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

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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 –

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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 basically 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.

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.

Choosing consumption to be difference-stationary is consistent with the applied econometric literature on consumption, 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),

[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).

Mulligan(2002, 2004), and it is also suggested by Lucas(1987, pp. 22-23). It 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 making it non-trivial to determine its impact on welfare costs. That would depend on the relative welfare-cost importance of short- versus long-term variability, which highlights the relevance of using a cointegrated VAR model. Finally, our econometric approach allows performing hypothesis testing on welfare costs. Since the latter are a non-linear function of VAR parameters, we apply the Delta Method to compute standard errors, testing whether welfare costs are statistically zero; see Duarte, Issler and Salvato(2005).

Sections 2 and 3 repectively provide the theoretical and statistical framework to evaluate welfare costs. Section 4 provides the empirical 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^*. 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 $E_t(\cdot)$ is the conditional expectation operator, β is the discount factor, and $u(\cdot)$ is the utility function.

Since Lucas modelled consumption trend as deterministic, 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 the cyclical component of $\ln(c_t)$. Moreover, $E(c_t)$ is not defined, which led Obstfeld(1994) to propose using $E_0(\cdot)$ in defining welfare costs:

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

Now, λ is the welfare cost associated with all the uncertainty in consumption. For that reason, we label it the *welfare cost of macroeconomic uncertainty.*

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 $c_t^* = E_0(c_t)$. They make the welfare cost to be a function of the weight α, $\lambda(\alpha)$, which solves:

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

In this setup $\lambda(0) = 1$, and λ, as defined by Lucas, is obtained as $\lambda = \lambda(1)$. They label $\lambda(1)$ 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:

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

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), every difference-stationary process can be decomposed as the sum of a deterministic term, a random walk trend, and a stationary cycle ($ARMA$ process):

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

where $\ln\left[\alpha_0 (1+\alpha_1)^t \cdot \exp\left(-\omega_t^2/2\right)\right]$ 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 $MA(\infty)$ 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 $\ln(c_t)$. 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 $\beta (1+\alpha_1)^{1-\phi} \exp\left[-\frac{(1-\phi)\phi\sigma_{11}}{2}\right] < 1$ and $\beta (1+\alpha_1)^{1-\phi} < 1$, the *total cost of business cycles* as a function of β and ϕ, $\lambda(\beta, \phi)$, is:

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

[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.

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 $\phi\neq 1$. The *marginal cost of business cycles* $\frac{\partial\lambda(\alpha,\beta,\phi)}{\partial\alpha}\big|_{\alpha=0}\equiv\lambda'(0,\beta,\phi)$ is:

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

similar formulas apply when $\phi=1$. As argued above, these formulas are computing respectively the total and 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 and are possibly cointegrated as in $[-1,1]'\,y_t$ because of the Permanent-Income Hypothesis (Campbell(1987)). A vector error-correction model ($VECM(p-1)$) is:

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

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 state-space form:

$$\begin{aligned}\Delta y_{t+1}&=Zf_{t+1} \\ f_{t+1}&=Tf_t+Z'\varepsilon_{t+1},\text{ where,} \\ f_{t+1}&=\begin{bmatrix}\Delta y_{t+1}\\ \Delta y_t\\ \alpha' y_{t-1}\end{bmatrix},\ T=\begin{bmatrix}\Gamma_1-\gamma\alpha'-\gamma\\ I_2\quad 0\quad 0\\ 0\quad \alpha'\quad 1\end{bmatrix},\ Z=\left[\mathbf{I}_2\,\mathbf{0}\,\mathbf{0}\right],\end{aligned} \tag{3.2}$$

and α is the cointegrating vector. Labelling the random-walk trend and the cyclical component of y_t respectively by μ_t and ψ_t, the Beveridge and Nelson(1981) trends and cycles are:

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

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. Its variance σ_{11} equals $VAR\left([1,0]\times\Delta\mu_t\right)$. Notice that:

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

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

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). We apply a standard Central-Limit Theorem for VAR estimates (e.g., Hamilton(1994)) coupled with the Delta Method (e.g., Greene(1997)) to test the hypotheses 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, U.S. real GNP, and U.S. population, were obtained from DRI during 1947-2000. We fitted a bi-variate VAR 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). Choosing one lag would have lead to serially correlated residuals. Cointegration test results (Johansen(1988, 1991)) show overwhelming evidence evidence that income and consumption cointegrate using the trace and the $\lambda_{\max}$ statistics. Further, testing that $[-1, 1]'$ is the cointegrating vector generated a p-value of 0.1089.

The total welfare cost of macroeconomic uncertainty are presented in Table 1; see also results using a linear trend and a Hodrick and Prescott(1997) filter to extract trends and cycles. For the Beveridge-Nelson decomposition they are about 0.9% of per-capita consumption, 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. Compared to the 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 of the former and and that the Hodrick-Prescott filter produces much smaller numbers matching those found by Lucas.

Table 2 presents estimates of the marginal welfare cost of macroeconomic uncertainty. 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. As we have argued in Section 2, we are 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 welfare costs allow the conclusion that they are not statistically zero. As far as we know, this is the first time that this hypothesis is actually tested using U.S. data.

5. Conclusions

Using only standard assumptions on preferences and an econometric approach for modelling consumption we computed the welfare costs 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 macroeconomic 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).

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Table 1: 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 2: 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)