managed a given economy is, acting like a thermometer of economic conditions and, consequently, being closely watched by economic agents. In a nutshell: there are several reasons on why inflation should rank very high on entrepreneurs' concerns, especially in economies with high inflation uncertainty such as Brazil.

It is not surprising, therefore, Pindyck and Solimano's (1993) finding that among several indicators of economic and political instability used on growth studies, inflation has the highest correlation with the volatility of the marginal profitability of capital, classified by them as a summary measure of uncertainty. They claim that inflation is a "robust explanator

[5] Another reason for investment smoothness is the existence of credit constrains. If a large fraction of firms are credit constrained then decreases in interest rates will not produce much effect for them.

[6] Note, however, that if on one hand inflation uncertainty will add a risk premium to nominal interest rates, implying an increase in the *ex ante* real interest rate, on the other hand, given inflation surprises, the *ex-post* real interest rate might actually turn out to be lower.

of investment". Moreover, they show that five years after stabilisation took place in Bolivia, Chile and Israel investment rates failed to reach their pre-inflation levels. One explanation for this sluggishness is that although inflation was reduced, uncertainty about future inflation remained high. Indeed, there is clear evidence suggesting that inflation uncertainty takes a long time to decrease following reduction in inflation, since it is linked to policy credibility. Clearly, the memory of very high and unstable inflation, the norm in Brazil for several generations, tends to linger, and this may impact investment decisions long after the actual end of hyperinflation.

Hoenig (1998) argues that low and stable inflation are a key factor behind the 1990s boom in the U.S. He claims that "A second favorable factor for the U.S. economy is the current low inflation environment and the likelihood that inflation will remain well-behaved. It is my view that the current low inflation environment is one of the reasons investment demand has been so strong throughout the expansion." Therefore, inflation uncertainty also seems to be relevant for investment decisions in low inflation economies.

Gagnon (1997) claims that the higher inflationary past in Canada and New Zealand vis-à-vis the U.S. and Australia respectively, explains the higher long term interest rates observed in the former countries relatively to the latter, despite the fact that at the time of the analysis the former had lower inflation rates than their neighbours in the previous five years. Da Silva Filho (2006a) argues that inflation uncertainty is the main factor behind both the share of nominal bonds in domestic public debt and the striking low maturity of those bonds in Brazil, even after one decade of economic stabilisation. This evidence highlights both the harmful effects of inflation uncertainty and the potential large benefits that should follow from economic policies that aim at reducing and keeping inflation low for extended periods of time.

This paper aim is twofold. First, it aims at investigating in details the behaviour of machines and equipment investment in Brazil since the 1980s, when investment rates began to drop sharply and have failed to recover more than ten years after the stabilisation of the economy in 1994. Second, it tests the hypothesis that inflation uncertainty has been harmful to investment in Brazil. The paper is organised as follows. Section 2 reviews the theoretical literature on the link between investment and uncertainty. Section 3 makes a selective review of the empirical evidence. Section 4 carries out a brief analysis of recent investment behaviour in Brazil as well as its likely main determinants. Section 5 seeks to uncover the main factors that have been driving capital accumulation in Brazil in the recent past and tests the investment-uncertainty link both for the short and long run. Differently from other papers in the literature the econometric uncertainty proxies use here are obtained using no future information. It also departs from others by allowing uncertainty effects to be asymmetric. The remaining section concludes the work.

2. The Elusive Theoretical Effects of Uncertainty on Investment: An Overview

The word uncertainty has an intrinsic negative meaning. It is widely perceived to be a hassle, to cause anxiety, discomfort or, in a few words, to decrease welfare. Hence most people's intuition is that uncertainty is harmful and whenever one can one tries to avoid it. A large number of economists also share this view. For example, it is widely believed that the instability and uncertainty brought by poor macroeconomic policies have adverse effects on growth. It is also widely believed that one key channel by which those effects are likely to feed into the economy is through investment. Even so, Krueger (1991) notices that "Development economists have long been frustrated with the tension between the obvious negative contribution of poor economic policies to growth rates and the failure of economic theory to provide a framework for analysis."

The frustration gets worse, given that the consensus shared by growth and development economists is not shared by those economists who delve into the intricacies of the link between investment and uncertainty. Actually, much of economy theory suggests that either uncertainty is likely to foster investment or that its effect is ambiguous. This is surprising, as uncertainty prevents the entrepreneur of looking too far ahead, which makes him reluctant in investing now and being caught with too much capital later on, since investment decisions cannot be undone easily. Moreover, informal evidence on the harmful effects of uncertainty is ubiquitous. For example, the behaviour of capital flows and country risk premia in developing countries is revealing: episodes of political, institutional and economic instability usually cause risk premia to soar and entail prompt reactions from investors, who take their resources out of those countries. Also, frequent episodes of stock market overreaction to a less certain scenario about a given firm or economy provides another good example. Crucially, surveys among entrepreneurs show overwhelmingly that a major factor that hampers investment decisions is uncertainty. For example, the CBI surveys carried out during the 1990s show that uncertainty about demand is the main factor cited by British companies that "are likely to limit (wholly or partly) your capital expenditures authorisations over the next twelve months." Hence, one would like to know what economic theory has to say about the effects of uncertainty on investment.

In a seminal article Hartman (1972) analysed the effect of output price uncertainty on investment for a firm operating in a competitive environment, facing quadratic adjustment costs and producing under constant returns to scale. In this setting he showed that the marginal revenue product of capital is convex in prices, which means that due to Jensen's inequality a mean preserving increase in uncertainty actually raises investment, since it increases the expected return of an additional unit of capital. This non intuitive result was disputed by Pindyck (1982) who claimed that Hartman's result was conditional on the firm facing convex adjustment costs. In his model the effects of uncertainty depend on the shape of adjustment costs and not on the shape of the marginal revenue of capital, as in Hartman's.[7] He argues that his model is more robust and that the above result remains irrespective of whether the firm is competitive or monopolistic. However, Abel (1983) criticised Pindyck's model claiming that its long run equilibrium was characterised by a non optimal zero expected change in investment condition. Then using the same stochastic specification for output price uncertainty as Pindyck's he builds a model for a competitive firm operating under constant returns to scale and facing convex adjustment costs and re-established Hartman's results, by showing that they are independent of the concavity of the marginal adjustment cost function.

Bernanke (1983) analyses the investment-uncertainty link when investment expenditures are irreversible. He brings the option concept into the analysis and introduces the bad news principle to show that an increase in uncertainty raises the option value of waiting for more information. Therefore, he concludes that when investment is irreversible optimal timing considerations imply that uncertainty leads to a postponement of investment decisions, which means that it decreases rather than increases investment. McDonald and Siegel (1986) performed some simulations and showed that under moderate levels of uncertainty the option value of waiting can be large, so as to double the required rate of return. Many other papers, such as Pindyck (1988), also built upon the option approach reaching the same conclusion; that uncertainty is harmful to investment.[8]

Caballero (1991) shows that the assumption of asymmetric adjustment costs present in the irreversible investment literature is important but not sufficient to produce a negative link

[7] He argues that this difference is due to the way randomness is approached in his model, evolving continuously rather than discretely. Also, in his model there is uncertainty only about future prices, while in Hartman's the current price is also uncertain.

[8] In Pindyck's model uncertainty does vanish with time, in opposition to Bernanke's model. Therefore, in his model there is a perpetual call option involved.

between investment and uncertainty and, therefore, to explain the conflicting result with regard to the convex adjustment cost literature. He states that "In fact, when firms are nearly competitive, the conclusion of Hartman and of Abel holds no matter how asymmetric adjustment costs are." He notices that since the irreversibility literature assumes that there is no cost of adjusting investment upwards, one needs to assume either imperfect competition and/or decreasing returns to scale to bound the size of the firm, and these are the assumptions that are actually behind the above negative link. In such setting the convexity of the marginal profitability of capital to the stochastic variable under analysis not only can be offset but actually overturned depending on the degree of imperfect competition and/or decreasing returns to scale. Hence the sign of the investment uncertainty link depends crucially on the assumptions about technology and/or market structure. Pindyck (1993) calls to attention that Caballero's result (as summarized in the quote above) depends on treating the firm in isolation and does not consider industry-wide uncertainty. Once the industry's negative sloping demand curve is brought into the analysis no ambiguity arises, which means that Hartman's result no longer holds even assuming perfect competition and CRS.[9]

Abel and Eberly (1994) set out a general model of investment which encompasses asymmetric adjustment costs, having irreversibility and the traditional convex costs as special cases, as well as fixed costs of investing. In their setting the optimal investment policy involves discontinuity. There are two thresholds: a "bad" one and a "good" one, which are defined in terms of the shadow price of capital, and depend on the specification of the adjustment cost function.[10] When the contribution of an additional unit of capital falls between both thresholds the firm stay put and no investment is undertaken. In other words: there is a range of inaction. When marginal q is greater than the good threshold, the firm adds capital, and when it is lower than the bad threshold it sells capital. In this setting higher uncertainty widens the wedge between both thresholds and, in principle, should discourage investment. However, for a price taking firm the marginal profitability of capital remains an increasing function of price uncertainty and, therefore, higher uncertainty increases investment. Hence, Abel and Eberly conclusion goes in the same direction of Caballero's in the sense that irreversibility, and now lumpiness, are not enough to provide a negative uncertainty-investment link. However, note that once again the positive effects of uncertainty

[9] Even though the marginal revenue product of capital remains convex in prices at the individual firm level.

[10] In the case when the operating profit function is linear in the capital stock and the adjustment cost function is linear homogenous in I and K, then the shadow price of capital equals Tobin's q. Moreover, as shown by Hayashi (1982) in that case average and marginal q are equal. This is relevant since the former is observable but the latter not.

on investment come within a perfect competition setting.[11]

Abel *et al.* (1996) considered a model in which there are both kinds of options: the usual call option, which represents the possibility of expanding the capital stock in the future, and a put option, which stands for the possibility of contracting the capital stock later. However, disinvestment is costly as the resale price of capital can be lower than the purchasing price. Moreover, they assumed that expansions are costly as well, given that by postponing investment the firm takes the risk of facing higher capital prices in the future. As usual, when there is uncertainty, the call option acts to delay investment, although here the incentive to postpone is lower because higher capital prices add to foregone profits, but the put option has just the opposite effect. As a consequence, the effect of uncertainty in their model depends on the value of both options and, therefore, is ambiguous. Another consequence is that now both very bad and very good news become irrelevant to firm's investment decisions.

2.1. An Assessment of the Theoretical Literature

The above overview should be enough to give one a representative flavour of the amazing degree of theoretical dissent that has historically characterised the investment-uncertainty literature. So what kind of conclusion one can reach about this literature? Is there any robust result that emerges from it? How serious should be taken the theoretical dissent? The first thing to notice is that notwithstanding the fact that it has brought a new crucial insight on the investment-uncertainty link, when analysed at face value the options approach of investment seems to be fragile. This fragility can be divided into two parts. First, the options approach does not offer a model of investment, but only of the relationship between the level of uncertainty and the *threshold* required to invest, which means that it does not determine the optimal level of investment.[12] Even though it does imply that uncertainty deters irreversible investment in the short run, it does not provide an answer about the long run effects of uncertainty on capital accumulation (see Abel and Eberly, 1999). The reason being that if on one hand more uncertainty discourage irreversible investment, on the other hand it increases the probability that firms are caught with too much capital in bad states of the world

[11] Moreover, notice that if competitive firms face industry-wide uncertainty, then Pindyck's results remain and uncertainty has a negative effect on investment even under perfect competition and constant returns to scale.
[12] It does show, however, that the timing of investment decisions is different under uncertainty.

(the hangover effect), which makes the total effect ambiguous.[13] Second, Abel *et al.* (1996) show that even in the short run the effects of uncertainty are not unambiguous. This outcome comes up as a result of adding partial reversibility into the analysis (i.e. adding a put option) and assuming that delaying investment is costly as well.

However, the above results must be carefully analysed. For example, Abel and Eberly (1999) assume that capital does not depreciate, which is a harmless simplification in many settings but not here. This means that once one allows for depreciation the hangover effect will be less likely to occur (and smaller if it occurs), reinforcing the "user cost channel". Also, their model takes into account existing firms only. Once new entrants are also considered the overall hangover effect should be smaller, since for those firms there is no such effect. Indeed, the historical evidence across countries shows that economies are much more likely to suffer from underinvestment than overinvestment, which gives support for a long run negative effect of uncertainty. The ambiguous results from Abel *et al.* (1996) also seem overstated since, as Carruth *et al.* (2000) notice, they hinge on treating both options symmetrically. Even though it is certainly true that irreversibility is an extreme assumption, since most investments show at least some degree of reversibility, it seems obvious that it is much more costly contracting than expanding the capital stock.

In a nutshell, the traditional Dixit and Pindyck irreversibility-type of models do suggest that uncertainty is harmful to investment in the short run. However, more general models produce ambiguous results, both for the short and the long run. Even so, at closer scrutiny these ambiguities seem largely overstated, since they hinge on a set of assumptions that are not very appealing. Hence, one still leaves this literature with the strong feeling that the net effect is very likely to be negative. Nonetheless, recent models are very useful in that they relax the irreversibility assumption, which is too extreme in most situations.[14] In its turn, a central part of the adjustment cost literature suggests that uncertainty is beneficial to investment. What lies behind that result is the fact that in many models the marginal profitability of capital is convex in the variable whose evolution is assumed to be uncertain. In those cases a mean preserving increase in uncertainty raises the expected profitability of one additional unit of capital and, hence, is likely to increases investment. Thus, one would like to known how reliable those counter intuitive results actually are, and how useful they are in

[13] For example, in an expanding industry uncertainty is likely to delay investment and, therefore, decrease the capital stock, but in a contracting industry the opposite effect is likely to hold since disinvestment would occur at a slower pace.

[14] Using a very detailed Italian investment survey Guiso and Parigi (1999) report that 17% of the firms stated that it is easy to dispose capital, while only 29% stated that capital expenditures are irreversible.

helping one to understand real investment behaviour. After a more detailed look at the evidence two robust findings arise.

First, the convexity of the marginal profitability of capital hinges on a very specific setting, in which one major factor is the market structure considered.[15] More specifically, behind the results that uncertainty should raise investment there is the assumption of competitive markets (e.g. Hartman, 1972; Bernanke, 1983; Abel & Eberly, 1994). However, perfect competition is basically a pedagogical simplification, with little resemblance to actual markets. Once this assumption is abandoned the effects of uncertainty are found to be negative.[16] Caballero (1997), for example, criticises those studies that, without further qualifications, use Hayashi's (1982) results and replace marginal q for average q since "the assumptions required for the equivalence between the two are not nearly satisfied in the industry or firms studied (e.g. Compustat)." Second, models in which uncertainty is beneficial focus on idiosyncratic risk (e.g. Hartman, 1972; Bernanke, 1983). They ignore both industry-wide and economy-wide uncertainty. However both types of uncertainty are likely to play a major role in actual investment decisions.[17] Once industry or economy-wide measures of uncertainty are considered their effects turn out to be negative, even assuming perfect competition, constant returns to scale and convex costs of adjustment (see Pindyck, 1993). This is so because even for a competitive industry its demand is negatively sloped. Hence, after reading the adjustment cost literature carefully one reaches the conclusion that the supposed positive effects of uncertainty, which economists make much fuss about, are not nearly as robust as one would like. Under reasonable assumptions about market structure and uncertainty sources the results are reversed, and uncertainty is likely to reduce investment.

A final remark about the convex adjustment cost literature refers, ironically, to the *ad hoc* nature of adjustment costs, which were initially conceived to cope with the evidence that aggregate investment is smooth, being much less sensitive to changes in interest rates than implied by the neoclassical model. However, the microeconomic evidence is sharply at odds with the idea of convex adjustment costs. Plant level studies mentioned in Caballero (1997) show unequivocally that actual investment is characterised by lumpiness, and occurs sparsely over time. For example, one study investigated 12,000 plants in the U.S. manufacturing sector and found that, on average, during the 1972–89 period, the largest investment episode carried

[15] Two other crucial elements are the degree of returns to scale and the functional form of adjustment costs.
[16] When deciding what type of uncertainty measure to use, Guiso and Parigi (1999) chose a measure that "except for firms facing a perfectly elastic demand curve, our measure of demand uncertainty is the more appropriate."
[17] For example, monetary policy decisions are closely observed by firms since they have a direct effect on future aggregate demand.

out by a given firm accounted for more than 25% of its total investment over that interval. Additionally, more than half of the establishments experienced an increase in their capital stock of nearly 50% in a single year. Nothing could be more damaging to the idea of convex adjustment costs than the evidence above. On the contrary, if adjustment costs (whatever they mean) are relevant to investment it seems more sensible to assume just the opposite: that they benefit from economies of scale and are more likely to be concave. Therefore, empirical studies, especially those that focus on more disaggregated data, are not only likely to be inconsistent with the evidence but indeed mis-specified. The consequences are non-trivial. As Carruth *et al.* (2000) notice "non-quadratic adjustment costs will imply that investment will not be linearly related to q, or other fundamentals correlated with q." Moreover, as Pindyck (1993) notices, the traditional adjustment cost set up, in which the firm's size is bounded only by adjustment costs, is incapable of handling irreversibility. The key role of non convexity in the existence of the option value of waiting is also called to attention by Bond and Cummins (2004).[18] Finally, risk aversion, which is a key element in determining how agents react to uncertainty, is surprisingly absent in almost all studies of the investment-uncertainty link. As Caballero (1991) points out "Risk aversion and incomplete markets are likely to make the investment-uncertainty relationship negative." This is one additional and convincing reason as to why uncertainty is likely to decrease investment.

Despite recent advances there remains much scope for further improvements in the understanding of the intricacies behind the investment-uncertainty link. This does not necessarily mean that economists should aim at producing models with unambiguous results, since sometimes ambiguity can be a natural outcome of economic behaviour. It means, among other things, that models should not rely on such fragile concepts such as convex adjustment costs, which play a key role in many models' results.

3. The Non Elusive Empirical Effects of Uncertainty on Investment

The empirical evidence, which is always of paramount importance in providing stylised facts and endorsing or dismissing economic theories, plays an even more crucial role in the analysis of the investment-uncertainty link, given the large dissent and conflicting

[18] Inadequate functional forms are not restricted to the curvature of the adjustment cost function. For example, earlier papers such as the widely cited studies from Hartman (1972) and Abel (1983) and also Caballero (1991) assume that adjustment costs do not depend on the capital stock. This implies that a firm, say, with twice the capital stock of another firm, faces adjustment cost four times as high as the smaller firm for a given percentual increase in its capital stock, which clearly is not a sensible assumption.

theoretical results seen above. Hence, this section makes a brief selective review of the empirical evidence on the investment-uncertainty link in order to assess whether the analytical dissent and ambiguity carry over to the empirical literature.

Huizinga (1993) analyses the effects of uncertainty about inflation, relative prices, the real wage and the profit rate on U.S. manufacturing investment during the 1954.1-1989.3 period.[19] The quarterly conditional standard deviation derived from ARCH models was chosen for the uncertainty proxies. Unfortunately, the estimated models seem to be mis-specified, which can explain some unexpected results. For example, relative prices are found not to matter for investment, while inflation has an unexpected strong positive effect. Oddly, a key variable, the real interest rate, is not included among the regressors. The effects of the several uncertainty proxies are conflicting: while uncertainty about relative prices and real wages appears to have negative effects, uncertainty about real profits was found to help investment. Moreover, uncertainty about inflation was found not to be relevant.

Ferderer (1993) investigates the investment-uncertainty link within the frameworks of the neoclassical and q models of investment. He uses the risk premium embedded in the term structure of interest rates as a proxy for uncertainty and finds that it affects adversely U.S. aggregate investment, during the 1969.3–1989.1 period. He also finds that the risk premium has a negative effect on contracts and orders for new plant and equipment.[20] Finally, he argues that the risk premium has a larger impact on investment than both the user cost of capital and average q. Unfortunately, the estimated models show persistent autocorrelation suggesting that there is some mis-specification involved.

Leahy and Whited (1996) build two measures of uncertainty based on the stock market: one based on the (forecast) volatility of asset returns, which should affect investment according to the theories seen above, and another one based on the covariance of those returns with the market, which is the relevant measure of risk according to the CAPM model. Using annual panel data on a set of U.S. manufacturing firms for the 1981–1987 period and a q-based approach they find that both proxies are insignificant. Guiso and Parigi (1999) analyses the investment-uncertainty link using data from the 1993 Survey on Investment and Manufacturing (SIM) on Italian firms.[21] That year's Survey has precious data on firms'

[19] The dependent variable is the investment to sales ratio.
[20] Hence, two different measures of investment are used: gross expenditures on producers' durable equipment and the real value of contracts and orders for new plant and equipment.
[21] Notice that the dependent variable is the ratio of *planned* investment to the capital stock rather than actual investment.

subjective probability distribution about their own future demand.[22] Using that information they built, for each firm, a measure of uncertainty and found evidence that those firms facing more uncertainty respond less to increases in expected demand. The qualitative results remained unaltered when they controlled for cash flow and financial constraints.[23] They also show that the negative effects of uncertainty remain when different types of investment are considered separately (structures, machinery & equipment, and vehicles). Other interesting results are that the adverse effects of uncertainty are larger for those firms that face more inelastic demand and smaller for those firms that can more easily sell their capital in second-hand markets, which conforms to the theories discussed in the last section.

Bond and Lombardi (2004) also use the Italian SIM to investigate the investment-uncertainty link during the 1984–1998 period. The key difference to Guiso and Parigi's work refers to the uncertainty measure used. Instead of firms' subjective probability distribution about future demand, which unfortunately is available only for the 1993 year, Bond and Lombardi use firms' one year ahead own investment plans.[24] The errors from those forecasts were used to build a proxy for uncertainty and allowed them to exploit the temporal content of the data, so that they carried out a dynamic panel study instead of a cross-section as Guiso and Parigi. Hence they were also able to estimate an error correction model to examine the short and long run effects of uncertainty on investment. Like Guiso and Parigi they find that investment responds less to real sales growth for those firms that face higher uncertainty levels. However, they were not able to find a long run effect of uncertainty on investment.[25] One possible explanation for that is the kind of uncertainty proxy they used. Instead of using uncertainty about a variable that affects future profits, such as demand, price or cost, they used uncertainty about investment itself. One problem with this proxy is that when firms first release their investment plans they already take into account any uncertainty, so that even if realised investment turns out to be equal to planned investment that does not mean that uncertainty had no effect on investment.[26] Therefore, any discrepancy between desired and actual investment should mainly reflect "extra uncertainty". From this point of view, the proxy used by Bond and Lombardi is likely to underestimate uncertainty.

[22] They also used information on irreversibility from the 1995 survey.
[23] However, both variables were not significant when added.
[24] The forecast horizon refers to one and three-year ahead expectations for demand growth.
[25] As Guiso and Parigi (1999) they included a cash flow variable in the model but, once again, it was found not to matter.
[26] Another reason could be that once approved and started it can be very costly to put a halt in investment expenditures, even if that would have been the decision had the firm known future outcomes before. This is especially true here if investment plans put in place in a given year usually carry on to the next year.

Using a q-based model Bond and Cummins (2004) investigated the investment-uncertainty link for publicly-traded U.S. firms during the 1982–1999 period, using three different uncertainty proxies: a) the volatility of firms' daily stock returns; b) the variance of past forecast errors committed by securities analysts; c) disagreement among analysts on individual firms' future profits forecasts.[27] They also build an alternative measure of average q using analysts' forecasts and control for expected profitability.[28] They find evidence that the two first proxies of uncertainty, and especially disagreement, have adverse effects investment behaviour.[29] Moreover, when proxied by disagreement, uncertainty was found to be harmful also in the long run. Bloom *et al.* (2005) analyse the effects of uncertainty on investment using a panel of firm-level data for traded U.K. manufacturing firms during the 1972–1991 period. They use the volatility of stock returns as a proxy for uncertainty and find that it affects adversely investment in the short run, but as in Bond and Cummins (2004) no effect is found for the long run.[30]

3.1. An Assessment of the Empirical Evidence

The first impression that emerges from this brief overview is the contrast between the empirical evidence and the theoretical literature. While the latter show a large degree of dissent and ambiguity the former shows overwhelmingly that uncertainty is harmful to investment. Therefore, it seems to confirm the previous assessment that the theoretical ambiguity is largely overstated. This result is not unexpected given that informal evidence showing that uncertainty deters investment decisions is pervasive. Nonetheless, a more detailed analysis can be very useful.

The first remark that should be made is that all the empirical papers reviewed above but one share a crucial feature: although the uncertainty proxies were derived using different methods and refer to different variables, they were built using only data available at the time uncertainty was assessed. It seems pretty obvious to say that if one aims at obtaining a reliable proxy for uncertainty a *necessary* condition is that no future information should be used when

[27] Interestingly, they remark that the three measures of uncertainty are poorly related to each other.
[28] That measure proved to be much more relevant in explaining investment behaviour than the standard q measure based on the market valuation of a firm. Indeed, when the latter is added to the regression it is not significant.
[29] The stock returns volatility was marginally significant.
[30] They also include a cash flow variable in the specifications, which is found to be significant.

obtaining those proxies, since no forecaster has such a benefit. However, although there has recently been important progress on this regard, the bulk of the investment-uncertainty literature is plagued by studies that derive temporally inconsistent uncertainty proxies. It is really unfortunate and surprising that the very variable that is at the core of the debate has not been given the proper care by most economists.

Though economists often put overmuch emphasis on the quantitative rather than on the qualitative aspect of the evidence, overlooking problems that would render many papers' conclusions unreliable or even invalid, the evidence from the papers above is supported by the bulk of the literature. Among the 18 studies listed by Carruth *et al.* (2000) in their survey of the investment-uncertainty link 12 found a negative effect for uncertainty and only one found a positive effect for a particular proxy (Huizinga, 1993). The remaining were inconclusive, apart from one study in which no effect was found. Interestingly, amongst the inconclusive ones lie half of those studies that use proxies based on the stock market. Indeed, the role of the stock market in explaining investment has always been problematic, as shows the q theory of investment. For example, Bond and Cummins (2004) built a measure of q based on analysts' forecasts and shows that it performs so much better than the traditional one, which is based on the stock market valuation, that when the latter is added to the regression it is uninformative. Moreover, they notice that the stock market volatility, which is used by them as a proxy for uncertainty, "is disconnected from the [U.S.] business cycle". Hence Samuelson's statement that "The stock market has predicted nine out of the last five recessions" is not surprising.

Carruth *et al.* (2000) divided the evidence according to the degree of aggregation used by each study and it turns out that the negative effects of uncertainty are much more evident in the aggregate studies. This is unexpected since one of the arguments for using disaggregated studies is that idiosyncratic uncertainty can wash out during aggregation (e.g. Guiso and Parigi, 1999), or that irreversibility constraints (i.e. periods with zero investment) are much more likely to be visible when the data is disaggregated (e.g. Servén, 1997).[31] Possible explanations for that result, given that those studies have obviously used broad measures of uncertainty, is that idiosyncratic uncertainty is either not as relevant as aggregate uncertainty or that the latter is a key component in the former.[32] For example, firms' expected

[31] As notices Servén, zero investment could not only indicate that the irreversibility constraint is binding but also that the firm finds itself in the range of inaction.

[32] However, since most of those studies use temporally inconsistent proxies, it is also possible that this result is largely due to measurement errors at the micro level.

output prices and demand may be highly influenced by expected inflation and real interest rates. Indeed the importance of macroeconomic factors in firms' investment decisions is more than expected and was also pointed out by Bernanke (1983) as to why the effects of uncertainty may not just cancel out in the aggregate.

The theoretical ambiguity resulting from whether idiosyncratic or broad measures of uncertainty are considered was addressed by Henley *et al.* (2003), who aimed at separating the effects on investment of firm-specific from industry-wide uncertainty. They found opposing effects: while the former appears to have a positive effect on investment the latter seems to be detrimental, with the net effect being positive. Also, the negative effects from sector-wide uncertainty were not found for low concentration industries. Although their work has the merit of trying to handle some of the theoretical ambiguities reviewed in Section 2, it remains unclear if the proxies used were able to capture appropriately both types of uncertainties. The sector-wide uncertainty proxy was simply the (unconditional) moving standard deviation of sectoral producer price index, while abnormal stock return volatility was used to measure firm-specific uncertainty, notwithstanding the issues shown above. Moreover, the price behaviour of a particular stock is highly correlated with the behaviour of its peers, suggesting that it captures more than just idiosyncratic uncertainty.

Nonetheless, recent evidence from disaggregated studies has been extremely useful in uncovering the channels through which uncertainty is likely to matter and in assessing theory implications. For example, Guiso and Parigi (1999) work shows that firms facing higher degree of irreversibility in their investment are more affected by uncertainty, which concurs to the predictions from the real options theory. It also shows that the negative effects of uncertainty are not conditional on capital aggregation. This is important since investment in building and vehicles are more easily reversible than investment in machines and equipments, since they are less firm or industry specific. However, at the same time it may also suggest that other mechanisms, apart from the "options channel", are likely to be relevant for investment decisions, such as risk aversion. On the other hand, a key prediction from the adjustment costs literature that the more competitive a firm is, the less likely it is to be affected adversely by uncertainty, has been more difficult to establish. Although Guiso and Parigi's work also show that uncertainty effects are higher for those firms with high market power, Ghosal and Lougani's (1996) paper shows just the opposite result.

Having welcomed the better care taken by some recent studies when deriving proxies for uncertainty and acknowledged the valuable evidence brought by disaggregated studies, one has to recognise that there is still much room left for improvement in empirical models' ability to explain actual investment and, consequently, in providing a more reliable terrain to test the investment-uncertainty link.[33] This is crucial, since if the model is mis-specified inferences are not reliable. It seems that part of the empirical difficulties lies in the fact that economists usually chose specifications that are close counterparts of stylised theoretical models, even though these models have a history of limited success in explaining actual investment. For example, q-based empirical models usually do not consider key explanatory variables such as relative prices since, in principle, average q should be a sufficient statistic. However, as argued above the data used in empirical studies usually violate the conditions for the equality between marginal and average q. Moreover, Bond and Cummins (2004) show that when securities analysts' forecasts are used to build average q the resulting statistic is much more informative than the traditional one, based on the stock market valuation. Therefore, one does not know in what extent uncertainty proxies added to q-based models are also capturing measurement errors, mis-specification or omitted variables. Although some studies do attempt to control for some possible omitted variables, such as cash flows, those models still struggle to explain actual investment. Even if average q was indeed a sufficient statistic and none of these problems existed, possible uncertainty effects would be captured by average q, and both the existence and interpretation of those effects would be largely a matter of faith. Similarly, neoclassical-based models usually consider the role of interest rates and relative prices in a rigid way, through the user cost of capital, and often left out other variables that could be relevant for investment. It is also uncertain how well interest rates and relative prices effects are appropriately captured by firm and year-specific effects in disaggregated studies, in both the neoclassical and q frameworks.

In many studies the link between uncertainty and investment is tested in a very naïve way, by just running a regression of investment on a given uncertainty proxy. No details are needed as to why this strategy is bound not only to produce unreliable but also misleading results. Finally, although the empirical evidence seems to show clearly that uncertainty is indeed harmful to investment, remarkably few studies have attempted to handle explicitly the short run and long run effects of uncertainty. This is not only important *per se*, but also due to the ambiguous results from the real options theory. In addition, few studies have aimed at

[33] Unfortunately most studies results are poorly reported and many of them do not provide any statistic for the model goodness of fit. Among the few that report lie those of Ghosal and Loungani's (1996) (adjusted R^2 is never above 0.28), Federer (1996) (adjusted R^2 is never above 0.38) and Bloom *et al.* (2005), (the correlation between the dependent variable and its fitted value is never above 0.31).

testing one key prediction of the options theory of investment: that the investment timing will differ under uncertainty. Carruth *et al.* (2000) review some of these papers and the evidence is, at best, mixed. This result is unexpected since some of the key papers they review concern investment in offshore oil production, which is a highly irreversible expenditure. Part of the reason could lie, once again, in the inadequacy of the uncertainty proxies used.

4. An Overview of Recent Investment Behaviour in Brazil

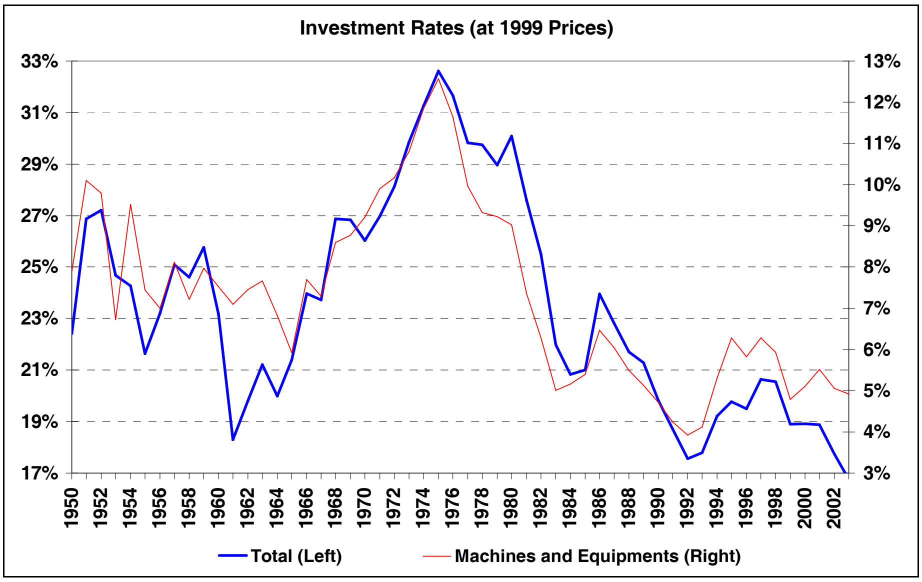
The post WW II Brazilian economic history can be divided into two clear periods: the period before the 1980s and the period ever since. The main distinguishing features that make the earlier 1980s a watershed on economic grounds are the sharp increase in inflation and the sizeable decrease in GDP growth that ensued. Annual CPI inflation reached the symbolic 100% mark in 1980, increasing very rapidly thereafter. By 1988 inflation had reached the shocking 1000% rate, and in last twelve months before July 1994, when the long awaited economic stabilisation finally began to take place, it reached the incredible 5,000% figure. Before that, however, five other stabilisation plans had been tried and failed since 1986. At the same time Brazil, which until the seventies was one of the fastest growing countries in the world, began to experience a significant GDP growth slowdown. While from 1940 until 1980 it grew a remarkable 6.8% on average, that rate was sharply reduced to just 2.25% during the 1980–1990 period and implied a 0.25% average increase in per-capita GDP. Those grim figures led the 1980 decade to become known as the lost decade. However, despite the pro-growth reforms that began to take place in 1990, such as trade liberalisation, privatisation and the stabilisation of the economy after 1994, the outcome of the 1990–2000 period was also very disappointing. The average GDP growth fell to 1.99%, implying an average increase of just 0.53% in per capita GDP.[34]

Another way of seeing the miserable economic performance as of early 1980s is to look at the behaviour of investment rates. Graph 1 plots both total and machines and equipments (M&E) investment rates at constant prices, and the sharp decrease in the investment to GDP ratio after the 1970s is eye-catching. During the 1980s the drop in the total rate of investment amounted to almost 9 percentage points (when measured at 1999 prices)

[34] Since the economy grew huge 9.2% in 1980 and plunged 4.35% in 1990, taking the eleven-year average with one overlapping year smooth out the effects of those years, providing a more sensible comparison between the two periods. Note that the relative performances are reversed when instead of comparing the 1980s with the 1990s one compares the 1980 decade with the 1990 decade.

and during the 1990s the situation continued to deteriorate as investment rates were unable to reach the level observed back in 1989.[35] Although there is certainly much room for improvements in the current macroeconomic performance, one should be aware that a simple comparison between the 1970s, which is used as a reference period by many Brazilian economists, with the 1980s and 1990s could be very misleading. When one analyses a longer time series it becomes clear that the high rates achieved during the 1970s were an exception rather than a rule for Brazil. They reflected a strategy which relied on heavy external borrowing when the Government refused to adjust the economic pace to the less favourable conditions produced by the first oil shock, as the developed countries did, a strategy that ended in the debt crisis in the 1980s. As the capital-output ratio rose above its long run equilibrium, lower future investment rates were indeed expected and inevitable. Hence, it makes more sense to compare recent rates with those observed before the 1970s. Even so, the former are well below the latter, especially regarding investment in M&E.

Graph 1
Investment Rates at 1999 Prices: 1950–2003



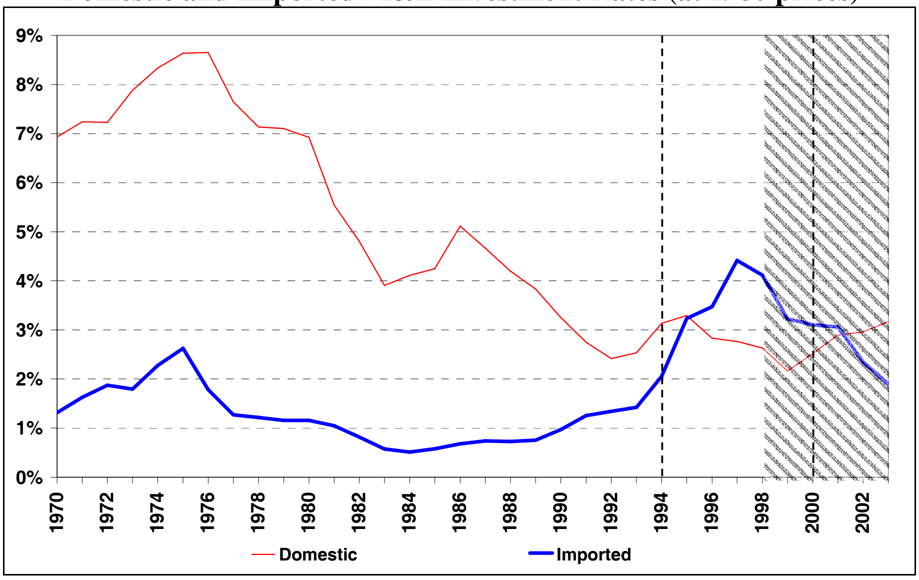
However, the most striking feature of recent investment behaviour in Brazil is the failure of investment rates to show any consistent sign of recovery after the stabilisation of the economy. Likewise inflation rates, in the ten years following the economic stabilisation (1995–2004) investment rates (at constant prices) have been at their lowest levels for, at least,

[35] As it will be seen shortly, the relative price of capital varied greatly since 1980, which means that real investment rates change drastically depending on which year is chosen as benchmark. Therefore, what matters in Graph 1 is the dynamic of investment rates and not its level, which is uninformative.

half a century (i.e. the average rate is lower than those in the 1950s, ..., 1990s). Moreover, after the securitisation of Brazilian external debt in 1994 the supply of external financing to Brazilian firms increased sharply, which makes this behaviour even harder to explain. Hence, besides lower growth (i.e. demand) one also would like to know what else seems to be hampering investment in Brazil since the 1980s.

Graph 2 portrays how domestic and imported M&E investment rates have evolved since 1980.[36] Some interesting findings are: a) the decrease in the domestic component accounted for practically all the fall in M&E investment rates during the 1980s; b) In early 1990s, while domestic M&E investment rates continued their downward path the imported share begins to rise after some years of stagnation; c) In 1994 imported M&E investment begins to rise rapidly, as the first dashed line points out, and by 1995 it actually overtakes its domestic counterpart; d) There is a sharp decrease in imported M&E investment rates after 1997, as shown by the shaded area; e) As the second dashed line calls to attention, after 1999 domestic M&E investment rates begin to increase after many years falling and continue rising until the end of sample. At the same time, imported M&E investment fails to bounce back and continues decreasing, being overtaken once again by the relative share of domestic investment in 2002.

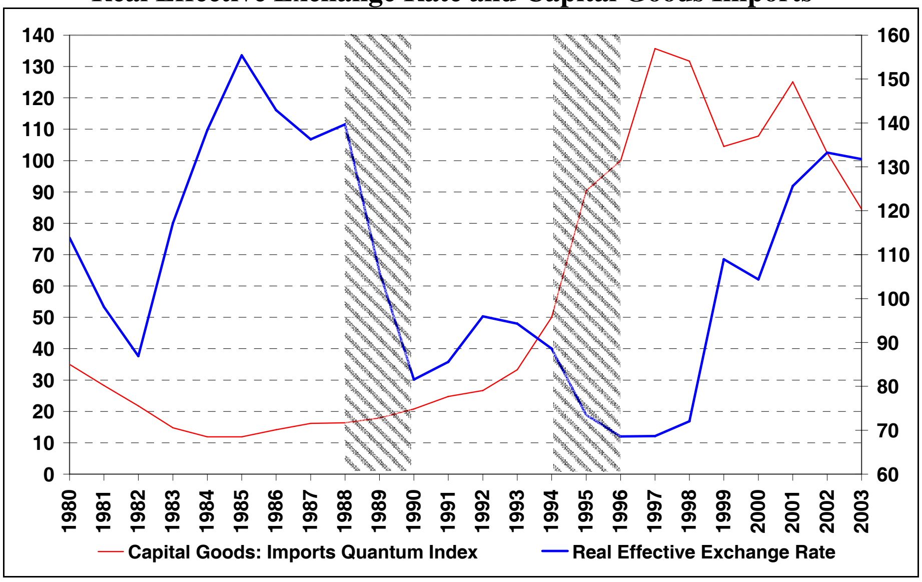
Graph 2
Domestic and Imported M&E Investment Rates (at 1980 prices)



[36] The term "domestic M&E" refers to those M&E that are produced domestically *and* used in production (i.e. it excludes the share of M&E that is produced internally but is exported). The term "imported M&E" refers to that fraction of M&E produced abroad and used in production.

Note that the increase in the imported share of M&E investment started in 1990, coinciding with the beginning of the trade liberalisation process in that same year, which came with the arrival of the new presidency, suggesting that there can be a causal link involved. This feeling gets stronger when one realises that domestic M&E investment rates continued to decrease during the 1990–92 period as expected, since the economy was in a deep recession. However, as the first shaded area in Graph 3 shows, there was a huge real exchange rate appreciation of around 40% in 1989-1990, which certainly played an important role in that result. In its turn, the sharp increase in imported M&E investment rates since 1994 and its subsequent sharp decrease after 1997, concomitantly with the increase in its domestic counterpart after 1999, seems to be unambiguously related to the behaviour of the real exchange rate. Indeed, as the second shaded area in shows, the Plano Real produced a fast and huge appreciation of the real exchange rate leading it to its most appreciated level since at least 1980.[37] That meant a large drop in (relative) domestic prices of imported M&E and certainly explains a sizeable part of the surge in the quantum of imported capital goods that followed, also plotted in Graph 3.

Graph 3
Real Effective Exchange Rate and Capital Goods Imports[38]



[37] The Plano Real (Real Plan), which was implemented in July 1994, was the economic stabilisation plan that finally was able to stabilise the economy.
[38] The real effective exchange rate was calculated using the 18 main Brazilian trade commercial partners. They represented around 77% of the Brazilian foreign trade along the sample. The weight of each country was given by a 2-year moving average in order to capture changes in the commercial profile along time. Note that a fall in the real exchange rate means appreciation.

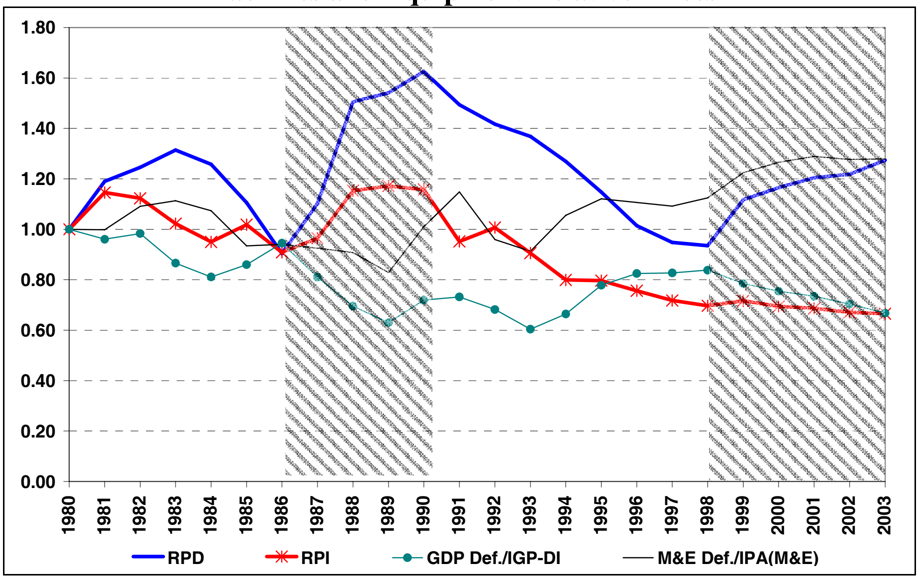
By the same token the large depreciation that followed the collapse of the fixed exchange regime in early 1999 helps to shed light on the sharp decrease in imported M&E investment rates and the revival of its domestic counterpart, shown by both Graphs 2 and 3. Indeed, Graph 3 shows that there was an *absolute* decrease in imported M&E after 1999. Notice that the decrease in both the share and absolute value of imported M&E actually began in 1998 and not 1999. That was due to the uncertainties produced by both the Asian and Russian crises, which led to two speculative attacks against the Real and forced the Central Bank to raise sharply interest rates twice, creating uncertainty about the maintenance of the Brazilian fixed exchange rate regime. Brazil's sovereign spread, or country risk, soared due to the higher macroeconomic uncertainty and caused external financing to dry up, creating an environment less conducive to investment decisions. Therefore, although the real exchange rate is not a variable explicitly taken into account by theoretical models of investment it does appear to matter for investment expenditures in Brazil. Indeed, as the Brazilian economy became more open since the 1990s its effect seems to have sharply increased, as imported M&E began to react both more promptly and more intensively to exchange rate changes. Hence, both factors are likely to be at work behind the sharp increase in imported M&E after 1993. The relevance of the exchange rate to investment expenditures has also been found elsewhere. For example, Bakhshi and Thompson (2002) and Ellis and Groth (2003) argue that the exchange rate is one important factor behind both the share of imported capital goods in total investment and the behaviour of the relative price of capital in the United Kingdom.

On the other hand, a price variable that is obviously theoretically relevant to investment is the price of capital or, more generally, the relative price of capital. Graph 4 shows the behaviour of the relative price of M&E in Brazil during the 1980–2003 period according to two different measures. In the first, the M&E deflator is divided by the GDP deflator, whereas in the second the wholesale price index of M&E [IPA–DI(M&E)] is divided by the general price index (IGP–DI).[39] Surprisingly, the two measures show some important differences: while the measure using relative price deflators (RPD) has risen by 27% during the sample, the measure using relative price indexes (RPI) shows a decrease of around 33%. Hence, not only there is a large quantitative difference but, more importantly, a qualitative divergence. Although one would have expected both series to show the same picture over the long run, it is important to note that this divergence does not necessarily mean that there is an

[39] The general price index is composed by three different price indices as follows: 60% comes from the WPI, 30% comes from the CPI and 10% comes from the National Construction Cost Index.

inconsistency between the two measures, nor that the inconsistency is large. The major reason being that while price indices measure inflation in a given basket of goods deflators measure inflation in the whole economy. Moreover, the former is more sensitive to changes in import prices than the latter (especially regarding the GDP deflator).

Graph 4
Machines and Equipment Relative Prices



In order to try to pinpoint the sources of divergence between the RPD and the RPI Graph 4 also plots the ratio between both measures' numerators and denominators, and some interesting conclusions arise. First, the "numerators ratio" is trendless until 1994, which means that both the M&E deflator and the WPI of M&E show basically the same picture as to the behaviour of M&E prices. However, since 1994 the former has risen much more relatively to the latter. This seems to be connected, at least to some degree, to the behaviour of the real exchange rate, since the WPI of M&E is probably more affected by changes in the real exchange rate than the M&E deflator, and the real exchange rate experienced a large appreciation from 1994 until 1998. However, since the real exchange rate depreciated sharply after 1998 this movement was expected to be reversed, but curiously that has not happened, as the second shaded area highlights. Second, the "denominators ratio" trends downward over the sample. It should be called to attention that since 60% of the IGP-DI inflation comes from the WPI inflation, which has a high content of tradable goods, it is more affected by changes in the exchange rate than the GDP deflator, which has a large content of non-tradable goods in it, and this difference probably explains to some degree the divergence between the two measures of overall inflation. Third, given this evidence, it does not seem that the bulk of the divergence between the two M&E relative prices series lie in the particular measure chosen to gauge M&E prices, but rather in the measure chosen to gauge the economy-wide inflation.

Three periods in Graph 4 deserve some comments. The first is the 1981–83 period, during which the RPD rose around 10%, while the RPI actually fell by almost 11%. Despite its small magnitude, the rise in the RPD is unexpected since during that period the Brazilian economy experienced its worst recession in the twentieth century: GDP fell by 6.3% and real investment in M&E plunged by 48%. On the other hand, the more intuitive behaviour of the RPI is almost entirely due to developments occurred in the 1983 year alone, when it fell by 9%. Indeed, in February of that year the Government devalued the exchange rate by 39%, and since the IGP-DI is much more affected by such changes than the GDP deflator, that event seems to basically explain the divergence. Hence, there seems to be a divergence but not an inconsistency between both measures of relative prices in that period. A second "interesting" period, called to attention by the second shaded area, is the 1999–2003 period, for two reasons. This is the first time in the sample that both measures diverge qualitatively for a prolonged period of time. While the RPI falls mildly, the RPD increases sharply. Analysing the "denominators ratio" during this period one sees that, as expected, it shows the opposite behaviour to the 1994–98 period, when the real exchange rate appreciated. However, as noted in the last paragraph, the numerators ratio unexpectedly continued to rise during this period.[40] Finally, even though the RPD and the RPI do not diverge qualitatively, the first shaded area highlights the period in which their difference builds up the most. During the 1987–90 period the RPD increases 80%, while the RPI increases 27%. Once again, suggestively, the real exchange rate experienced a sizeable appreciation of more than 45% during the 1987–90 period, which seems to partially explains this divergence.[41]

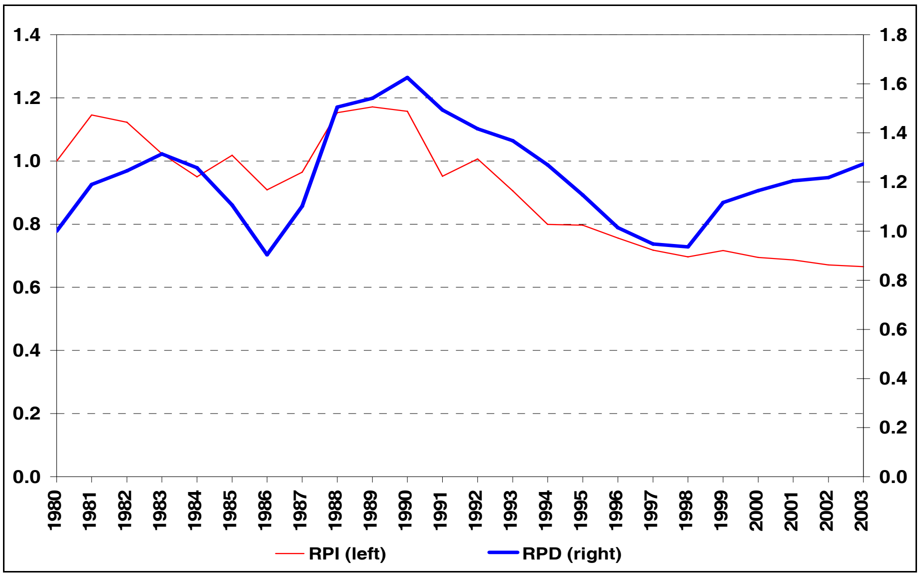
Graph 5 plots the RPD and the RPI in different axes in order to maximise (or not) the similarities between them, and it shows a much more benign picture of both series behaviour, despite the differences pinpointed above. Apart from the post-1999 period, the RPD and the RPI convey basically the same qualitative message regarding M&E relative prices behaviour. Indeed, from 1989 until 1998 their behaviour is remarkably similar, with the former

[40] However, notice that when the total effect is decomposed, changes in the denominators ratio are actually more important to explain the divergence between the RPD and the RPI than the numerators ratio. While the (inverse) of the former increased by 25.4% during the 1999–2003 period the latter increased by half of that amount (13.7%).

[41] Likewise the 1999–2003 period, here the denominators ratio also contributes the most to the widening gap between the two relative price series (31.3% against 7.5%).

decreasing by 37.9% and the later by 39.6%. Overall, there seems to be mainly a level discrepancy between both series. Nonetheless, the most puzzling feature of Graph 4 and 5 is not actually self-evident, which is the conflicting behaviour of the RPD in Brazil vis-à-vis the international evidence, which shows that the relative price of capital has become cheaper worldwide.[42] Bakhshi and Thompson (2002) argue that higher relative technological growth in the production of investment goods (both in relation to other sectors of the economy and in relation to other countries) might explain part of the fall in the relative price of capital in the U.K. They also claim that this factor might be behind the recent appreciation of the pound, which, by its turn, would also help to explain the fall in the relative price of capital. This "productivity hypothesis" could as well be behind the puzzling behaviour of RPD in Brazil, but now in the opposite direction, since productivity gains have been very dismal since 1980 (see da Silva Filho, 2006b).

Graph 5
The Relative Price of M&E



It might also be possible that the chaotic Brazilian inflationary history could be in some way behind this conflicting evidence. Indeed, inflation could help to explain these developments in two ways. First, as inflation rises and reaches extremely high rates it becomes more and more difficult do disentangle nominal from real changes in prices. For example, it is widely known that high inflation affects seriously the accuracy with which

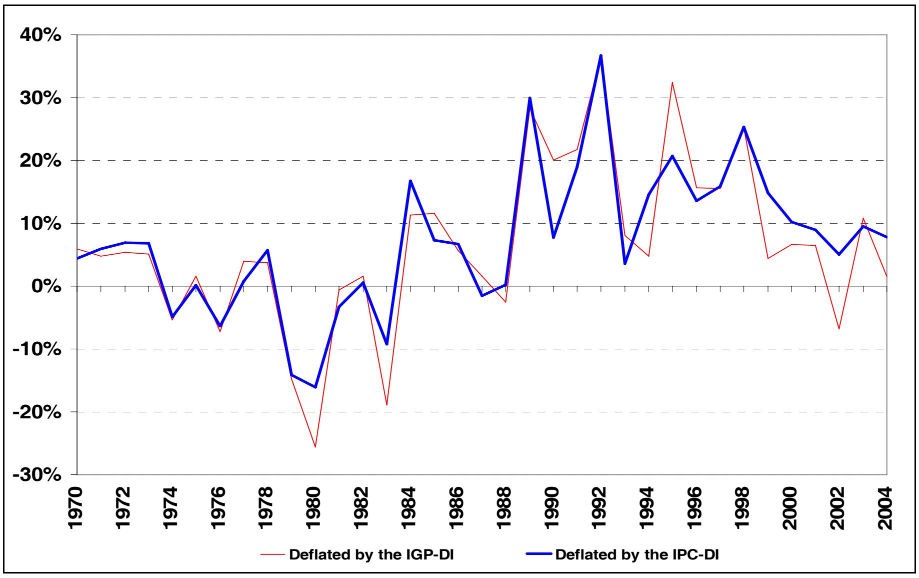
[42] For example, Ellis and Groth (2003) show that the relative price of capital (measured by relative deflators) has fallen by 40% since 1980 in the U.K.

balance sheets reflect the actual situation of a firm (e.g. profits). A myriad of similar distortions occur when one has to rely on rules and conventions made for a low inflation environment. In a nutshell: this conflicting evidence can be, to some extent, the result of mis-measurement. Second, by decreasing the efficiency of the price system and entailing several economic costs, inflation changes the structure of incentives in the economy. For example, one cost of inflation is that it drains productive resources to activities which the sole purpose is to protect agents from its costs. Also, inflation uncertainty shortens planning horizons, which has direct consequences on investment plans. Although the "inflation hypothesis" has certainly some appeal, it is interesting to note that the RPD actually reversed its upward trend in 1990 and, in agreement with the international evidence, fell sharply from 1990 until 1998.[43] However, during the 1990–94 period inflation was actually higher than in the 1980s, so that its effects on the behaviour of the RPD might be more complicated to uncover, and other factors might have been important as well.[44] Therefore, the unusual behaviour of the RPD requires a separate and deeper investigation of its own, which is not the aim here. Moreover, although the exchange rate seems to explain much of the divergence between the RPD and the RPI, one also would like to know whether other factors were at play. However, for the purposes of this paper and taking into consideration the strategy followed in the next section, the current analysis should be enough.

Graph 6 shows two measures of (ex-post) real interest rates for Brazil, where nominal rates paid by bank certificate deposits (CDB) are deflated by both the consumer price index (CPI-DI) and the general price index (IGP-DI). Two features stand out: the extreme variation in real rates and the sharp contrast between the 1980s and the 1990s. During the 1980s real interest rates not only were much lower than those that prevailed during the 1990s, but in the early 1980s real rates were extremely negative due to controls imposed by the Government on nominal interest rates.[45] The high real rates during the 1989–1992 period were aimed at both keeping the attractiveness of public bonds in an environment of low governmental credibility and taming the explosive inflationary process, while those that prevailed during the 1995–1998 period were aimed at attracting foreign capital to sustain the large current account deficits that arose after the implementation of the fixed exchange rate regime.

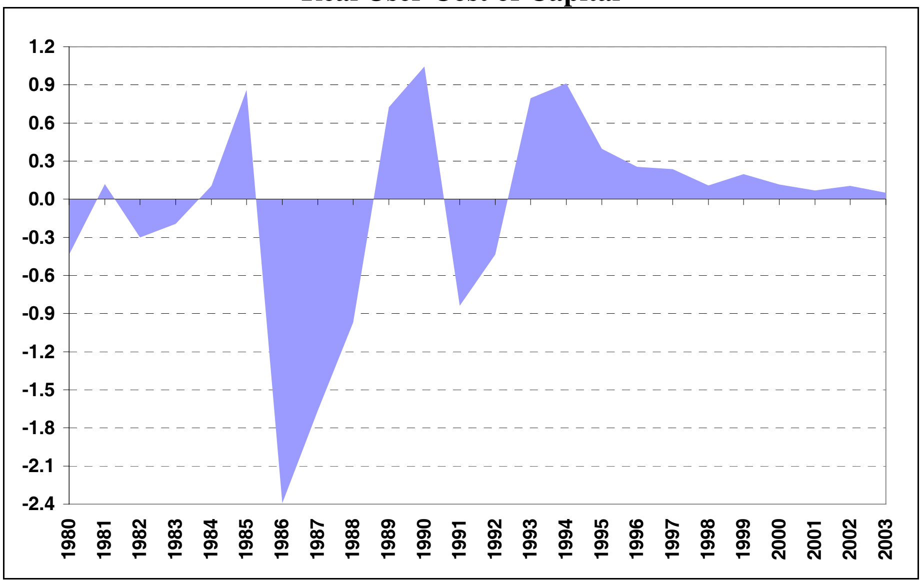
[43] Moreover, as shown above, during the 1990s the RPD and the RPI have a very similar behaviour.
[44] One possible explanation could be that during the 1980s agents learned to live with and got adapted to a high inflation environment. Indeed, several distortions caused by inflation were mitigated as indexation became widespread during the 1980s as, for example, rules and conventions used in accounting practices were modified.
[45] On this the reader is referred to the detailed description provided by Loureiro and Barbosa (2003).

Graph 6
Annual Real Interest Rates



Finally, Graph 7 shows the empirical counterpart for Brazil of the well-known real user cost of capital concept (using the RPI), in which besides the nominal interest rate, the depreciation rate and capital gains are also considered.[46]

Graph 7
Real User Cost of Capital



The user cost results from an optimisation problem in which the firm maximises the present value of future cash flows (equation 1). The first order condition gives the discrete

[46] Due to data limitations taxes, investment tax credit and depreciation allowances are ignored.

time equivalent of Jorgenson's real user cost of capital (equation 2),

$$\max_{K} \mathrm{V} = \sum_{t=1}^{\infty} \frac{1}{(1+R)^{t-1}} \left[P_t F(K_t, L_t) - P_{I,t} I_t - w_t L_t \right] \tag{1}$$

$$\frac{\partial F_t}{\partial K_t} = \frac{P_{I,t}}{P_t} - \frac{P_{I,t+1}}{P_t} \frac{1-\delta}{1+R_t} \tag{2}$$

where I is gross investment, P is the output price, P_I is the price of M&E, δ is the depreciation rate and R is the nominal interest rate.[47]

Once again there is a sharp difference between the 1980s and the 1990s. Not only the real user cost was much lower in the 1980s than in the 1990s but it was very volatile and negative during most of the period. The situation changed drastically in the 1990s: after the negative values of 1990 and 1991, the real user cost became highly positive in 1993, and kept being positive until the end of the sample. Nonetheless, it started decreasing consistently since 1995 due to lower nominal interest rates, and turned out to be much less volatile during that period.

5. Empirical Results

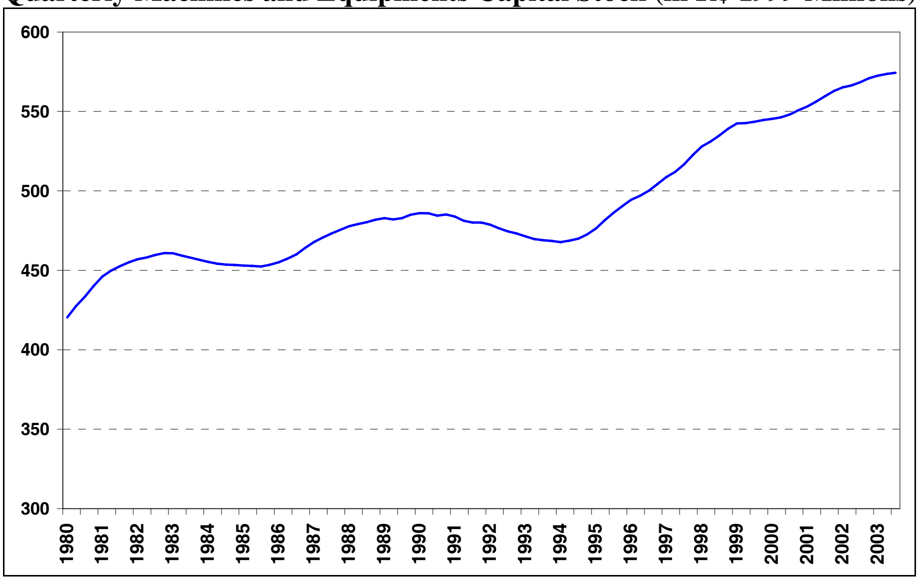
As noted in the last section, at least as striking as the sharp reduction in investment rates (at constant prices) during the 1980s is their behaviour since 1995. The long awaited stabilisation of the Brazilian economy has not brought a consistent recovery of investment rates yet. As a matter of fact, they have been surprisingly at their lowest levels since 1950. One important factor behind this "reluctance to invest" or "lack of animal spirits" is that macroeconomic uncertainty remains high in Brazil. For example, da Silva Filho (2006a) provides evidence that despite the sharp reduction in inflation rates inflation uncertainty continues to be high in Brazil, and is the most likely cause behind the very low average maturity attached to nominal public bonds.[48]

Hence, this section's goal is twofold: first, it seeks to identify some of the main factors behind the dismal investment behaviour in Brazil during the 1980–2003 period. Second, it

[47] The annual depreciation rate used was 8%, which is the same rate used by da Silva Filho (2006b).
[48] In 2007 the IBGE released a significant revision of the National Accounts, going back to 1995. However, the investment picture remained the same as the one portrayed here. Recently, however, investment rates seem to be finally trending upwards.

tests the hypothesis that inflation uncertainty has been affecting adversely capital accumulation in Brazil. In order to accomplish that an equilibrium correction model (EqCM) is estimated, so that one is able to disentangle short-run from long-run effects. Note that since firms decide how much to invest based on their desired capital stock, the variable under analysis will be the capital stock. Since there is no official quarterly series of M&E capital stock available in Brazil an estimate was built employing the same methodology used by da Silva Filho (2006b) except for two small differences: first, the initial capital stock is now given by da Silva Filho's (2006b) estimate for the 1980.1 capital stock, which is practically purged from any errors incurred in the initial estimate; second, since there are no quarterly M&E investment series going back to 1980 available in Brazil but there is one for aggregate investment, the former was constructed in the following way: a quarterly series of real aggregate investment was built using real changes calculated by the Economic Applied Research Institute (IPEA). That series was multiplied by the annual share of M&E investment in total investment according to the National Accounts. By assuming that within each year that share remained constant a quarterly series of M&E investment was obtained, in which its annual changes match exactly those from the National Accounts.

Graph 8
Quarterly Machines and Equipments Capital Stock (in R$ 1999 Millions)



Graph 8 shows the behaviour of the resulting series during the 1980–2003 period. It provides an alternative look at the disappointing behaviour of investment rates since the 1980s. From 1982 until 1994 the M&E capital stock grew only 3.8%, which means that net investment was practically zero in that period. However, despite the low investment rates since the 1990s the M&E capital stock actually started to grow once again in 1995, after more than one decade of nearly stagnation. This development is hidden when one looks only at investment rates, and gives a much less pessimistic picture on recent investment behaviour.

Two types of inflation uncertainty proxies are used here. The first one are the temporally consistent out-of-sample inflation forecast errors, for several horizons, obtained by da Silva Filho (2006a): $\nu_{i,t}^{ar} = \Delta_i \ln P_t - E_{t-i}(\Delta_i \ln P_t)$ where P_t is the CPI–DI and i = 1, …, 4. For each quarter during the 1974.1–2002.4 period a different AR model was estimated in order to generate inflation forecasts up to one year ahead. The second proxy is the one-quarter ahead inflation forecasting errors from a random walk model. This proxy is motivated by da Silva Filho's (2006a) finding that one quarter ahead out-of-sample inflation forecasting errors from AR models are very similar to forecast errors generated from a simple random walk model: $\nu_{1,t}^{rw} = \Delta \ln \mathrm{P_t} - \Delta \ln P_{t-1}$, where P_t is the CPI–DI. This is not surprising given the historical high unpredictability of inflation in Brazil. Graph 1 in Appendix 2 shows the AR forecasting errors for the four horizons considered, while Graph 2 shows that all of them are positively correlated to the inflation level, implying that the higher the inflation rate the more uncertain it is. Graph 2 shows the cross-plot between one-step ahead errors from the AR and random walk models. They are highly correlated with a R^2 equal to 0.81.

It is important to make a brief digression about how inflation uncertainty effects are tested in this paper. The traditional procedure in the literature when one tests the effects of uncertainty about a given variable is to include in the model the variance of the forecast errors. However, this approach may not be appropriate under some circumstances, giving misleading results. The problem with this procedure is that it imposes a symmetric effect from positive and negative errors. This symmetry should not be imposed but tested, since there are many reasons to believe that agents' reactions to negative and positive errors might be different, either quantitatively or even qualitatively. For example, the idea behind asymmetric (G)ARCH models is that a positive error increases (decreases) more uncertainty than a negative error of the same magnitude. Such models provide one interpretation of asymmetric effects: that they help forecast some forward looking aspects of uncertainty. However, even though asymmetric (G)ARCH models are an improvement by allowing asymmetric effects, they still impose too much structure in the model.[49] For example, da Silva Filho (2006a) calls to attention that negative inflation forecast errors are likely not only to *decrease* uncertainty

[49] Note that in the traditional (pure) irreversibility literature, the bad news principle also implies asymmetric responses, but in that case only downside uncertainty matters.

but mainly to be beneficial. He argues that this is likely to happen since the evidence from surveys show that inflation is usually underpredicted when it is rising and overpredicted when it is falling. This implies that when inflation is falling agents are systematically overpredicting it or, putting in another way, inflation is falling faster than anticipated. Therefore, negative forecast errors are likely to act like good news since things are going better than expected. As an alternative example, imagine that profits are being systematically underpredicted by firms. It is very hard to accept the idea that systematic profits underprediction will increase uncertainty and lead the firm to decrease its investment.[50] The opposite is likely to occur.

Note that the asymmetry stems mainly from the survey evidence showing systematic inflation forecasting errors in the pattern described above. If this is not the case, then the scope for "good news" shrinks and asymmetric effects are less likely. Why is this so? Because if, say, inflation is falling but forecast errors are two-sided, then things are not improving faster than expected.[51] Therefore, in order to test for inflation uncertainty effects on investment while allowing for asymmetric effects, both forecast errors themselves and their absolute values will be included in the General Unrestricted Model (GUM).

Besides the variables mentioned so far two additional variables will be used to model capital accumulation in Brazil: industrial capacity utilisation and real wages. Both are obviously relevant for investment decisions. The former because it shows how intensively the capital stock is being used, and the second because capital and labour are, to some degree, substitutes. Finally, due to data limitations other variables that could be relevant in explaining investment expenditures such as import tariffs, credit conditions and profits are not taken into account.

Table 1 gives the unit root tests for all the variables with the exception of the inflation uncertainty proxies, which are obviously stationary. All variables are in logs, unless otherwise stated.[52] The variables found to be stationary are the real interest rate, r, the real user cost of capital, ucc, and real wages, w, while the capital stock, k, real output, y, the relative price index, rpi, the real effective exchange rate, $reer$, and capacity utilisation, uci, were found to have a unit root.

[50] One might well say that in this case uncertainty about future profits is indeed high since they cannot be accurately assessed. However, in this case one needs to qualify this uncertainty by saying that it is "good uncertainty", which is conducive to more investment.
[51] Actually, depending on which variable is being analysed things can be even more complicated. For example, assume that exchange rate forecasts errors follow the same pattern as inflation forecast errors. In this case while systematic overprediction probably means good news to importers it will have just the opposite effect to exporters, so that in the aggregate both effects may offset each other.
[52] Note that both the real interest rate and the real user cost of capital are expressed as log(1 + rate).

Table 1
ADF Unit Root Tests[53]

Variable	$1-\hat{\gamma}$	t_{ADF}	Lag	t_{lag}	t_{lag} –*prob*	*F-prob*
			LEVELS			
k	0.977	-3.22	3	2.83	0.00	0.82
y	0.740	-3.18	4	6.53	0.00	–
reer	0.947	-1.46	0	–	–	0.18
rpi	0.856	-2.84	2	2.19	0.03	0.38
r (deflated by the IGP)	0.269	-5.06**	1	-2.3	0.02	0.72
ucc (using the RPI)	0.051	-5.27**	3	2.05	0.04	0.35
uci	0.633	-3.22	2	-2.344	0.02	0.09
w (deflated by the IGP)[54]	0.798	-3.486*	4	4.30	0.00	–
			FIRST DIFFERENCES			
Δk	0.829	5.49*	4	4.12	0.00	–
Δy	-0.468	-4.69**	4	2.13	0.04	–
Δreer	0.083	-8.59**	0	–	–	0.12
Δrpi	-0.093	-6.87**	2	-2.38	0.02	0.27
Δuci	-0.792	-11.17**	1	3.73	0.00	0.17

Since the widely used Engle-Granger (EG) test is a very poor way of testing cointegration (see Maddala and Kim, 1998) it is not used in this paper. It was criticised by Kremers *et al.* (1992) for imposing a common factor restriction in the equation dynamics. However, the empirical evidence usually does not support such an assumption (Hendry and Doornik, 2001), which implies a loss of power. Kremers *et al.* (1992) proposed a test based on a single equation error correction model (ECM), which does not impose such constraint. Even so, an important weakness of their test is that it is not similar. However, Kiviet and Phillips (1992) developed a test, based on an unrestricted ECM, which has this property. Banerjee *et al.* (1993) show evidence that the power of this test can be high relatively to the EG test.[55] The cointegration test used in this paper is a variant of ECM Kiviet and Phillips's test, and it is known in the literature as the PC-Give unit root test (see Hendry and Doornik, 2001). The test focuses on the coefficient of the lagged dependent variable in the unrestricted equilibrium

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[53] The test equation is given by $\Delta y_t = m + \beta t + \gamma y_{t-1} + \sum_{i=1}^{4} \delta_i \Delta y_{t-i} + \varepsilon_t$. Unit root results are unchanged when a different deflator (i.e. the CPI-DI instead of the IGP-DI) is used to measure real interest rates and real wages. Likewise, the results are also unaltered regardless of which relative price series is used (RPI or RPD) or chosen when calculating the real user cost of capital.

[54] One would expect real wages to be non-stationary given that productivity usually grows over time, which raises the possibility that this result could be simply a statistical artifact.

[55] Note, however, that in the absence of weak exogeneity it is not a good way of finding cointegration.

correction model. In the models estimated below it is assumed that all information needed for inference on the parameters of interest comes from the conditional model alone.

Before proceeding note that the GUM, given by equation (3), includes all the variables discussed so far, not being the empirical counterpart of a particular theoretical model. The number of lags was usually set to five.

$$\begin{aligned}\Delta k_t &= \beta_0 + \textstyle\sum_{i=1}^{3} S_i + \beta_1 T + \beta_2 k_{t-1}^{*} + \beta_3 uci_{t-1} + \beta_4 ucc_{t-1} + \beta_5 r_{t-1} + \beta_6 rp_{t-1} \\ &+ \beta_7 reer_{t-1} + \beta_8 w_{t-1} + \beta_5 \pi_{t-1} + \beta_6 s_{t-1} + \textstyle\sum_{i=0}^{n} \Delta lags_{t-i} + dummies + \varepsilon_t\end{aligned} \tag{3}$$

where: *rp* are relative prices (*rpi* or *rpd*, as defined earlier), k^* is the capital stock divided by real output and π is the inflation rate. The remaining variables were defined before.

While some purists may not be sympathetic to this approach it is indeed highly desirable for two main reasons. First, the empirical model should be general enough to maximise the chances that those variables retained during the reduction process are indeed relevant. Second, theoretical investment models do not have a good reputation for successfully describing actual investment. Hence, it is not sensible to replicate models that are well known to struggle with the evidence. More importantly, the aim here is explaining capital accumulation and not testing theoretical models, which have been tested to exhaustion elsewhere. By including all variables deemed to be theoretically relevant one gives the chance for the data to speak for itself. For the same reason, in addition to the real user cost of capital, relative prices and the real interest rate are also included in the GUM separately. This setting has the advantage of giving more flexibility to the specification, improving the chances of uncovering price effects that are not restricted to enter the model only in the way the theory predicts. Finally, output homogeneity is imposed throughout, since the restriction is not usually rejected. This is desirable since homogeneity is theoretically appealing and has been frequently found elsewhere. Hence, as noted above, the dependent variable in the long run solution is the capital stock divided by the output, k^*.

In searching for congruent specifications a general-to-specific modelling approach was used in an equilibrium correction framework, with the help of PcGets, which is an automatic econometric model selection software (see Hendry and Krolzig, 2001; see also Hoover and Perez, 1999). The liberal strategy in PcGets, which minimises the chance of omitting a relevant variable, was used. Equation (4) shows the unrestricted equilibrium correction model

(EqCM) chosen when the random-walk inflation uncertainty proxy is used. The model's fit and residuals graphs as well as those with the recursive estimates are placed in Appendix 2. The recursive coefficients seem stable and the recursive Chow tests are not significant. The diagnostic tests are satisfactory, all variables have the correct theoretical signs and cointegration is found, so that the model seems to be well specified.

$$\begin{aligned}
\Delta k = {} & \underset{(7.51)}{0.020} - \underset{(-7.36)}{0.000077}\,T + \underset{(3.05)}{0.0024}\,D82.1 + \underset{(5.12)}{0.0067}\,D90.2 + \underset{(3.76)}{0.0030}\,D94.2 \\
& - \underset{(-3.82)}{0.0030}\,D99.2 - \underset{(13.5)}{0.61}\,\Delta k_{t-1} + \underset{(2.97)}{0.0067}\,\Delta y_{t-2} - \underset{(-3.39)}{0.0061}\,\Delta y_{t-3} + \underset{(3.80)}{0.0037}\,\Delta_4 w_{t-1} \\
& - \underset{(-6.60)}{0.014}\,k^{*}_{t-1} + \underset{(4.94)}{0.013}\,\Delta_2 uci_t + \underset{(4.06)}{0.013}\,uci_{t-3} - \underset{(-4.28)}{0.014}\,r_{t-2} + \underset{(4.17)}{0.0086}\,\Delta r_{t-2} \qquad (4) \\
& - \underset{(-5.55)}{0.0060}\,rpi_{t-1} + \underset{(2.12)}{0.0032}\,\Delta_2 rpi_{t-1} - \underset{(-3.16)}{0.0012}\,reer_{t-2} - \underset{(-3.07)}{0.0038}\,s^{rw}_{1,t-1} + \underset{(3.11)}{0.0030}\,\Delta s^{rw}_{1,t-1} \\
& + \underset{(3.31)}{0.0023}\,\Delta s^{rw}_{1,t-2} - \underset{(-2.17)}{0.0010}\,\Delta\left|s^{rw}_{1,t-3}\right|
\end{aligned}$$

T = 89 (1981.4–2003.4); $\hat{\sigma} = 0.075\%$; R^2 = 0.97; DW = 2.29;

AR 1–5: $F(5, 62)$ = 1.59 (0.18); ARCH 1–4: $F(4, 59)$ = 1.15 (0.34); Hetero: $F(38, 28)$ = 0.43 (0.99); Normality: $\chi^2(2)$ = 2.33 (0.31); RESET: $F(1, 66)$ = 0.14 (0.71).

Long run elasticities: *uci* = 1; *r* = –1; *rpi* = –0.4; *rer* = –0.09; $s_1^{rw} = 0.27$.

Note that the relative price of capital is highly significant and has the correct theoretical sign, giving further support to the choice made earlier on favouring the RPI over the RPD. The fact that the real exchange rate is significant means that it captures changes in relative prices that are not fully captured by the RPI alone. The negative sign is consistent with the recent Brazilian experience, in which firms take advantage of periods of real exchange rate appreciation and increase their imports of M&E. However, one could claim that theoretically the sign could be positive as well, since appreciation decreases the profitability of exports and can lead to lower investment rates. Note also that even though the real user cost of capital is not found to be relevant, the real interest rate is highly significant. Hence, since two components of the former are already present in the model (the real interest rate and relative prices) this result is not unexpected and shows the adequacy of having chosen a more general specification. This result also suggests one possible reason on why in many empirical investment equations the user cost of capital is not found to be very relevant. As one would expect capacity utilisation appears to be an important determinant of capital accumulation in the long run, however, according to this specification, real wages seem to matter only in the short run. One possible explanation for this result is that labour saving embodied technological gains occurs regardless of wage developments. The last three dummies are associated clearly with important economic events. The second (second quarter of 1990) and the third (second quarter of 1994) dummies refer to the quarter following the implementation of the Collor and the Real Plans, respectively. The last dummy (second quarter of 1999) refers to the quarter following the collapse of the fixed exchange regime.

Finally, the inflation uncertainty proxy ($s_{1,t}^{rw} = v_{1,t}^{rw}$) is found to be both statistically significant, with the expected theoretical sign, and economically relevant with a long-run elasticity equal to 0.27, suggesting that inflation uncertainty does seem to be a relevant factor in driving long run capital accumulation in Brazil. Note that the delta effects imply over half the weight at lag t-3. It should also be called to attention that equation (4) suggests that inflation uncertainty effects are asymmetric, as argued earlier on. This is a potentially important result for the investment literature, which has neglected the possibility that uncertainty might have asymmetric effects on investment behaviour. Moreover, negative errors are considered "good news", being conducive to capital accumulation.

The real interest rate and capacity utilisation have long-run elasticities approximately equal to unity, apparently playing leading roles in investment decisions (along with demand, here proxied by output).[56] Relative prices also seem to have an important influence on investment expenditures, with a long-run elasticity just below half. In its turn, real exchange rate effects seem to be small. However the small coefficient could be deceptive since not only may real exchange rate effects already be captured by relative prices but also because real exchange rates can vary by as much as 15%–20% in short periods of time.

Equation (5) shows an alternative specification, also using the random walk inflation uncertainty proxy ($s_{1,t}^{rw} = v_{1,t}^{rw}$). As before, graphical evidence on the model's fit and residuals as well as recursive graphs are placed in Appendix 2. The diagnostic tests are satisfactory, all variables have the correct theoretical signs and cointegration is very strong, so that this model also seems to be congruent with the data.

Some important differences between equations (4) and (5) are: first, the real user cost of capital is now found to be relevant. Even so, it is more than ten times less relevant

[56] Note that Caballero (1997) found a near unity coefficient for the user cost of capital when studying M&E investment for the U.S. He also cites two other studies with similar conclusions.

economically than the real interest rate. Second, in this specification what seems to be the most relevant are *changes* in forecast errors rather than forecast errors themselves. Or, putting it differently: what seems to matter the most is the acceleration of inflation, whose effects seem to be very persistent, rather than changes in inflation, a result similar to that of da Silva Filho (2006b), where acceleration effects were found to be relevant to productivity developments. Once again inflation uncertainty effects are found to be asymmetric, since both signed and absolute value effects are present in the model. Finally, the elasticity of capacity utilisation is smaller than previously found. On the other hand the real interest rate, relative price and real exchange rate elasticities are very close to the values found in equation (4).

$$\begin{aligned}
\Delta k = {} & \underset{(10.09)}{0.029} - \underset{(-6.92)}{0.0016}\, S_2 - \underset{(-12.6)}{0.00013}\, T + \underset{(3.28)}{0.0045}\, D90.2 - \underset{(-3.08)}{0.0027}\, D99.2 + \underset{(11.8)}{0.12}\, \Delta_4 k_{t-1} \\
& + \underset{(9.71)}{0.011}\, \Delta_3 w_{t-1} - \underset{(-12.2)}{0.022}\, k^{*}_{t-1} + \underset{(4.92)}{0.012}\, \Delta_2 uci_t + \underset{(4.63)}{0.014}\, uci_{t-3} - \underset{(-5.95)}{0.019}\, r_{t-2} \\
& + \underset{(4.79)}{0.011}\, \Delta r_{t-2} - \underset{(-4.76)}{0.0016}\, ucc_{t-1} - \underset{(-9.13)}{0.011}\, rpi_{t-1} - \underset{(-4.14)}{0.0017}\, reer_{t-2} - \underset{(-6.57)}{0.0064}\, \Delta s^{rw}_{1,t} \\
& - \underset{(-6.08)}{0.016}\, ma6\Delta s^{rw}_{1,t-1} - \underset{(-6.75)}{0.0076}\, \Delta\left|s^{rw}_{1,t}\right| - \underset{(-3.11)}{0.0021}\, \Delta\left|s^{rw}_{1,t-1}\right| - \underset{(-4.70)}{0.0029}\, \Delta\left|s^{rw}_{1,t-2}\right|
\end{aligned} \tag{5}$$

T = 90 (1981.3–2003.4); $\hat{\sigma} = 0.083\%$; R^2 = 0.97; DW = 1.84;
AR: F(5, 65) = 1.35 (0.25); ARCH: F(4, 62) = 0.87 (0.49); Hetero: F(35, 34) = 0.51 (0.97); Normality: $\chi^2(2)$ = 0.33 (0.85); RESET: F(1, 69) = 1.88 (0.18).
Long run elasticities: *uci* = 0.6; *r* = 0.9; *ucc* = 0.07; *rpi* = –0.5; *rer* = –0.08.

Equation (6) shows another specification, but now using the inflation uncertainty proxy based on one-quarter ahead out-of-sample forecasts errors from da Silva Filho (2006a). ($s^{ar}_{1,t} = v^{ar}_{1,t}$) Graphical evidence is also placed in Appendix 2. Diagnostic tests are not significant and all variables have the expected sign, which increases the confidence in the model's quality. Note, however, that in this specification capacity utilisation does not enter in the long-run solution. Although the level of capacity utilisation is very significant in equations (4) and (5), its absence or small significance in the long-run solution was actually found in several specifications. This result is not one of the most intuitive and a possible explanation is that since the 1980s economic growth in Brazil has been characterised by boom and bust cycles, so that entrepreneurs might wisely have learnt to understate the importance of current demand conditions, since tomorrow might conceal the next crisis. Hence, once high capacity levels are reached firms stay put for a while to make sure new demand conditions are there to stay before committing to more investment. During this period they prefer to incur the extra costs of overtime than to hire more workers and increase its capital stock. This behaviour would be coherent with both what happened both during the high inflation period, when several stabilisation plans were put in place, and with the post stabilisation period, when Brazil experienced two speculative attacks. It also fits the very recent experience in which several inflation targets were breached upwards, creating uncertainty about future monetary policy. Another possibility is that capacity utilisation level effects are to some extent captured by this rich specification, which also has the user cost of capital and real wages entering the long-run solution, although the latter is not very significant.

$$\begin{aligned}\Delta k = {} & \underset{(0.453)}{0.0037} - \underset{(-2.40)}{0.00075} S_0 - \underset{(-3.48)}{0.0014} S_1 - \underset{(-3.06)}{0.0011} S_2 - \underset{(-5.31)}{0.00010} T + \underset{(4.40)}{0.0041} D94.2 \\ & - \underset{(-3.23)}{0.0028} D99.2 + \underset{(10.7)}{0.55} \Delta k_{t-1} - \underset{(-2.88)}{0.012} \Delta_3 y_{t-1} - \underset{(-5.96)}{0.019} k^*_{t-1} + \underset{(4.38)}{0.010} \Delta_2 uci_t \\ & - \underset{(-3.30)}{0.011} r_{t-2} + \underset{(3.16)}{0.0073} \Delta r_{t-2} - \underset{(-5.72)}{0.0026} ucc_{t-1} + \underset{(5.20)}{0.0017} \Delta ucc_{t-1} - \underset{(-7.63)}{0.014} rpi_{t-1} \\ & + \underset{(4.04)}{0.0059} \Delta_4 rpi_{t-1} + \underset{(2.37)}{0.0041} w_{t-1} + \underset{(2.84)}{0.0039} \Delta_3 w_{t-1} - \underset{(-2.11)}{0.00091} reer_{t-1} \\ & - \underset{(-4.51)}{0.0060} s^{ar}_{1,t-1} - \underset{(-3.63)}{0.0037} \Delta s^{ar}_{1,t-1} - \underset{(-3.36)}{0.0044} \Delta \left| s^{ar}_{1,t} \right| - \underset{(-4.11)}{0.0044} \Delta \left| s^{ar}_{1,t-1} \right| - \underset{(-3.27)}{0.0029} \Delta \left| s^{ar}_{1,t-2} \right|\end{aligned} \tag{6}$$

T = 91 (1981.2–2003.4); $\hat{\sigma} = 0.080\%$; R^2 = 0.97; DW = 2.12;

AR: F(5, 61) = 1.30 (0.28); ARCH: F(4, 58) = 0.22 (0.93); Hetero: F(43, 22) = 0.37 (0.997); Normality: $\chi^2(2)$ = 0.73 (0.70); RESET: F(1, 65) = 1.66 (0.20).

Long run elasticities: *r* = –0.6; *ucc* = 0.1; *rpi* = –0.7; *rer* = –0.05; *w* = 0.2; $s_1^{ar} = 0.32$.

Overall the evidence is very similar to that provided by model (4). For example, the real user cost of capital matters in the long run and its elasticity is much smaller than that of the real interest rate, although the difference here is not as big as before. The elasticity of investment with respect to relative prices, the real exchange rate and the user cost are close to those of model (4). However, the elasticity with regard to the real interest rate is not as large as in models (4) and (5). Finally, the new inflation uncertainty proxy is highly statistically significant, with a large long-run effect that is very similar to what was found in model (4).

Moreover, as before, asymmetric effects are present, and signed effects seem to be more relevant than absolute value effects.

So far only one-quarter ahead inflation uncertainty proxies have been considered. However, note that several lags are involved in equations (4), (5) and (6), suggesting that what seems to matter to firms is uncertainty over a longer horizon. Therefore, a natural question is that of what evidence emerges if longer term uncertainty proxies are used instead. Equation (7) shows a specification that uses one-year ahead inflation forecasts errors from da Silva Filho (2006a) as the inflation uncertainty proxy ($s_{4,t}^{ar} = v_{4,t}^{ar}$). Two features stand out in this model: the fact that it is very parsimonious and that the recursive coefficients are very stable. As before, the diagnostic tests are insignificant and all variables have the expected theoretical sign.

$$\begin{aligned}\Delta k = & \underset{(7.19)}{0.020} - \underset{(-7.68)}{0.000088}T + \underset{(4.38)}{0.0050}D90.2 + \underset{(3.71)}{0.0033}D94.2 - \underset{(-4.10)}{0.0036}D99.2 + \underset{(15.1)}{0.65}\Delta k_{t-1} \\ & - \underset{(-10.3)}{0.020}k_{t-1}^{*} + \underset{(5.83)}{0.014}\Delta_2 uci_t + \underset{(2.32)}{0.0056}uci_{t-3} - \underset{(-3.81)}{0.0076}r_{t-3} - \underset{(-3.55)}{0.0050}rpi_{t-2} \\ & + \underset{(3.41)}{0.0048}\Delta_3 rpi_{t-2} - \underset{(-2.47)}{0.00098}reer_{t-2} - \underset{(-3.73)}{0.00088}s_{4,t-1}^{ar} - \underset{(-3.27)}{0.00073}\left|s_{4,t-1}^{ar}\right| \\ & - \underset{(-2.66)}{0.00044}\Delta s_{4,t-1}^{ar}\end{aligned} \tag{7}$$

T = 91 (1981.2–2003.4); $\hat{\sigma} = 0.085\%$; $R^2 = 0.96$; DW = 2.02;

AR: F(5, 70) = 1.57 (0.18); ARCH: F(4, 67) = 0.20 (0.93); Hetero: F(26, 48) = 0.55 (0.95); Normality: $\chi^2(2) = 1.73$ (0.42); RESET: F(1, 74) = 0.098 (0.75).

Long run elasticities: *uci* = –0.3; *r* = –0.4; *rpi* = –0.3; *rer* = –0.05; $s_4^{ar} = 0.04$.

The implied real interest rate and capacity utilisation responses are smaller than in previous models. Similarly to model (4), the real user cost seems not to be relevant to capital accumulation in Brazil (beyond the effects already captured by the real interest rate and relative price variables). Model (7) also suggests that real wages are not relevant, both in the short and long run. Finally, the new inflation uncertainty proxy is highly statistically significant and, once again, its effects are asymmetric. However, the implied long-run elasticity is much smaller, yet economically relevant, than those from one-quarter ahead proxies. One possible explanation for such a result is that the historical high uncertainty environment that has characterised the Brazilian economy has shortened economic agents' planning horizons, and shorter-run uncertainty measures became more informative to assess the economic outlook.

Although congruent models have been obtained using the relative price index, which has been significant and with the correct theoretical sign throughout, it is interesting to investigate whether inflation uncertainty effects are robust to the choice of the relative price measure. With that purpose equation (8) shows one last specification (for the random walk uncertainty proxy case), but now using the RPD instead of the RPI. All diagnostic tests are satisfactory as well as the graphical evidence on the model's fit and adequacy, placed also in Appendix 2.

$$\begin{aligned}
\Delta k = &\underset{(5.01)}{0.040} - \underset{(-2.35)}{0.00058} S_0 - \underset{(-5.82)}{0.000089} T + \underset{(2.72)}{0.0026} D82.1 + \underset{(2.90)}{0.0037} D90.2 + \underset{(3.65)}{0.0034} D94.2 \\
&- \underset{(-3.76)}{0.0035} D99.2 + \underset{(12.4)}{0.61} \Delta k_{t-1} - \underset{(-11.1)}{0.023} k^*_{t-1} - \underset{(4.11)}{0.011} \Delta_2 uci_t - \underset{(-5.43)}{0.020} r_{t-2} + \underset{(4.89)}{0.012} \Delta r_{t-2} \\
&- \underset{(-5.17)}{0.0053} rpd_{t-1} + \underset{(3.07)}{0.0037} \Delta_3 rpd_{t-1} - \underset{(-3.10)}{0.0014} reer_{t-2} - \underset{(-2.65)}{0.0044} w_{t-1} + \underset{(4.19)}{0.0054} \Delta_4 w_{t-1} \\
&- \underset{(-3.55)}{0.0065} s^{rw}_{1,t-1} + \underset{(4.01)}{0.0054} \Delta s^{rw}_{1,t-1} + \underset{(3.45)}{0.0032} \Delta s^{rw}_{1,t-2} - \underset{(-2.00)}{0.0011} \Delta \left| s^{ar}_{1,t-1} \right|
\end{aligned} \qquad (8)$$

T = 89 (1981.4–2003.4); $\hat{\sigma} = 0.086\%$; R^2 = 0.97; DW = 2.16;

AR: F(5, 63) = 0.91 (0.48); ARCH: F(4, 60) = 0.37 (0.83); Hetero: F(35, 32) = 0.54 (0.96); Normality: $\chi^2(2)$ = 2.59 (0.27); RESET: F(1, 67) = 0.53 (0.47).

Long run elasticities: r = –0.9; rp = –0.2; rer = –0.06; w = 0.2; $s_1^{rw} = 0.28$.

Hence, regardless of which relative price measure is chosen, inflation uncertainty remains highly significant statistically. Moreover, not only its effect remains large on economic grounds but its magnitude is practically the same as found before. However, this time the model has two unexpected results: (changes) in capacity utilisation and real wages have the opposite of the expected sign. This last result could be linked to a failure of the model to control adequately for output effects, since along an isoquant, capital and labour are substitutes. The most likely factor to have caused this outcome seems to have been the use of the relative price deflator, which employs the GDP deflator to measure the overall price level. These difficulties suggest that the RPI should be preferred over the RPD.

In a nutshell, regardless of which inflation uncertainty proxy or relative price measure are used, in all models inflation uncertainty is highly significant both statistically and economically. Therefore, the evidence strongly suggests that inflation uncertainty is relevant in explaining capital accumulation in Brazil. This result helps to shed some light on the sluggishness of real investment rates to recover in Brazil, even after more than ten years from the stabilisation of the economy. More broadly, it also helps to understand the dismal performance of investment rates in Brazil during the last 25 years. It should be noted that the effects of inflation uncertainty on capital accumulation are not restricted to those captured by the proxies used above. As argued before, inflation uncertainty adds a risk premium to nominal interest rates and, therefore, is likely to increase real interest rates. Moreover, although not included in the models above due to data limitations, inflation uncertainty is also likely to affect investment through its effects on the credit market. Therefore, the effects captured here should be seen as a lower bound and, therefore, should be regarded as highly significant.

6. Conclusion

Any firm faces uncertainty over many dimensions. For example, there is uncertainty about its costs, the demand it faces and the price of its products, as well as uncertainty about the success of newly created products and its competitors' strategies. Even though some types of uncertainties are bound to be more relevant to some firms than to others (e.g. the exchange rate to importers and exporters) and firm specific uncertainty plays a major role in investment decisions, note that uncertainty about inflation is at the root of many uncertainties. For example, since tax systems are not perfectly indexed, even if anticipated, inflation increases effective tax rates and lowers depreciation allowances, causing allocative distortions. Hence, inflation uncertainty also means uncertainty about tax rates and depreciation. Crucially, inflation uncertainty implies uncertainty about the future stance of monetary policy, which, by its turn, implies uncertainty about future interest rates, demand and prices. Under inflation uncertainty, risk averse agents require a risk premium to buy nominal bonds, which raises the cost of capital and depresses investment. Finally, inflation matters because it summarizes how well managed is a given economy, acting like a thermometer of economic conditions and, consenquently, is closely watched by economic agents. Hence, there are several reasons on why inflation uncertainty should rank very high on entrepreneurs' concerns.

On the other hand, low and stable inflation boosts confidence and is likely to foster investment. It also makes planning easier, since inflation distorts markets signals (see Lucas, 1973; Friedman, 1977). Indeed, it is worth quoting yet again…Hoenig's (1998) statement that "A second favorable factor for the U.S. economy is the current low inflation environment and the likelihood that inflation will remain well-behaved. It is my view that the current low inflation environment is one of the reasons investment demand has been so strong throughout the expansion. (…) The low inflation that we have seen in this expansion, for example, has been associated with less inflation volatility than in earlier, higher inflation periods. The associated reduction in inflation uncertainty has surely been a positive factor for investment in plant and equipment."

Notwithstanding the above background, the empirical literature on the link between inflation uncertainty and investment is scant. This paper has made a contribution to fill this gap by investigating the effects of inflation uncertainty on M&E capital accumulation in Brazil. It also aimed at uncovering the main factors that seemed to have driven investment expenditures in Brazil during the 1980–2003 period. Together with the steep rise in inflation in the 1980s, the Brazilian economy experienced a sharp reduction in real investment rates, which have failed to show any consistent sign of recovery even ten years after the stabilisation of the economy. One important candidate behind this dismal result is inflation uncertainty, which still remains high despite much lower inflation rates since 1994. This is very likely to be the case if, for example, credit markets were distorted by inflation uncertainty, as seems to have been the case, or if inflation uncertainty caused higher real interest rates, increasing the user cost of capital. Given the history of high inflation and high inflation uncertainty, few countries seem to provide a better opportunity for testing such a link as Brazil. On the other hand the inflation disarray that took place after the 1970s led to the implementation of several stabilisations plans, which caused several structural breaks to the economy, making the econometric analysis much more difficult. Moreover, both poor and limited data availability posed further challenges to the analysis. To my best knowledge, this is the first work that not only analyses the behaviour of the quarterly M&E capital stock in Brazil but also investigates the effects of inflation uncertainty on M&E investment in Brazil.

One crucial factor when testing the investment-uncertainty link is obviously to obtain a reliable proxy for uncertainty. It is self-evident that in order to accomplish this task a *necessary* condition is that no future information should be used when obtaining those proxies, since no forecaster has such a benefit. Nonetheless, as it was called to attention, this literature is plagued by temporally inconsistent econometric uncertainty proxies, especially from (G)ARCH models. Such proxies are not only bound to understate actual uncertainty faced by forecasters but are also likely to produce misleading inferences. In sharp contrast to the usual practice, this essay used econometric proxies that restrict the information set to that effectively known by forecasters. Da Silva Filho (2006a) shows evidence that actual inflation forecasts are usually biased and produce systematic forecast errors. The inflation uncertainty proxies used here resemble the pattern observed in actual inflation forecasts.

This paper has also called to attention the puzzling behaviour of the relative price of M&E in Brazil, when measured by the relative price deflators (RPD). While the international evidence shows that the relative price of capital has become cheaper worldwide, the opposite behaviour was found for Brazil. It was argued that measurement error, probably in part due to inflation, could be one factor behind this odd behaviour. However, other legitimate factors could also be at play, and a separate investigation is required to better understand this phenomenon. Interestingly, when relative prices are measured using the relative price index (RPI), the resulting series matches the international evidence. It was argued that, to a large degree, the discrepancy seems to be linked to differences in the construction of price indexes vis-à-vis deflators, so that the divergence cannot be necessarily understood as an inconsistency between the two relative price measures. It was shown that most difference between the RPD and the RPI lay in the denominator (i.e. the measure gauging economy-wide inflation), since GDP is less affected by changes in the exchange rate than is the General Price Index. Nonetheless, this issue deserves further investigation. In order to check for robustness, both measures of relative prices were used in the investment equations, and the conclusions on the key drivers of investment remained broadly unchanged.

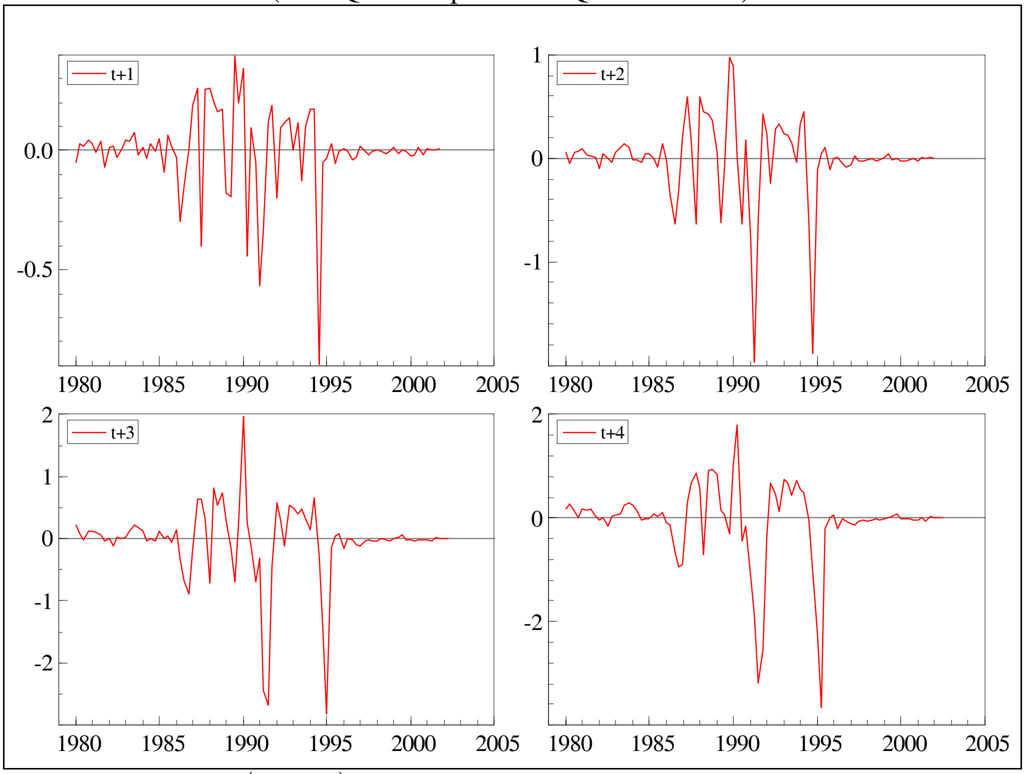
In sharp contrast to much evidence showing a limited role for price variables, the real interest rate is found to be a key factor in explaining capital accumulation in Brazil, both statistically and economically. Two factors are very likely to help explaining this result. First, the strategy used here was to start from the most general model possible, avoiding imposing untested restrictions. This meant that besides the user cost of capital, which constrains the interest rate and relative prices to enter the model in a very specific way, both the real interest rate and the relative price of capital were included separately in the model. This strategy proved to be successful, since not only are the last two variables always highly significant, but also have more explanatory power than the real user cost of capital, to the point that the latter is sometimes absent from the long run solution. This result suggests one possible reason for the limited role played by the user cost in many empirical studies. Second, real interest rates have varied greatly in Brazil during the period analysed, which makes it easier to uncover their effects. The relative price of capital was also found to be highly significant, regardless of which of the two alternative measures was chosen. Moreover, the real exchange rate, which is a variable usually not taken explicitly into account in theoretical models of investment, seem to be by itself (i.e. besides its effect through relative prices) relevant in explaining investment behaviour in Brazil. Indeed, it was found, not surprisingly, that imports of M&E soared in periods of exchange rate appreciation in Brazil. However, one has to recognise the informal evidence, which strongly suggests that the trade liberalisation that took place since 1990 in Brazil has made this response both faster and bigger.

More importantly, the results show convincing evidence that inflation uncertainty has been harmful to capital accumulation in Brazil. The evidence keeps unchanged across several specifications and when different proxies are used, so that they appear to be very robust. Moreover, differently from the common practice in the literature, this paper allowed inflation uncertainty to affect investment asymmetrically. The strategy has paid off and positive inflation forecasting errors were found to be more harmful than positive errors, which, actually, seems to act like good news. Overall, the evidence strongly suggests that inflation uncertainty is not just a nuisance, as in Lucas' (1973) model, and seems to deter capital accumulation both in the short and long run. Finally, one should bear in mind that the inflation uncertainty proxies capture only the direct effects of uncertainty on capital accumulation. It is also most likely that inflation uncertainty affects investment by increasing the user cost of capital and reducing the availability of credit. Indeed, Hoenig (1998) also argues that "Thus, low inflation may stimulate investment by reducing risk premia. As a result, low inflation makes it easier for firms to finance entrepreneurial projects." Therefore, the harmful effects of inflation uncertainty on capital accumulation in Brazil are likely to be much more important than this work suggests. However, the evidence presented here shed crucial light on the reasons behind the sluggishness of real investment rates in Brazil more than one decade after the stabilisation of the economy. It also highlights the possible large welfare gains from a policy, such as the current inflation targeting regime, aimed at keeping inflation both low and stable for long periods of time.

Appendix 1

Graph 1

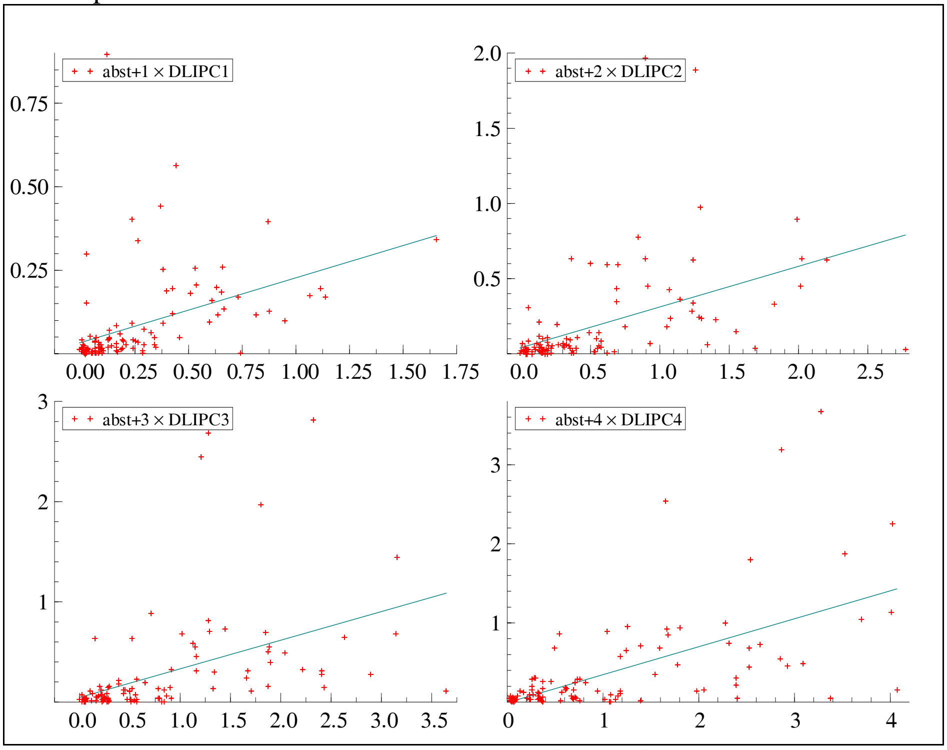
Simulated Real Time Out-of-Sample Inflation Forecasts Errors
(One-Quarter up to Four-Quarter Ahead)



Obs: t+i = $\Delta_i \ln P_t - E_{t-i}(\Delta_i \ln P_t)$, i = 1,…,4 and P = CPI.

Graph 2

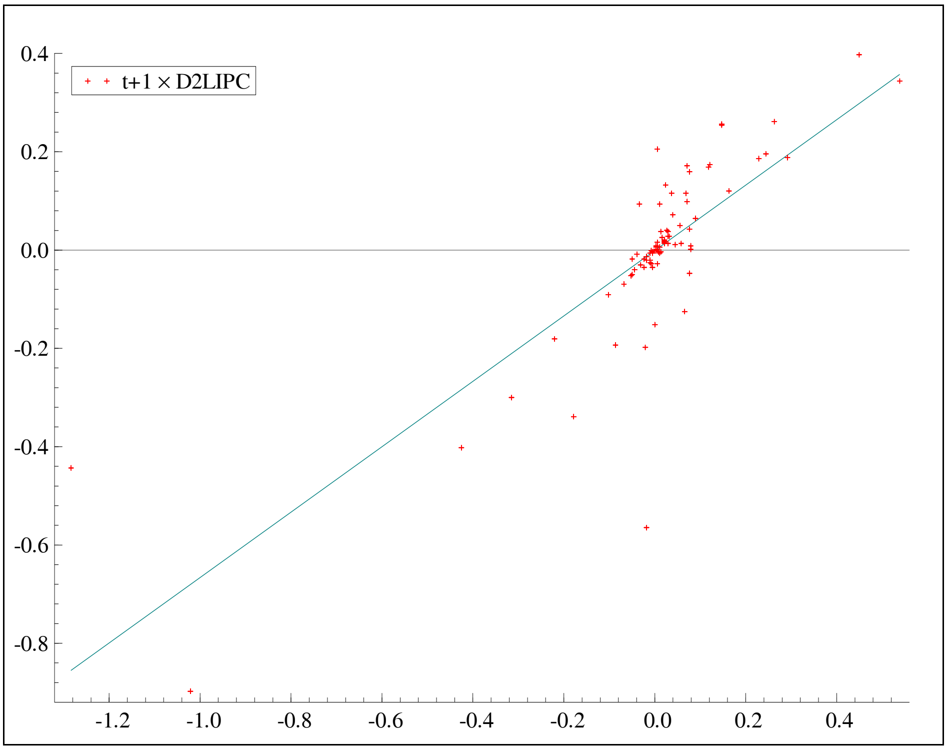
Simulated Real Time Out-of-Sample Absolute Inflation Forecasts Errors
Up to One-Year Ahead and Inflation Rates Over the Forecast Period



Obs: DLIPCi = $\Delta_i \ln P_t$, abst+i = $\left|\Delta_i \ln P_t - E_{t-i}\left(\Delta_i \ln P_t\right)\right|$, i = 1,…,4.

Graph 3

Simulated Real Time One-Quarter Ahead Out-of-Sample
Inflation Forecasts Errors and Random-Walk Errors

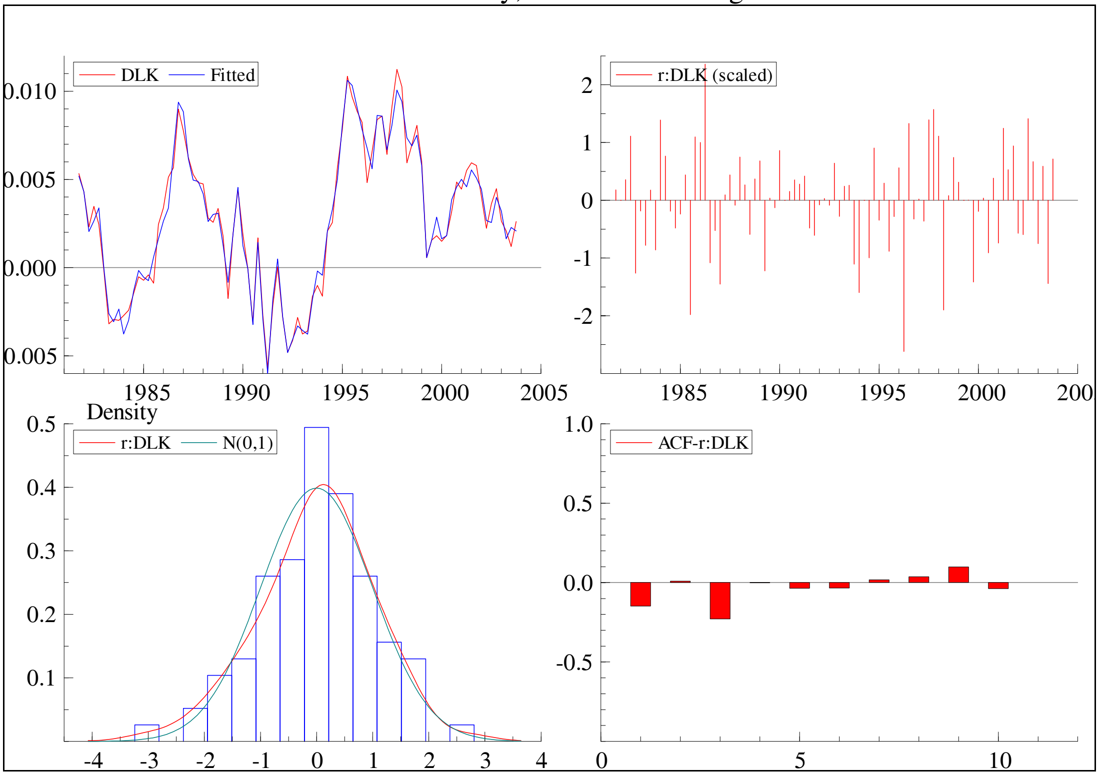


Obs: D2LIPC = $\Delta^2 \ln P_t$, t+i = $\Delta \ln P_t - E_{t-1}\left(\Delta \ln P_t\right)$.

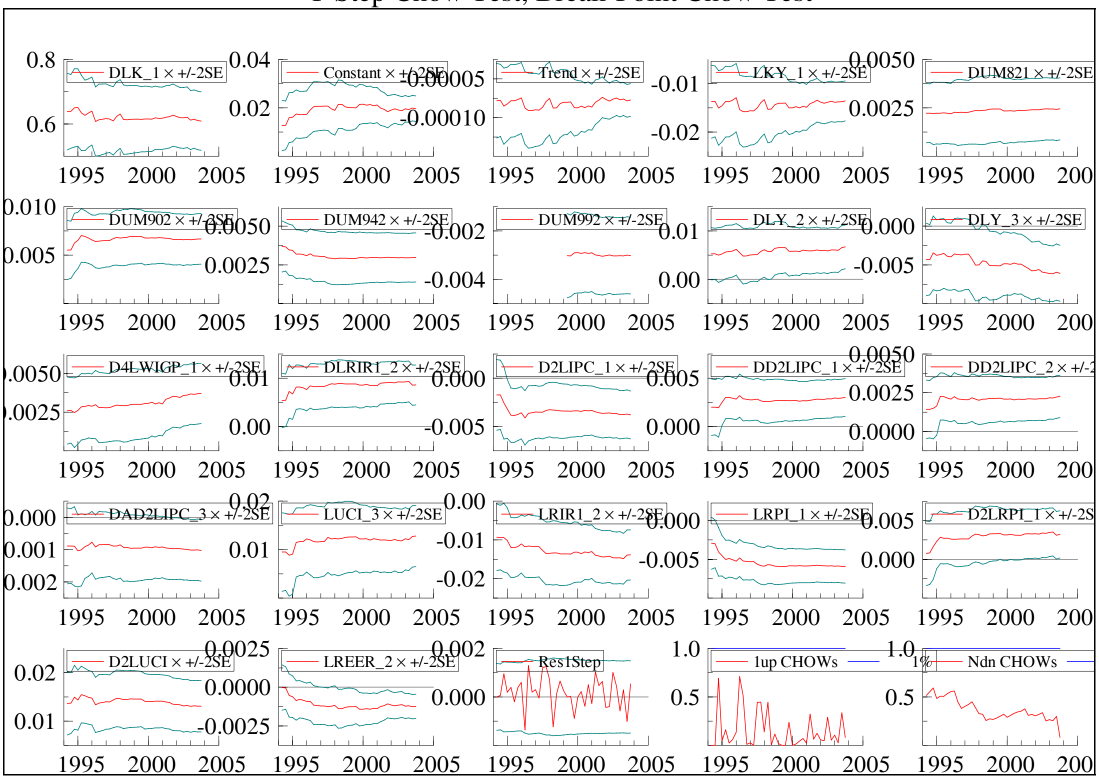
Appendix 2

Equation 4

Fitted and Actual Values for *y*, Scale Residuals, Residual Histogram and Estimated Density, Residual Correlogram.

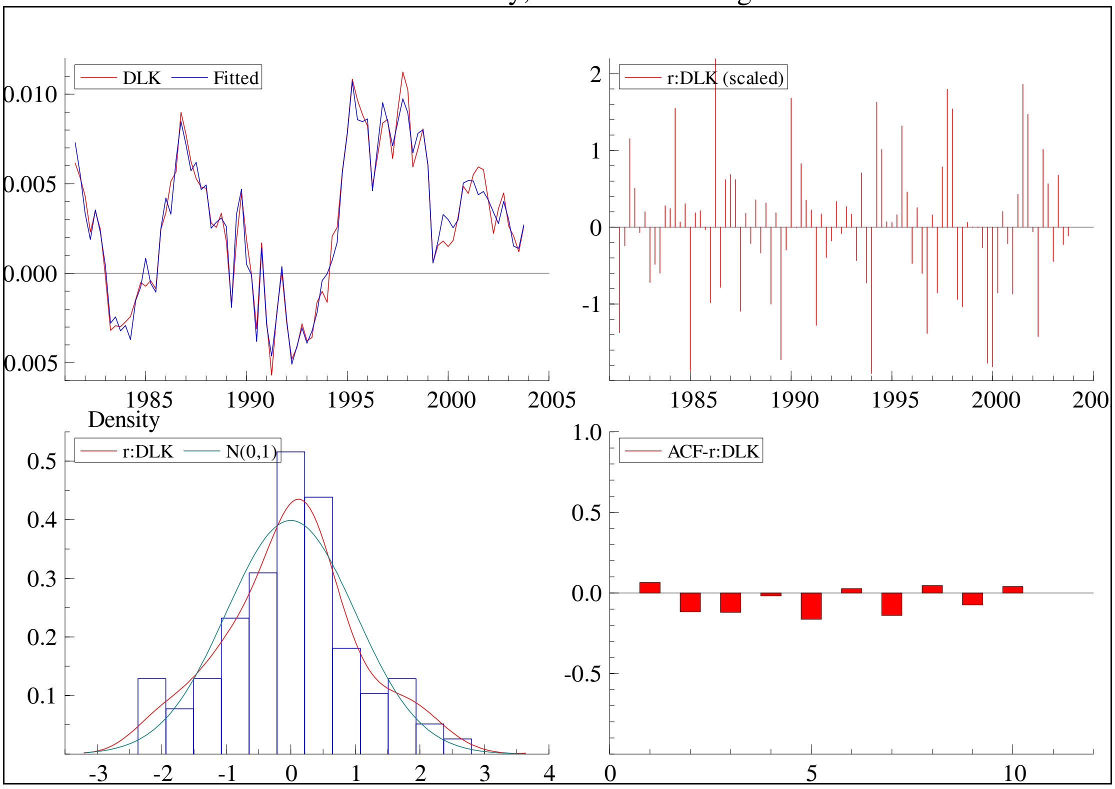


Recursive estimates, 1-Step Residuals +/- 2 S.E., 1-Step Chow Test, Break-Point Chow Test

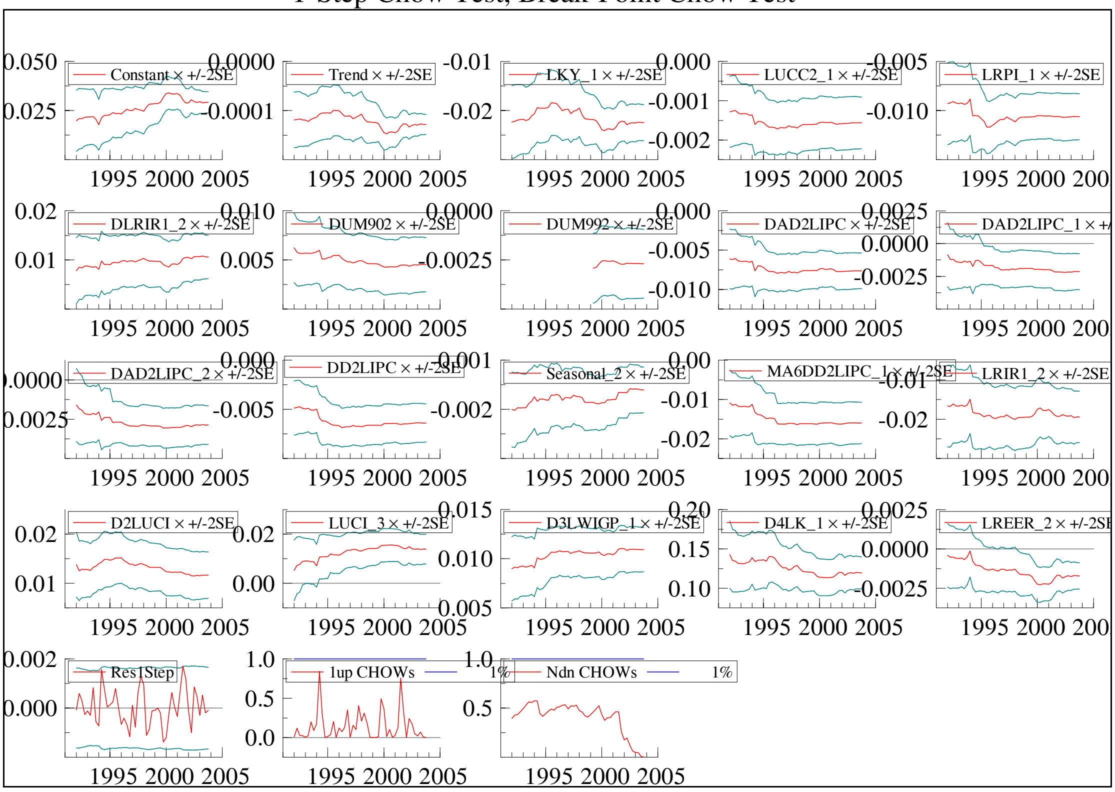


Equation 5

Fitted and Actual Values for *y*, Scale Residuals, Residual Histogram and Estimated Density, Residual Correlogram.

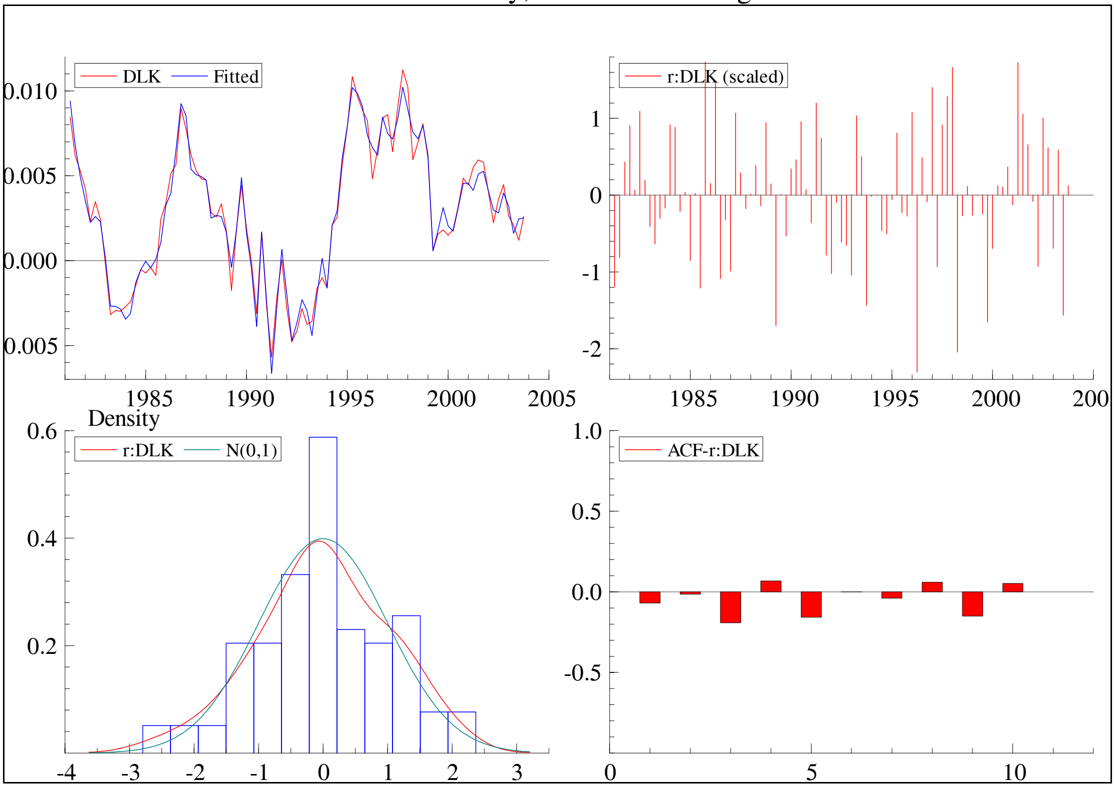


Recursive estimates, 1-Step Residuals +/- 2 S.E.,
1-Step Chow Test, Break-Point Chow Test

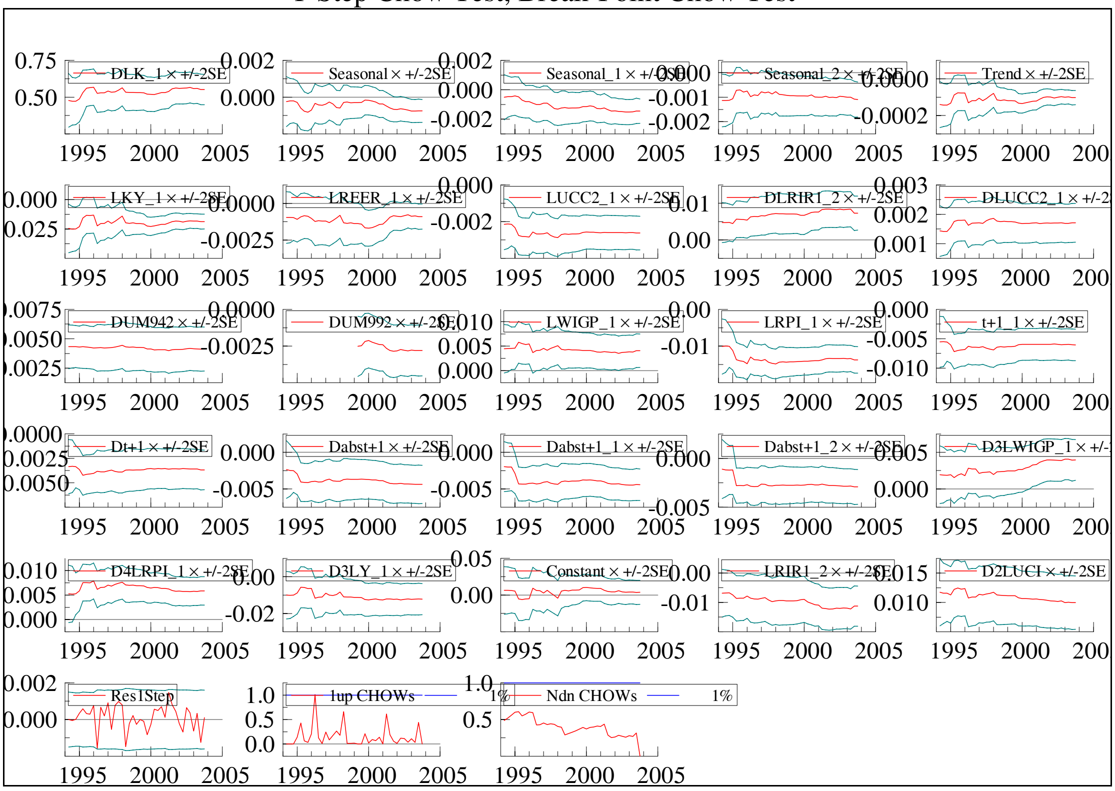


Equation 6

Fitted and Actual Values for *y*, Scale Residuals, Residual Histogram and Estimated Density, Residual Correlogram.

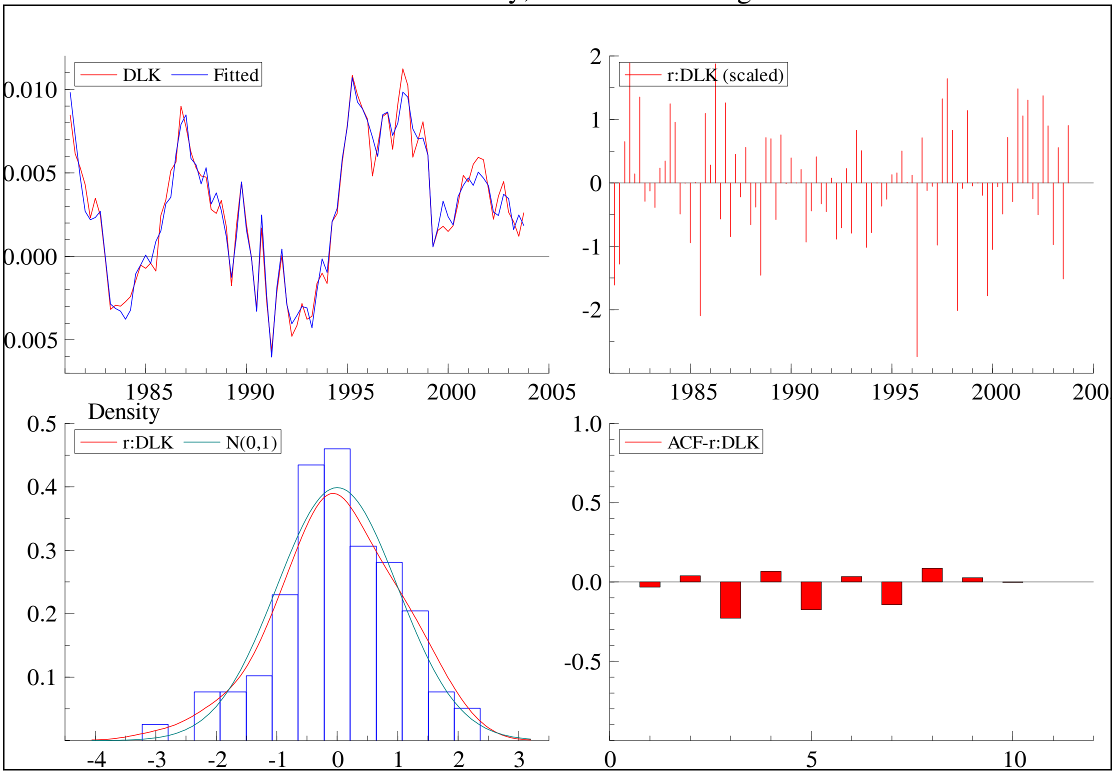


Recursive estimates, 1-Step Residuals +/- 2 S.E., 1-Step Chow Test, Break-Point Chow Test

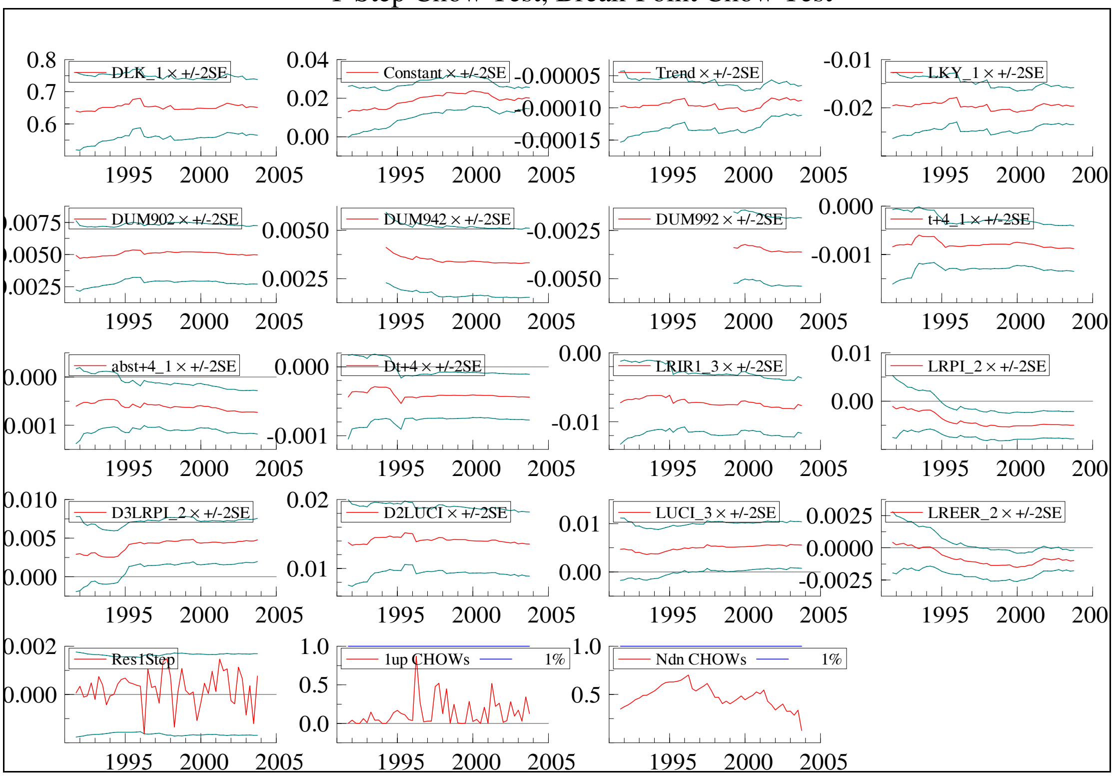


Equation 7

Fitted and Actual Values for *y*, Scale Residuals, Residual Histogram and Estimated Density, Residual Correlogram.

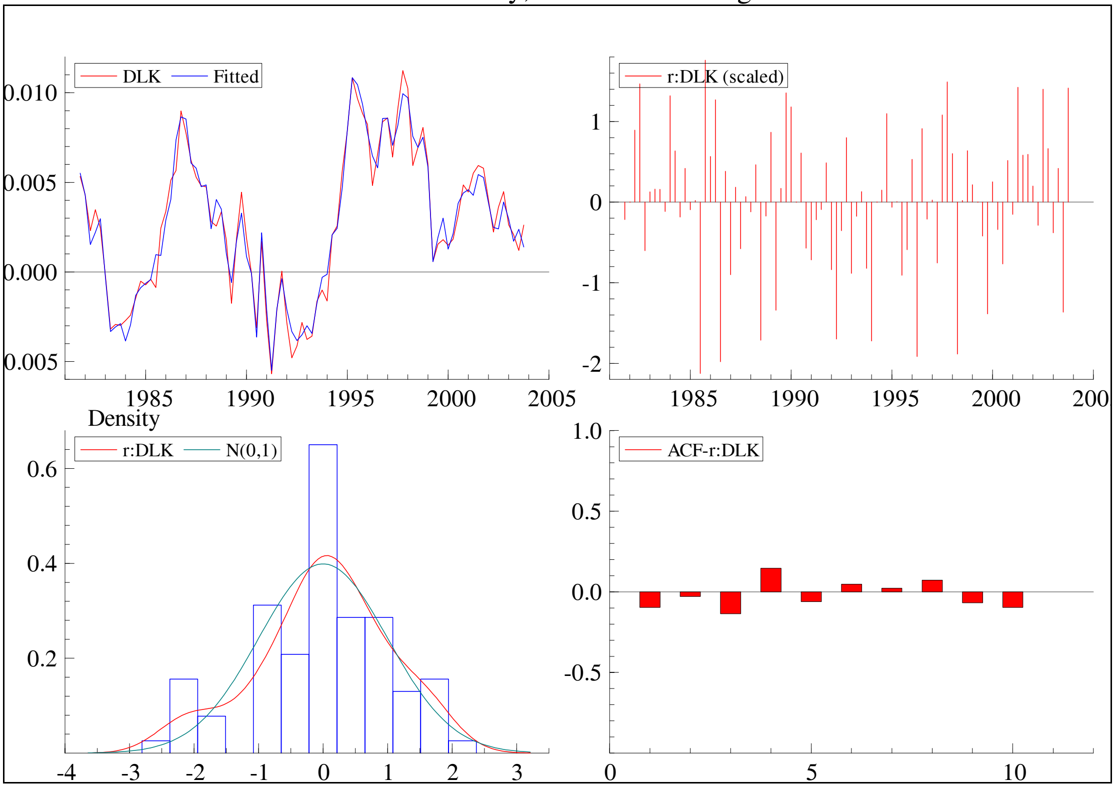


Recursive estimates, 1-Step Residuals +/- 2 S.E., 1-Step Chow Test, Break-Point Chow Test

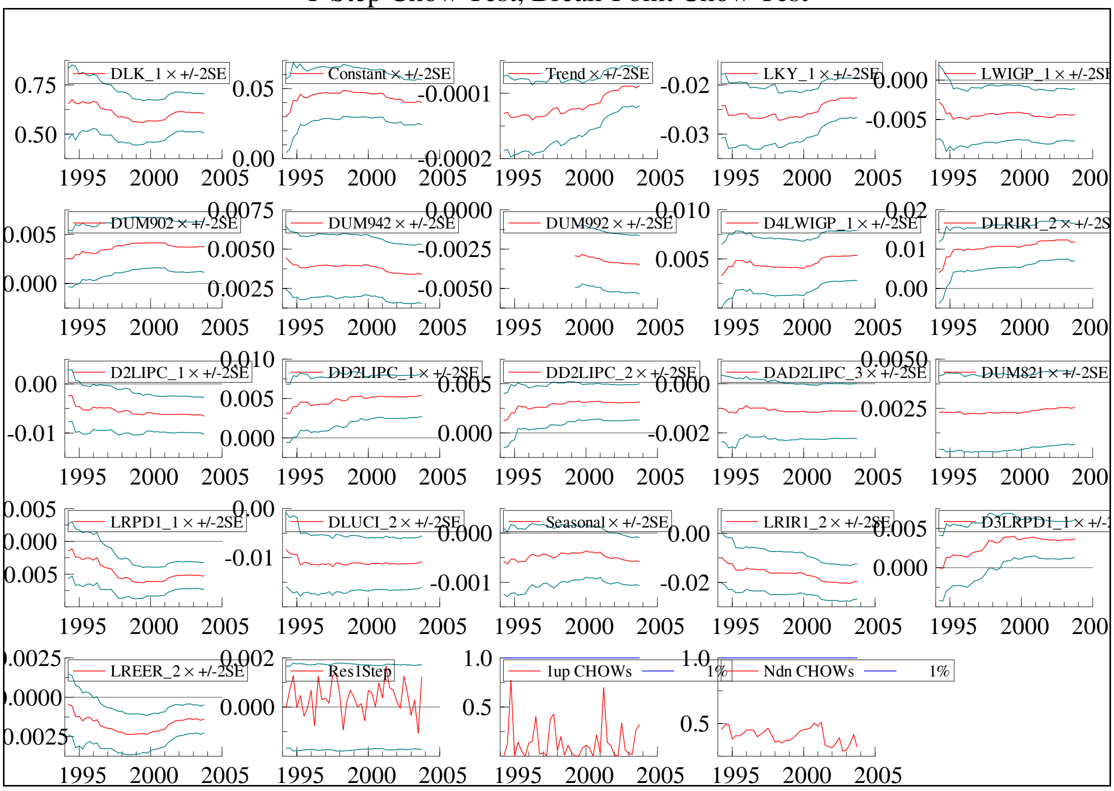


Equation 8

Fitted and Actual Values for *y*, Scale Residuals, Residual Histogram and Estimated Density, Residual Correlogram.



Recursive estimates, 1-Step Residuals +/- 2 S.E., 1-Step Chow Test, Break-Point Chow Test



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