FUNDAÇÃO GETULIO VARGAS
EPGE
Escola de Pós-Graduação em Economia

Ensaios Econômicos

Escola de
Pós Graduação
em Economia
da Fundação
Getulio Vargas

Nº 605 ISSN 0104-8910

The Welfare Cost of Macroeconomic Uncertainty in the Post–War Period

João Victor Issler, Afonso Arinos de Mello Franco, Osmani Teixeira de Carvalho Guillén

Dezembro de 2005

Os artigos publicados são de inteira responsabilidade de seus autores. As opiniões neles emitidas não exprimem, necessariamente, o ponto de vista da Fundação Getulio Vargas.

The Welfare Cost of Macroeconomic Uncertainty in the Post-War Period*

João Victor Issler†
Graduate School of Economics - EPGE
Getulio Vargas Foundation
Praia de Botafogo 190 s. 1100
Rio de Janeiro, RJ 22253-900
Brazil

Afonso Arinos de Mello Franco
Graduate School of Economics - EPGE
Getulio Vargas Foundation
Praia de Botafogo 190 s. 1100
Rio de Janeiro, RJ 22253-900
Brazil

Osmani Teixeira de Carvalho Guillén
Banco Central do Brasil and IBMEC
Av. Presidente Vargas, 730 - Centro
Rio de Janeiro, RJ 20.071-001
Brazil

Keywords: Welfare costs of business cycles, Beveridge-Nelson decomposition.
JEL Codes: E32; C32; C53.
November, 2005.

Abstract

Lucas(1987) has shown the surprising result that the welfare cost of business cycles is quite small. Using standard assumptions on preferences and a fully-fledged econometric model we computed the welfare costs of macroeconomic uncertainty for the post-WWII era using the multivariate Beveridge-Nelson decomposition for trends and cycles, which considers not only business-cycle uncertainty but also uncertainty from the stochastic trend in consumption. The post-WWII period is relatively quiet, with the welfare costs of uncertainty being about 0.9% of per-capita consumption. Although changing the decomposition method changed substantially initial results, the welfare cost of uncertainty is qualitatively small in the post-WWII era –

*We gratefully acknowledge the comments of Luís Braido, Larry Christiano, Wouter den Haan, Robert F. Engle, Daniel Ferreira, Pedro C. Ferreira, Antonio Fiorencio, Clive Granger, Soren Johansen, Rodolfo Manuelli, Samuel Pessoa and Octavio Tourinho on earlier versions of this paper. All remaining errors are ours. We thank CNPq-Brazil and PRONEX for financial support.

†Corresponding author. E-mail: jissler@fgv.br.

about $175.00 a year per-capita in the U.S. We also computed the *marginal welfare cost of macroeconomic uncertainty* using this same technique. It is about twice as large as the welfare cost – $350.00 a year per-capita.

1. Introduction

Lucas (1987, 3) calculates the amount of extra consumption a rational consumer would require in order to be indifferent between the sequence of observed consumption under uncertainty and a cycle-free sequence with no uncertainty. For 1983 figures, using post-WWII data, extra consumption is about $ 8.50 per person in the U.S. (or 0.04% of personal consumption per-capita), a surprisingly low amount. Subsequent work have either changed the environment of the problem or relaxed its basic assumptions. For example, Imrohoroglu (1989) and Atkeson and Phelan (1995) recalculated welfare costs under incomplete markets. Obstfeld(1994), Van Wincoop(1994), Pemberton(1996), Dolmas(1998) and Tallarini(2000) have either changed preferences or relaxed expected utility maximization. More recently, Alvarez and Jermann(2004) have extended the initial framework proposed by Lucas to include what they have labelled the *marginal cost of business cycles*, where, in a more realistic exercise, observed consumption is compared with a convex combination of observed consumption and consumption with no uncertainty.

There are two points to note about previous research. First, the whole literature uses calibration-oriented methods, although the computation of welfare costs can be performed using econometric models. Second, in some of the subsequent papers, welfare costs reached up to 25% of per-capita consumption, a surprisingly high amount. As argued by Otrok(2001), "it is trivial to make the welfare cost of business cycle as large as one wants by simply choosing an appropriate form for preferences," since, when time separability of the utility function is lost, consumers treat economic fluctuations as changes in growth rates.

In this paper we depart from the original exercise in Lucas and from the above literature in two different ways. First, we keep preferences as in the original exercise avoiding the critique by Otrok. Second, we base our welfare-cost computations on an fully-fledged econometric model. We employ the Beveridge and Nelson (1981) decomposition making the trend of the log of consumption to be a random walk[1], which is extracted considering the joint behavior of consumption and income, where the possibility of cointegration is entertained. A natural way to implement this is by using a cointegrated vector autoregressive (VAR) model.

Using a cointegrated VAR model as the basis of the welfare-cost exercise is one of the key elements that makes our approach different from those used in previous research. First, choosing consumption to be difference-stationary is consistent with the applied econometric literature on con-

[1] Lucas(1987, pp. 22-23, footnote 1) explicitly considers the possibility that the trend in consumption is stochastic as in Nelson and Plosser(1982).

sumption, e.g., Hall(1978), Nelson and Plosser(1982), Campbell(1987), Campbell and Deaton(1989), King et al.(1991), Cochrane(1994), Vahid and Engle(1997), Issler and Vahid(2001), Mulligan(2002, 2004), and it is also suggested by Lucas(1987, pp. 22-23). Second, the use of the Beveridge-Nelson decomposition is potentially interesting because the unconditional variance of (the log of) consumption will be infinite, which may lead to a high payoff for eliminating consumption variability. As noted by Obstfeld, using a stochastic-trend model can also reduce the variability of the cyclical component. Therefore, it is not obvious what would be the final impact of a random-walk trend on welfare costs. That would depend on the relative welfare-cost importance of short-term versus long-term variability. This highlights the relevance of using a cointegrated VAR model, which takes into account a long-term constraint in the data (Campbell(1987)) and its short-term influence on the behavior of consumption and income. Finally, our econometric approach allows performing hypothesis testing on welfare cost measures. Since welfare-cost formulas are non-linear on key parameters, we apply the Delta Method to compute standard errors, testing whether or not welfare costs are statistically zero following the procedure used in Duarte, Issler and Salvato(2005).

The paper is divided as follows. Section 2 provides a theoretical and statistical framework to evaluate the welfare costs of business cycles. Section 3 provides the estimates that are used in calculating them. Section 4 provides the calculations results, and Section 5 concludes.

2. The Problem

Lucas (1987) assumes that consumption (c_t) is *log-Normally* distributed about a deterministic trend:

$$c_t = \alpha_0 (1+\alpha_1)^t \exp\left(-\frac{1}{2}\sigma_z^2\right) z_t,$$

where $\ln(z_t) \sim N(0, \sigma_z^2)$. Cycle-free consumption is defined as the sequence $\{c_t^*\}_{t=0}^{\infty}$, where $c_t^* = E(c_t) = \alpha_0 (1+\alpha_1)^t$. Notice that c_t represents a mean-preserving spread of c_t^*. Risk averse consumers prefer $\{c_t^*\}_{t=0}^{\infty}$ to $\{c_t\}_{t=0}^{\infty}$. Lucas proposed measuring the welfare cost of business cycles λ as a solution to:

$$E\left(E_0 \sum_{t=0}^{\infty} \beta^t u((1+\lambda) c_t)\right) = \sum_{t=0}^{\infty} \beta^t u(c_t^*), \tag{2.1}$$

where $E_t(\cdot) = E(\cdot \mid \Omega_t)$ is the conditional expectation operator of a random variable, using Ω_t as the information set, β is the discount factor and $u(\cdot)$ is the utility function.

Since the trend is deterministic above, eliminating *all the cyclical variability* in $\ln(c_t)$ is equivalent to eliminating *all* its variability. Under difference-stationarity, this equivalence is lost, since uncertainty comes both in the trend and in the cyclical component of $\ln(c_t)$. Moreover, $E(c_t)$ is not defined, which led Obstfeld(1994) to propose using the conditional expectation operator $E_0(\cdot)$

in defining welfare costs:

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left((1+\lambda)\, c_t\right) = \sum_{t=0}^{\infty} \beta^t u\left(E_0\left(c_t\right)\right). \tag{2.2}$$

Now, λ is the welfare cost associated with all the uncertainty in consumption, not only cyclical uncertainty. For that reason, we label it the *welfare cost of macroeconomic uncertainty*.

More generally, Alvarez and Jermann(2004) propose offering the consumer a convex combination of $\{c_t^*\}_{t=0}^{\infty}$ and $\{c_t\}_{t=0}^{\infty}$: $(1-\alpha)\, c_t + \alpha c_t^*$, where $c_t^* = E_0\left(c_t\right)$, allowing for a possible unit root in consumption. They make the welfare cost to be a function of the weight α, $\lambda\left(\alpha\right)$, which solves:

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(\left(1+\lambda\left(\alpha\right)\right) c_t\right) = E_0 \sum_{t=0}^{\infty} \beta^t u\left(\left(1-\alpha\right) c_t + \alpha c_t^*\right). \tag{2.3}$$

In this setup $\lambda\left(0\right) = 1$, and λ, as defined by Lucas, is obtained as $\lambda = \lambda\left(1\right)$. They label $\lambda\left(1\right)$ as the *total cost of business cycles* and define the *marginal cost of business cycles*, obtained after differentiating (2.3) with respect to α as:

$$\lambda'\left(0\right) = \frac{E_0 \sum_{t=0}^{\infty} \left[\beta^t u'\left(c_t\right) \times E_0\left(c_t\right)\right]}{E_0 \sum_{t=0}^{\infty} \left[\beta^t u'\left(c_t\right) \times c_t\right]} - 1. \tag{2.4}$$

To start our discussion of using difference-stationary consumption, we maintain Lucas' assumption that the utility function is in the CES class and time separable, with relative risk-aversion coefficient ϕ:

$$u(c_t) = \frac{c_t^{1-\phi} - 1}{1-\phi}. \tag{2.5}$$

As shown in Beveridge and Nelson(1981), and later generalized by Stock and Watson(1988), every difference-stationary process can be decomposed as the sum of a deterministic term, a random walk trend, and a stationary cycle ($ARMA$ process):

$$\ln\left(c_t\right) = \ln\left(\alpha_0\right) + \ln\left(1+\alpha_1\right) \cdot t - \frac{\omega_t^2}{2} + \sum_{i=1}^{t} \xi_i + \sum_{j=0}^{t-1} b_j \zeta_{t-j} \tag{2.6}$$

where $\ln\left[\alpha_0 \left(1+\alpha_1\right)^t \cdot \exp\left(-\omega_t^2/2\right)\right]$ is deterministic given past information, $\sum_{i=1}^{t} \xi_i$ is the pure random-walk trend component, $\sum_{j=0}^{t-1} b_j \zeta_{t-j}$ is the $MA\left(\infty\right)$ representation of the stationary part (cycle), and $\omega_t^2 = \sigma_{11} \cdot t + 2 \cdot \sigma_{12} \sum_{j=0}^{t-1} b_j + \sigma_{22} \sum_{j=0}^{t-1} b_j^2$ is the conditional variance of $\ln\left(c_t\right)$. The permanent and transitory shocks, ξ_t and ζ_t respectively, obey:

$$\begin{pmatrix} \xi_t \\ \zeta_t \end{pmatrix} \sim IN\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix}\right), \tag{2.7}$$

i.e., shocks are Normal and independent across time but may be contemporaneously correlated if $\sigma_{12} \neq 0$[2].

If $\beta\left(1+\alpha_1\right)^{1-\phi}\exp\left[-\frac{(1-\phi)\phi\sigma_{11}}{2}\right] < 1$ and $\beta\left(1+\alpha_1\right)^{1-\phi} < 1$, the *total cost of business cycles* (Lucas) as a function of β and ϕ, $\lambda(\beta,\phi)$, is:

$$\lambda(\beta,\phi) = \exp\left[\frac{\phi\left(2\widetilde{\sigma}_{12}+\widetilde{\sigma}_{22}\right)}{2}\right]\left\{\frac{\left(1-\beta\left(1+\alpha_1\right)^{1-\phi}\exp\left[-\frac{(1-\phi)\phi\sigma_{11}}{2}\right]\right)}{\left(1-\beta\left(1+\alpha_1\right)^{1-\phi}\right)}\right\}^{1/(1-\phi)} - 1, \tag{2.8}$$

if we replace $\sigma_{12}\sum_{j=0}^{t-1} b_j$ and $\sigma_{22}\sum_{j=0}^{t-1} b_j^2$ by their respective unconditional counterparts, $\widetilde{\sigma}_{12} = \sigma_{12}\sum_{j=0}^{\infty} b_j$ and $\widetilde{\sigma}_{22} = \sigma_{22}\sum_{j=0}^{\infty} b_j^2$. For the sake of simplicity, this is the way we chose to estimate $\lambda(\beta,\phi)$ in this paper when $\phi \neq 1$; a similar formula applies when $\phi = 1$.

If $\beta\left(1+\alpha_1\right)^{1-\phi}\cdot\exp\left(\frac{\phi(1+\phi)}{2}\sigma_{11}\right) < 1$ and $\beta\left(1+\alpha_1\right)^{1-\phi}\cdot\exp\left(-\frac{\phi(1-\phi)}{2}\sigma_{11}\right) < 1$, the *marginal cost of business cycles* (Alvarez and Jermann) $\frac{\partial\lambda(\alpha,\beta,\phi)}{\partial\alpha}\big|_{\alpha=0} \equiv \lambda'(0,\beta,\phi)$ is:

$$\lambda'(0,\beta,\phi) = \frac{\exp\left(\phi\left(2\widetilde{\sigma}_{12}+\widetilde{\sigma}_{22}\right)\right)\left[1-\beta\left(1+\alpha_1\right)^{1-\phi}\cdot\exp\left(-\frac{\phi(1-\phi)}{2}\sigma_{11}\right)\right]}{\left[1-\beta\left(1+\alpha_1\right)^{1-\phi}\cdot\exp\left(\frac{\phi(1+\phi)}{2}\sigma_{11}\right)\right]} - 1; \tag{2.9}$$

a similar formula applies when $\phi = 1$.

Because we allow for trend and cyclical uncertainty in (2.8) and (2.9), these formulas are indeed computing respectively the welfare cost and the marginal welfare cost of macroeconomic uncertainty.

3. Reduced Form and Long-Run Constraints

Denote by $y_t = \left(\ln\left(c_t\right), \ln\left(I_t\right)\right)'$ a 2×1 vector containing respectively the logarithms of consumption and disposable income per-capita. We assume that both series contain a unit-root but there is (possibly) cointegration in the form $\left[-1,1\right]' y_t$, as a consequence of the Permanent-Income Hypothesis (Campbell(1987)). A vector error-correction model ($VECM(p-1)$) is:

$$\Delta\, y_t = \Gamma_1\,\Delta\, y_{t-1} + \ \ldots\ + \Gamma_{p-1}\,\Delta\, y_{t-p+1} + \gamma\left[-1,1\right]' y_{t-p} + \varepsilon_t. \tag{3.1}$$

Proietti(1997) shows how to extract trends and cycles from the elements in y_t using a state-space representation. Jumping to our results, system (3.1) is well described by a $VECM(1)$, with the

[2] In the scalar version of the Beveridge-Nelson representation ξ_t and ζ_t are perfectly correlated, which does not hold in general in a multivariate framework as ours.

following state-space form:

$$\begin{aligned}
\Delta y_{t+1} &= Z f_{t+1} \\
f_{t+1} &= T f_t + Z' \varepsilon_{t+1}, \text{ where,} \\
f_{t+1} &= \begin{bmatrix} \Delta y_{t+1} \\ \Delta y_t \\ \alpha' y_{t-1} \end{bmatrix}, \; T = \begin{bmatrix} \Gamma_1 - \gamma\alpha' - \gamma \\ I_2 \quad 0 \quad 0 \\ 0 \quad \alpha' \quad 1 \end{bmatrix}, \; Z = [\mathbf{I_2}\ \mathbf{0}\ \mathbf{0}],
\end{aligned} \tag{3.2}$$

and α is the cointegrating vector. If we label the random-walk trend and the cyclical component of y_t respectively by μ_t and ψ_t, we can compute the Beveridge and Nelson(1981) trends and cycles as:

$$\begin{aligned}
\psi_t &= -\lim_{l\to\infty} \sum_{i=1}^{l} E_t \left[\Delta y_{t+i}\right] = -Z \left[I - T\right]^{-1} T f_t, \text{ and,} \\
\mu_t &= y_t - \psi_t.
\end{aligned}$$

Identifying the parameters in (2.8) and (2.9) is straightforward. Apart from an irrelevant constant, the trend innovation in consumption ξ_t is simply $\underset{1\times 2}{[1,0]} \times \underset{2\times 1}{\Delta\mu_t}$, because the trend is a random walk. The variance of the trend component σ_{11} equals $VAR\left([1,0] \times \Delta\mu_t\right)$. To compute the cyclical innovation notice that:

$$\ln\left(c_t\right) - E_{t-1}\left(\ln\left(c_t\right)\right) = [1,0] \times \varepsilon_t = \xi_t + \zeta_t,$$

which identifies ζ_t up to an irrelevant constant using $[1,0] \times (\varepsilon_t - \Delta\mu_t) = \zeta_t$. With this estimate of ζ_t we can compute σ_{12} and σ_{22}. A similar approach allows computing $\widetilde{\sigma}_{12}$ and $\widetilde{\sigma}_{22}$ using the cycle in consumption instead of its innovation.

Using the Delta Method we can compute the standard errors of the estimates of $\lambda(\cdot)$ and of $\lambda'(\cdot)$ in (2.8) and (2.9), since these are ultimately non-linear functions of cointegrated VAR estimates. We apply a standard Central-Limit Theorem for VAR estimates (e.g., Hamilton(1994)) coupled with the Delta Method (e.g., Greene(1997)) to that end, which allows testing the hypothesis that welfare costs are statistically zero; see Duarte, Issler and Salvato(2003).

4. Empirical Results

Annual data for U.S. consumption of non-durables and services, for U.S. real GNP, and for U.S. population, were obtained from DRI from 1947 through 2000. We fitted a bi-variate vector autoregression for the logs of consumption and income. Lag-length selection indicated a $VAR(2)$ containing a restricted time trend and an unrestricted constant; see Johansen and Juselius(1990). Although the Schwarz criterion chose one lag, the Hannann-Quinn criterion chose two lags and diagnostic tests showed that choosing one lag would lead to serially correlated residuals. Cointegration

test results (Johansen(1988, 1991)) are presented in Table 1. There is evidence of one unit root, i.e., income and consumption cointegrate. Further testing whether or not $[-1, 1]'$ is the cointegrating vector could not reject this hypothesis. Hence, our final econometric model is a $VECM(1)$ with $[-1, 1]'$ as cointegrating vector.

Table 2 displays parameter estimates associated with (the log of) consumption. To be able to compare the results of the Beveridge and Nelson decomposition with those of other popular methods of modelling trends, we also present these same estimates when a linear trend and a Hodrick and Prescott(1997) filter are used to extract trends and cycles from consumption.

The estimates of the (total) welfare cost of macroeconomic uncertainty in the post-war U.S. are presented in Table 3 alongside with Lucas' benchmark values. Welfare costs are about 0.9% of per-capita consumption using the Beveridge-Nelson decomposition, which amounts to $175.77 per person in 2000 US$. Although this is more than 20 times the benchmark value suggested by Lucas, it is still not very high. When we compare Beveridge-Nelson results with those using a linear time trend and the Hodrick and Prescott(1997) filter, we find that using the Beveridge-Nelson decomposition produces welfare costs three times bigger than those using a linear trend, whereas the Hodrick-Prescott filter produces much smaller numbers matching those found by Lucas.

Table 4 presents the estimates of the marginal welfare cost of macroeconomic uncertainty in the post-war U.S. They are about 1.9% of per-capita consumption using the Beveridge-Nelson decomposition – twice as big as total welfare costs. This result can be compared to those found by Alvarez and Jermann(2004). For the 1954-97 period, they find about 0.20% when an 8-year low-pass filter is used to extract cycles, about 0.30% when a one-sided filter is used, and about 0.77% and 1.40% when a geometric and a linear filter are used respectively. Our estimate is higher than all their estimates, although closer to that found using the linear filter. As we have argued in Section 2, when the Beveridge-Nelson decomposition is used in the form proposed here, we are indeed computing the welfare costs of eliminating all consumption variation. Since the method used in Alvarez and Jermann eliminates only uncertainty that occurs at business-cycle frequencies it is not surprising that our estimates are higher than theirs.

Finally, our estimates of the standard errors of (total and marginal) welfare costs of macroeconomic uncertainty and of business cycles allow the conclusion that they are not statistically zero. As far as we know, regarding U.S. data, this is the first time that this hypothesis is actually tested.

5. Conclusions

Using only standard assumptions on preferences and an econometric approach for modelling consumption we computed the welfare cost of macroeconomic uncertainty for the post-WWII period using the Beveridge and Nelson(1981) decomposition. We found that the post-WWII era is a relatively quiet one, with total and marginal welfare costs being respectively about 0.9% and 1.9% of

consumption. Although the benchmark values computed by Lucas are about 1/20 of our total-cost estimate, our basic conclusion is that deepening counter-cyclical policies is futile. Despite of these small welfare-cost values, we found them to be statistically significant.

The way we have proposed measuring welfare costs here can be interpreted as the cost of eliminating all consumption uncertainty. The challenge for future research is to find a suitable way of measuring welfare costs of business cycles when the trend function is credible and not deterministic. Notice that these remarks are similar to the closing remarks in Alvarez and Jermann(2004).

References

Alvarez, F. and Jermann, U., 2004, "Using Asset Prices to Measure the Cost of Business Cycles," *Journal of Political Economy*, 112(6), pp. 1223-56.

Atkeson, A. and Phelan, C., 1995, "Reconsidering the Cost of Business Cycles with Incomplete Markets", *NBER Macroeconomics Annual*, 187-207, with discussions.

Beveridge, S. and Nelson, C.R., 1981, "A New Approach to Decomposition of Economic Time Series into a Permanent and Transitory Components with Particular Attention to Measurement of the 'Business Cycle'," *Journal of Monetary Economics*, 7, 151-174.

Campbell, J. 1987, "Does Saving Anticipate Declining Labor Income? An Alternative Test of the Permanent Income Hypothesis," *Econometrica*, vol. 55(6), pp. 1249-73.

Campbell, John Y. and Deaton, Angus 1989, "Why is Consumption So Smooth?" *The Review of Economic Studies* 56:357-374.

Cochrane, J.H., 1994, "Permanent and Transitory Components of GNP and Stock Prices," *Quarterly Journal of Economics*, 30, 241-265.

Dolmas, J., 1998, "Risk Preferences and the Welfare Cost of Business Cycles", *Review of Economic Dynamics*, 1, 646-676.

Duarte, A.M., Issler, J.V., and Salvato, M., 2004, "Are Business Cycles all Alike in Europe?," Mimeo., Graduate School of Economics, Getulio Vargas Foundation, 2003.

Greene, W.H., 1997, "*Econometric Analysis,*" New York: Prentice Hall.

Hall, R.E., 1978, "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence," *Journal of Political Economy*, 86, 971-987.

Hamilton, 1994, "*Time Series Analysis.*" Princeton: Princeton University Press.

Hodrick, R.J. and Prescott, E.C., 1997, "Postwar U.S. Business Cycles: An Empirical Investigation," *Journal of Money, Credit, and Banking*, 29, 116.

Imrohoroglu, Ayse, 1989, "Cost of Business Cycles With Indivisibilities and Liquidity Constraints", *Journal of Political Economy*, 97 (6) , 1364-1383.

Issler, J.V. and Vahid, F., 2001, "Common Cycles and the Importance of Transitory Shocks to Macroeconomic Aggregates," *Journal of Monetary Economics*, 47, 449-475.

Johansen, S., 1988, "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 12, pp. 231-254.

Johansen, S., 1991, "Estimation and Hypothesis Testing of Cointegrated Vectors in Gaussian Vector Autoregressions", *Econometrica*, vol. 59-6, pp. 1551-1580.

Johansen, S. and Juselius, K., 1990, "Maximum Likelihood Estimation and Inference on Cointegration - with Applications to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, vol. 52, pp. 169-210.

King, R.G., Plosser, C.I., Stock, J.H. and Watson, M.W., 1991, "Stochastic Trends and Economic Fluctuations", *American Economics Review*, 81, 819-840.

Lucas, R., 1987, "*Models of Business Cycles*," Oxford: Blackwell.

Mulligan, C. (2002), "Capital, Interest, and Aggregate Intertemporal Substitution," Working Paper # w9373: National Bureau of Economic Research.

Mulligan, C. (2004), "Robust Aggregate Implications of Stochastic Discount Factor Volatility," Working Paper # w10210: National Bureau of Economic Research.

Nelson, C.R. and Plosser, C., 1982, "Trends and Random Walks in Macroeconomics Time Series," *Journal of Monetary Economics*, 10, 1045-1066.

Obstfeld, M., 1994, "Evaluating Risky Consumption Paths: The Role of Intertemporal Substitutability," *European Economic Review*, 38, 1471-1486.

Otrok, C., 2001, "On Measuring the Welfare Cost of Business Cycles," *Journal of Monetary Economics,* 47, 61-92.

Pemberton, J., 1996, "Growth Trends,Cyclical Fluctuations,and Welfare with Non-Expected Utility Preferences," *Economic Letters*, 50, 387-392.

Proietti, T., 1997, "Short-run Dynamics in Cointegrated Systems", *Oxford Bulletin of Economics and Statistics,* 59 (3), 405-422.

Stock, J.H. and Watson, M.W., 1988, "Testing for Common Trends," *Journal of the American Statistical Association*, 83, 1097-1107.

Tallarini Jr., T.D., 2000, "Risk-sensitive Real Business Cycles", *Journal of Monetary Economics,* 45, 507-532.

Stock, J. and Watson, M., 1988, "Testing for Common Trends," *Journal of the American Statistical Association*, 83, pp. 1097-1109.

Vahid, F. and Engle, R.F.(1997), "Codependent Cycles," *Journal Econometrics*, vol. 80, pp. 199-121.

Van Wincoop, E., 1994, "Welfare Gains From International Risksharing", *Journal of Monetary Economics,* 34, 175-200.

Table 1: Cointegration test – Johansen(1988, 1991) Technique

Cointegrating Vectors under H_0	Eigenvalues	Trace Stat.	5 % Crit. Value	$\lambda_{\max}$ Stat.	5 % Crit. Value
None	0.325858	27.011	25.32	21.292	23.65
At most 1	0.100480	5.718	12.25	5.718	16.26

Estimate of the cointegrating vector is: $(-1, 1.32)$.

H_0 : cointegrating vector $= (-1, 1)$, conditional on $r = 1$, p-value $= 0.108936$.

Table 2: Consumption – Parameter Estimates Used in Equations (2.8) and (2.9)

	Sample Period: 1947-2000		
	Beveridge-Nelson Decomposition	Hodrick-Prescott Filter	Linear Trend
$\widehat{\ln(1+\alpha_1)}$	0.02338	0.0234	0.0234
$\widehat{\sigma_{11}}$	0.00048	–	–
$\widehat{\widetilde{\sigma}_{12}}$	-0.00022	–	–
$\widehat{\widetilde{\sigma}_{22}}$	0.00031	0.0002	0.0011

Notes: (a) For the Beveridge-Nelson decomposition, trends and cycles were extracted according to the procedure discussed in Section 3. Also, $\widetilde{\sigma}_{12} = \sigma_{12} \sum_{j=0}^{\infty} b_j$ and $\widetilde{\sigma}_{22} = \sigma_{22} \sum_{j=0}^{\infty} b_j^2$ are estimated as described at the end of Section 3; (b) Trends and cycles were also extracted using the Hodrick and Prescott(1997) filter and a linear time trend. When the Hodrick and Prescott filter is used the trend is stochastic, although it was treated as non-stochastic following Lucas(1987) and Alvarez and Jermann(2004); (c) The estimate of $\ln(1+\alpha_1)$ when the Hodrick and Prescott filter is used is the trend-coefficient estimate obtained when we regress the Hodrick and Prescott trend estimate on a constant and a time trend.

Table 3: Total Cost of Macroeconomic Uncertainty: Consumption Compensation $\lambda(\beta, \phi)$ in %
Standard Errors in Parenthesis

(a) Lucas (1987) Benchmark Values

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950$, 0.971, 0.985	0.008	0.042	0.08	0.17

(b) Beveridge-Nelson Decomposition 1947-2000

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950$	0.45	0.76	0.79	0.74
	(0.012)	(0.020)	(0.020)	(0.019)
$\beta = 0.971$	0.80	0.92	0.89	0.79
	(0.022)	(0.024)	(0.023)	(0.021)
$\beta = 0.985$	1.59	1.06	0.96	0.83
.	(0.043)	(0.028)	(0.025)	(0.022)

(c) Hodrick-Prescott Filter 1947-2000

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950, 0.971, 0.985$	0.01	0.04	0.08	0.16
.	(0.0002)	(0.0011)	(0.0022)	(0.0043)

(d) Linear Time Trend 1947-2000

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950, 0.971, 0.985$	0.05	0.27	0.54	1.08
.	(0.001)	(0.007)	(0.014)	(0.029)

Table 4: Marginal Cost of Macroeconomic Uncertainty: Consumption Compensation $\lambda'(0, \beta, \phi)$ in %

Standard Errors in Parenthesis

(a) Lucas (1987) Benchmark Values

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950$, 0.971, 0.985	0.008	0.042	0.08	0.17

(b) Beveridge-Nelson Decomposition 1947-2000

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950$	0.91	1.58	1.70	1.75
	(0.024)	(0.042)	(0.047)	(0.055)
$\beta = 0.971$	1.63	1.92	1.92	1.90
	(0.044)	(0.052)	(0.054)	(0.060)
$\beta = 0.985$	3.26	2.22	2.08	2.00
.	(0.091)	(0.061)	(0.059)	(0.064)

(c) Hodrick-Prescott Filter 1947-2000

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950, 0.971, 0.985$	0.02	0.08	0.16	0.32
.	(0.0004)	(0.002)	(0.004)	(0.009)

(d) Linear Time Trend 1947-2000

β Equivalent in a Yearly Basis	$\phi = 1$	$\phi = 5$	$\phi = 10$	$\phi = 20$
$\beta = 0.950, 0.971, 0.985$	0.11	0.54	1.08	2.18
.	(0.003)	(0.014)	(0.029)	(0.059)

Últimos Ensaios Econômicos da EPGE

[580] Gina E. Acosta Rojas, Germán Calfat, e Renato Galvão Flôres Junior. *Trade and Infrastructure: evidences from the Andean Community*. Ensaios Econômicos da EPGE 580, EPGE–FGV, Mar 2005.

[581] Edmundo Maia de Oliveira Ribeiro e Fernando de Holanda Barbosa. *A Demanda de Reservas Bancárias no Brasil*. Ensaios Econômicos da EPGE 581, EPGE–FGV, Mar 2005.

[582] Fernando de Holanda Barbosa. *A Paridade do Poder de Compra: Existe um Quebra–Cabeça?*. Ensaios Econômicos da EPGE 582, EPGE–FGV, Mar 2005.

[583] Fabio Araujo, João Victor Issler, e Marcelo Fernandes. *Estimating the Stochastic Discount Factor without a Utility Function*. Ensaios Econômicos da EPGE 583, EPGE–FGV, Mar 2005.

[584] Rubens Penha Cysne. *What Happens After the Central Bank of Brazil Increases the Target Interbank Rate by 1%?*. Ensaios Econômicos da EPGE 584, EPGE–FGV, Mar 2005.

[585] GUSTAVO GONZAGA, Naércio Menezes Filho, e Maria Cristina Trindade Terra. *Trade Liberalization and the Evolution of Skill Earnings Differentials in Brazil*. Ensaios Econômicos da EPGE 585, EPGE–FGV, Abr 2005.

[586] Rubens Penha Cysne. *Equity–Premium Puzzle: Evidence From Brazilian Data*. Ensaios Econômicos da EPGE 586, EPGE–FGV, Abr 2005.

[587] Luiz Renato Regis de Oliveira Lima e Andrei Simonassi. *Dinâmica Não–Linear e Sustentabilidade da Dívida Pública Brasileira*. Ensaios Econômicos da EPGE 587, EPGE–FGV, Abr 2005.

[588] Maria Cristina Trindade Terra e Ana Lucia Vahia de Abreu. *Purchasing Power Parity: The Choice of Price Index*. Ensaios Econômicos da EPGE 588, EPGE–FGV, Abr 2005.

[589] Osmani Teixeira de Carvalho Guillén, João Victor Issler, e George Athanasopoulos. *Forecasting Accuracy and Estimation Uncertainty using VAR Models with Short– and Long–Term Economic Restrictions: A Monte–Carlo Study*. Ensaios Econômicos da EPGE 589, EPGE–FGV, Abr 2005.

[590] Pedro Cavalcanti Gomes Ferreira e Samuel de Abreu Pessôa. *The Effects of Longevity and Distortions on Education and Retirement*. Ensaios Econômicos da EPGE 590, EPGE–FGV, Jun 2005.

[591] Fernando de Holanda Barbosa. *The Contagion Effect of Public Debt on Monetary Policy: The Brazilian Experience*. Ensaios Econômicos da EPGE 591, EPGE–FGV, Jun 2005.

[592] Rubens Penha Cysne. *An Overview of Some Historical Brazilian Macroeconomic Series and Some Open Questions*. Ensaios Econômicos da EPGE 592, EPGE–FGV, Jun 2005.

[593] Luiz Renato Regis de Oliveira Lima e Raquel Menezes Bezerra Sampaio. *The Asymmetric Behavior of the U.S. Public Debt.*. Ensaios Econômicos da EPGE 593, EPGE–FGV, Jul 2005.

[594] Pedro Cavalcanti Gomes Ferreira, Roberto de Góes Ellery Junior, e Victor Gomes. *Produtividade Agregada Brasileira (1970–2000): declínio robusto e fraca recuperação*. Ensaios Econômicos da EPGE 594, EPGE–FGV, Jul 2005.

[595] Carlos Eugênio Ellery Lustosa da Costa e Lucas Jóver Maestri. *The Interaction Between Unemployment Insurance and Human Capital Policies*. Ensaios Econômicos da EPGE 595, EPGE–FGV, Jul 2005.

[596] Carlos Eugênio Ellery Lustosa da Costa. *Yet Another Reason to Tax Goods*. Ensaios Econômicos da EPGE 596, EPGE–FGV, Jul 2005.

[597] Marco Antonio Cesar Bonomo e Maria Cristina Trindade Terra. *Special Interests and Political Business Cycles*. Ensaios Econômicos da EPGE 597, EPGE–FGV, Ago 2005.

[598] Renato Galvão Flôres Junior. *Investimento Direto Estrangeiro no Mercosul: Uma Visão Geral*. Ensaios Econômicos da EPGE 598, EPGE–FGV, Ago 2005.

[599] Aloisio Pessoa de Araújo e Bruno Funchal. *Past and Future of the Bankruptcy Law in Brazil and Latin America*. Ensaios Econômicos da EPGE 599, EPGE–FGV, Ago 2005.

[600] Marco Antonio Cesar Bonomo e Carlos Carvalho. *Imperfectly Credible Disinflation under Endogenous Time–Dependent Pricing*. Ensaios Econômicos da EPGE 600, EPGE–FGV, Ago 2005.

[601] Pedro Cavalcanti Gomes Ferreira. *Sobre a Inexistente Relação entre Política Industrial e Comércio Exterior*. Ensaios Econômicos da EPGE 601, EPGE–FGV, Set 2005.

[602] Luiz Renato Regis de Oliveira Lima, Raquel Sampaio, e Wagner Gaglianone. *Limite de Endividamento e Sustentabilidade Fiscal no Brasil: Uma abordagem via modelo Quantílico Auto–Regressivo (QAR)*. Ensaios Econômicos da EPGE 602, EPGE–FGV, Out 2005.

[603] Ricardo de Oliveira Cavalcanti e Ed Nosal. *Some Benefits of Cyclical Monetary Policy*. Ensaios Econômicos da EPGE 603, EPGE–FGV, Out 2005.

[604] Pedro Cavalcanti Gomes Ferreira e Leandro Gonçalves do Nascimento. *Welfare and Growth Effects of Alternative Fiscal Rules for Infrastructure Investment in Brazil*. Ensaios Econômicos da EPGE 604, EPGE–FGV, Nov 2005.