IMF WORKING PAPER

WP/90/109

INTERNATIONAL MONETARY FUND

Research Department

The Macroeconomic Effects of Capital Controls and the Stabilization of the Balance of Trade

Prepared by Enrique G. Mendoza*

Authorized for Distribution by Peter B. Clark

November 1990

Abstract

A dynamic stochastic equilibrium model of a small open economy is used to quantify the macroeconomic effects of introducing capital controls to stabilize the balance of trade. This model focuses on the role of international trade and foreign debt as instruments that help smooth consumption in response to productivity or terms-of-trade disturbances. The model rationalizes some key empirical regularities that characterize business fluctuations and the dynamics of savings and investment in post-war Canada. The results show that capital controls have small effects on both the basic characteristics of macroeconomic fluctuations and the level of welfare. A fiscal strategy that successfully enforces capital controls by introducing taxes on foreign interest income is also studied in some detail.

JEL Classification Numbers:
131, 431,

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*This paper is based on the last chapter of my dissertation at the University of Western Ontario. I am indebted to Dave Backus, Peter Clark, Michael Dooley, Jeremy Greenwood, Gregory Huffman, Patrick Kehoe, Michael Parkin, Assaf Razin, and Lars Svensson for helpful suggestions and comments. Helpful comments from participants at the Third Canadian Macro Study Group Conference, held in Queen's University, and seminar participants at the International Monetary Fund are also gratefully acknowledged. All remaining errors are my own.

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Summary

This paper undertakes a quantitative investigation of the macroeconomic effects of a policy that uses capital controls to stabilize or improve the balance of trade of a stylized small open economy. Numerical simulations of a dynamic stochastic model are used to explore the effects of this policy on economic activity and welfare, and are also applied to produce a scheme of taxes on foreign interest income that allows the government to implement capital controls successfully. The analysis starts out from a benchmark model in which trade is undertaken freely and capital is perfectly mobile. The simulations show that this economy mimics many of the key empirical regularities, including the correlation between savings and investment, that have characterized Canadian postwar business cycles.

The paper is a quantitative application of the vast theoretical literature developed in the last decade on the effects of economic policy from the perspective of intertemporal optimizing models. This literature has challenged the traditional wisdom of income-expenditure models by showing that the nature, timing, and permanence of policy changes result in different responses in the relevant target variables. However, the scarcity of supporting empirical work has prevented advocates of this innovative approach from providing specific examples of how policy analysis could be conducted in practice. For a long time, quantitative analysis of these models was restricted to an unrealistic framework in which economic agents are endowed with perfect foresight. Recent developments in solution methods for dynamic stochastic optimization problems have helped to overcome this problem, as the present paper illustrates.

The numerical analysis shows that in a model where international trade serves only to smooth consumption in response to moderate fluctuations in domestic productivity or in the terms of trade, capital controls and trade-balance targeting are almost neutral. Welfare losses are minimal, and economic activity reacts only to the extent that investment in domestic capital must replace the accumulation of external assets, or debt, as the main vehicle for savings.

"...the main social gains from a deeper understanding of business cycles, whatever form this deeper understanding may take, will be in helping us to see how to avoid large mistakes with policies that have minimally inefficient side-effects, not in devising ever more subtle policies to remove the residual amount of business-cycle risk."

Robert E. Lucas Jr., Models of Business Cycles, 1987.

I. Introduction

A series of intertemporal optimizing models that study the macroeconomic effects of economic policy in the context of the open economy have been developed in recent years. With the exception of rare empirical investigations, like those undertaken by Ahmed (1986) and Hercowitz (1986), the majority of these studies have focused on the theoretical analysis of simplified dynamic structures. Models in which individuals live only for two periods and are endowed with perfect foresight have been used to study capital controls, dual exchange rates and other issues in monetary and fiscal policies. 1/ These models were followed by more sophisticated extensions that consider overlapping generations or individuals with infinite life horizons, still in a deterministic framework. 2/

The conclusions obtained from this literature suggest that the effects of economic policies depend critically on the public's perception regarding the nature, timing and permanence of policy changes. For instance, consider the response of the current account to an increase in government expenditure financed by lump-sum taxation in an exchange economy inhabited by identical individuals. If the increase in taxes and government expenditures is introduced temporarily at date t, the reaction of individuals is to distribute its impact on consumption across time by borrowing in world capital markets to finance additional imports in order to sustain current consumption. The current account worsens at date t but improves in the future, as individuals repay the additional debt contracted when the fiscal expansion took place. Similar arguments indicate that the current account improves at date t and worsens in the future if the fiscal expansion does not take place immediately but is expected to occur at some date t+n, and that the current account is neutral to a permanent increase in government expenditures and taxes.

These results contrast sharply with the predictions of traditional income-expenditure models. In this framework, a fiscal expansion shifts the IS curve temporarily to the right and, if the exchange rate is flexible and capital is perfectly mobile, produces an appreciation of the exchange rate

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1/ See for example Adams and Greenwood (1985), Greenwood and Kimbrough (1987), Aschauer and Greenwood (1985), Greenwood and Kimbrough (1985), and Kimbrough (1986).

2/ For instance, Obstfeld (1981a) and (1981b) investigated exchange-rate dynamics and devaluations, Obstfeld (1986) and Frenkel and Razin (1986b) analyzed dual exchange rates, and Frenkel and Razin (1986a) and (1987) studied various aspects of fiscal policy.

that shifts the IS back to its original position. The economy maintains the same equilibrium levels for the interest rate and income, private consumption behavior is unchanged, and the current account worsens to make room for the enlargement in government consumption.

Despite the fact that the conclusions reached by the theoretical work on intertemporal models challenge some of the traditional views on open-economy policy analysis, the shortage of empirical work has remained an obstacle in the process of translating the theory into specific policy recommendations. Until very recently, quantitative research in this area was limited to models in which uncertainty and risk aversion had to be ignored. However, during the last ten years various new methods for the numerical analysis of stochastic dynamic macroeconomic models have been produced. These methods, which emerged from the innovative work on real business cycles by Kydland and Prescott (1982) and Long and Plosser (1983), allow researchers to compute the equilibrium processes that characterize macroeconomic developments in artificial economies affected by stochastic disturbances.

Recent research has been oriented to utilize these new numerical methods to analyze economic policies in models of closed economies. The studies by Cooley and Hansen (1987), Greenwood and Huffman (1988) and McGrattan (1988) were the first attempts to undertake this task. This literature studies the effects of monetary and fiscal policies on the assumption that individuals formulate optimal intertemporal plans that change as the economic environment is altered. By proceeding in this manner, the analysis of economic policies complies with the standards set by Lucas (1976) and (1987). Thus, the rules of behavior of individuals are not assumed to be invariant to policy changes and arguments about economic welfare are explicitly linked to lifetime utility-maximizing choices.

In an attempt to extend this line of research, the present paper undertakes a quantitative investigation of the macroeconomic effects of economic policy in the context of a small open economy. The paper studies a policy that stabilizes the balance of trade at a certain target level by introducing capital controls. These controls are enforced by imposing a tax on foreign interest income that is rebated in the form of a lump-sum transfer. The numerical analysis determines the effects of this policy on economic welfare and economic activity, and calculates the state-contingent schedule of taxes that would allow the government to implement it successfully.

The paper is organized as follows: Section II describes a dynamic stochastic model of a small open economy that incorporates some theoretical developments made by Obstfeld (1981a) and Epstein (1983). The model considers optimal intertemporal planning in an environment in which domestic capital and net holdings of foreign assets can be utilized as vehicles of savings, and where the rate of time preference is an increasing function of past consumption. In Section III, the potential for the model to be a useful tool for policy analysis is established by studying its ability to replicate the observed stylized facts of an actual economy. Section IV studies the effects of introducing capital controls to stabilize the balance of trade at some desired level. The effect of this policy on economic welfare is determined with different measures of "compensating variations," in terms of utility levels associated with constant-consumption paths, and the effect on economic activity is studied by comparing the statistical moments that characterize business cycles in the policy-restricted version of the model with those of the unrestricted prototype. The same section also analyzes a fiscal strategy that the government could follow to implement the policy. Some concluding remarks are included in the last section.

II. A Dynamic Stochastic Model of a Small Open Economy

This section presents the artificial economy to be studied in the rest of the paper. In the first part of the section, the structure of preferences, technology and financial markets that characterizes the economy is described. Since this paper deals with two situations, one where no capital controls or trade-balance targets are in place and one where such a policy is introduced, the financial structure of the artificial economy adopts two forms. In the unrestricted, or free-trade, version of the model, individuals have unlimited access to the world's capital market, whereas in the policy-restricted version of the model they are forced to accumulate a certain predetermined amount of foreign assets. This additional restriction is enforced by a government that levies the appropriate tax, or pays the appropriate subsidy, on foreign interest income. This schedule of taxes and subsidies is studied later in the paper. The second part of the section characterizes the equilibrium of the two versions of the model as the solution of discrete-time dynamic programming problems.

1. Preferences, Technology and Financial Structure

Preferences: All agents are infinitely-lived and identical, and preferences are described by the Stationary Cardinal Utility function formulated by Epstein (1983): 1/

$$E\left[\sum_{t=0}^{\infty}\left\{u(C_t-G(L_t))\exp\left(-\sum_{\tau=0}^{t-1}v(C_\tau-G(L_\tau))\right)\right\}\right]. \tag{1}$$

where:

1/ The information set needed to formulate the rational expectation defined in (1) is discussed later in the text.

$$u(C_t - G(L_t)) = \frac{[C_t - \frac{L_t^{\omega}}{\omega}]^{(1-\gamma)} - 1}{1-\gamma}, \qquad \omega>1,\ \gamma>1, \tag{2}$$

$$v(C_t - G(L_t)) = \beta \ln\left(1 + C_t - \frac{L_t^{\omega}}{\omega}\right), \qquad \beta>0. \tag{3}$$

In these expressions C_t denotes private consumption and L_t are the productive services provided by labor.

The lifetime utility function formulated in (1) is adopted from Epstein (1983). It constitutes the stochastic analog of the utility function employed by Obstfeld (1981a) and (1981b). In Obstfeld's work, the existence of a well-behaved deterministic stationary equilibrium for the holdings of international assets is ensured by assuming that the rate of time preference is an increasing function of past consumption levels. Such a deterministic steady state is obtained when the world's real interest rate and the rate of time preference are equalized. Otherwise, as discussed in Helpman and Razin (1982) or Frenkel and Razin (1987), whenever the rate of interest is greater (smaller) than the rate of time preference, individuals accumulate (deplete) foreign assets in order to finance an increasing (decreasing) consumption stream. Therefore, the constant-time-preference representation of lifetime utility cannot be utilized to study the process by which this long-run equilibrium is reached, and an alternative formulation such as the Stationary Cardinal Utility must be introduced. 1/

The instantaneous-utility and time-preference functions defined in (2) and (3) simplify the analysis by specifying preferences in terms of the composite good C_t-$G(L_t)$, thus making the intratemporal marginal rate of substitution between consumption and labor depend on the latter only. 2/ This allows the model to focus expressly on the interaction of domestic capital and foreign assets as alternative vehicles of savings. The cost, however, is that the wealth effect on labor supply is eliminated.

1/ Frenkel and Razin (1987) study how a well-defined steady-state equilibrium can also be obtained by assuming that individuals face a positive probability of dying each period.

2/ Equations (2) and (3) were formulated so as to satisfy the conditions from Theorem 5 in Epstein (1983). This theorem proves that Stationary Cardinal Utility satisfies the requirements of dynamic programming and makes consumption in any period behave as a normal good. Theorems 3 and 4 by the same author established that the same conditions, added to either a neoclassical production function or a linear technology, guarantee the existence of a stationary limiting distribution of the state variables.

Technology: The economy produces an internationally tradable composite commodity with the following production technology:

$$G(K_t, L_t, K_{t+1}) = \exp(e_t)\ K_t^{\alpha} L_t^{1-\alpha} - \left(\frac{\phi}{2}\right)(K_{t+1}-K_t)^2, \qquad (4)$$

$$0<\alpha<1, \quad \phi>0,$$

Here, e_t is a random shock to productivity or the terms of trade to be discussed in more detail later, $K_t^{\alpha}L_t^{1-\alpha}$ is a Cobb-Douglas production function, K_t is the domestic capital stock and $(\Phi/2)(K_{t+1}-K_t)^2$ is the cost of adjusting the capital stock as a function of net investment. 1/ Next, the capital evolution equation is given by:

$$K_{t+1} = (1-\delta)K_t + I_t, \qquad 0\leq\delta\leq 1, \qquad (5)$$

where δ is a constant rate of depreciation and I_t is gross investment.

Financial Structure: The financial structure of the economy adopts two forms. In the first case, free trade in foreign financial assets is allowed by the government. Agents have unrestricted access to a competitive international capital market where foreign assets A_t, paying or charging the non-random real rate of return r^*, are exchanged with the rest of the world. 2/ Thus, the holdings of foreign assets evolve according to

$$A_{t+1} = TB_t + A_t(1+r^*), \qquad (6)$$

where TB_t is the balance of trade.

In the second case the government permanently restricts foreign-asset accumulation to a predetermined target $\hat{A}$. Here the evolution of foreign assets is described by

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1/ The relevance of capital-adjustment-costs in small open-economy real business cycle models was explored by Mendoza (1989b). If capital accumulation does not bear explicit adjustment costs, the desire of individuals to equalize the expected marginal-utility-weighted rates of return paid on domestic capital and foreign assets causes investment in the artificial economy to exhibit too much variability and too little co-movement and persistence, relative to actual moments.

2/ The assumption that r^* is non-random is introduced for simplicity, but is not trivial. Fluctuations in the rate of interest introduce income and substitution effects on consumption, the direction of the former depending on whether the economy is a net foreign borrower or lender. However, interest-rate shocks with less than 5 percent standard deviation do not have a significant impact on the equilibrium process of the free-trade economy. An interpretation of this result is provided in Mendoza (1988) and (1989a).

$$A_{t+1} = \hat{A}. \tag{7}$$

In this case, the balance of trade after the date in which the policy is implemented is given by $TB_t=-r^*\hat{A}$.

The combination of domestic production with foreign borrowing, or lending, results in the following resource constraint: 1/

$$C_t + I_t + TB_t \leq \exp(e_t)\ K_t^{\alpha} L_t^{1-\alpha} - (\frac{\Phi}{2})(K_{t+1}-K_t)^2. \tag{8}$$

The cost of adjustment included in (4) and (8) indicates that the total cost of altering the capital stock increases with the size of the desired adjustment, and hence it implies that investment changes are to be undertaken in a gradual manner. This formulation of the technology also assumes that the domestic economy is a small participant in the world capital market, so that the interest rate r^* is regarded as an exogenous variable.

2. Stochastic Equilibrium and the Dynamic Programming Problem

The Free-Trade Economy: The dynamic equilibrium of the unrestricted model is represented by a set of state-contingent decision rules for consumption, labor supply, capital accumulation and foreign-asset accumulation that maximize (1), given K_0, A_0 and e_0, subject to (4)-(6), (8), the intertemporal solvency restriction--which is enforced by imposing an upper bound Δ on foreign debt--and the usual non-negativity restrictions on K, L and C. 2/ The time-recursive structure of the Stationary Cardinal Utility function simplifies the analysis and solution of this intertemporal optimization problem because it implies that dynamic programming techniques can be applied.

The state of the economy is fully described each period by the values of K_t, A_t and e_t. Given this information, and the knowledge of the

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1/ This specification of the financial structure ignores the role of international trade in contingent claims as a form of risk sharing. However, the introduction of a risk-less international asset still allows individuals to insure themselves against the risk of fluctuations in domestic productivity. Furthermore, recent findings by Cole and Obstfeld (1989) suggest that for certain specifications of preferences and technology, the competitive allocations are independent of the completeness of international financial markets.

2/ Although Chamberlain and Wilson (1984) showed that solvency restrictions may take complicated forms in stochastic models, in the numerical investigation performed here the upper bound on debt was sufficient to rule out Ponzi-type schemes. Long-run solvency is verified numerically by noting that the stationary probability of setting foreign-asset holdings below -1.14 is infinitesimal.

stochastic process of the disturbances, individuals choose K_{t+1}, A_{t+1}, C_t and L_t so as to solve the following dynamic programming problem:

$$V(K_t, A_t, e_t^s) = \max\left\{ \frac{\left(C_t - \frac{\hat{L}_t^{\omega}}{\omega}\right)^{(1-\gamma)} - 1}{(1-\gamma)} + \exp\left[-\beta \ln\left(1 + C_t - \frac{\hat{L}_t^{\omega}}{\omega}\right)\right]\left[\sum_{r=1}^{2} \pi_{s,r} V\left(K_{t+1}, A_{t+1}, e_{t+1}^{r}\right)\right]\right\}, \tag{9}$$

subject to

$$C_t = \exp(e_t) K_t^{\alpha} \hat{L}_t^{(1-\alpha)} - \left(\frac{\phi}{2}\right)(K_{t+1} - K_t)^2 - K_{t+1} + K_t(1-\delta) + (1+r^*)A_t - A_{t+1},$$

$$\hat{L}_t = argmax_{(L_t)} \left\{ \exp(e_t) K_t^{\alpha} L_t^{(1-\alpha)} - \frac{L_t^{\omega}}{\omega} \right\},$$

$A_t \geq \Delta$, $K_t \geq 0$, $L_t \geq 0$, *and* $C_t \geq 0$.

The symbol π_{sr}, for s,r=1,2, denotes the one-step conditional transition probability of the next-period's technological or real-exchange-rate disturbance. These transition probabilities must satisfy the conditions that $0 \leq \pi_{sr} \leq 1$ and $\pi_{s1} + \pi_{s2} = 1$ for s,r=1,2.

In order to preserve tractability, the stochastic structure of the shocks is simplified by introducing a two-point Markov process. Thus, at any date in time, the shocks can only take one of two values

$$e_t \in E = \{ e^1, e^2 \}. \tag{10}$$

Furthermore, it is also assumed that the transition probabilities and the shocks themselves are symmetric: $\pi_{11} = \pi_{22} = \pi$ and $e^1 = -e^2 = e$. Therefore, the asymptotic standard deviation, σ_e, and the first-order autocorrelation *coefficient*, ρ_e, *that characterize the stochastic process of the disturbances* are determined by $\sigma_e = e$ and $\rho_e = 2\pi - 1$ respectively.

The values of the parameters γ (coefficient of relative risk aversion), ω (1 plus the inverse of the intertemporal elasticity of substitution in labor supply), α (capital's share in output), δ (depreciation rate), β (the consumption elasticity of the rate of time preference) and r^* (the world's real interest rate), are selected using long-run averages of actual data, the restrictions imposed by the deterministic steady-state equilibrium of the model, and also by attempting to approximate some of the estimates obtained in the relevant empirical literature. These structural parameters are assigned the following values: 1/

$$\alpha=0.32,\quad r^*=0.04,\quad \gamma=1.6,$$
$$\delta=0.1,\quad \omega=1.455,\quad \textit{and}\quad \beta=0.11. \tag{11}$$

The model is calibrated by adjusting the value of the parameters Φ, e and π to replicate a subset of the observed moments calculated with detrended post-war Canadian data. The first parameter is selected so as to mimic the variability of private investment, and the second and third are determined so as to replicate the variability and first-order serial autocorrelation of GDP.

The Restricted-Trade Economy: The equilibrium of the restricted-trade model is characterized in a similar manner as in the free-trade model, except that foreign assets are not a choice variable and (7) replaces (6) because of the capital controls being implemented. The dynamic programming problem defined in (9) is modified to incorporate the restriction that A_{t+1} must equal $\hat{A}$ in every period. All other elements of the problem remain the same. In fact, this problem is equivalent to the one that characterizes a closed-economy real business cycle model, except that a constant equal to the trade-balance target is added into the resource constraint. Also, since the restricted model is used to evaluate the effects of imposing different trade-balance targets $-r^*\hat{A}$, it adopts the same parameter values used to calibrate the unrestricted model.

III. Simulations for the Free-Trade Economy

In order to utilize the free-trade model as a benchmark for the evaluation of the effects of the policy under discussion, it is important to establish first how useful is it as an accurate description of a real-world small open economy. According to Lucas (1976) and (1987), a useful model for policy-analysis purposes is one that fits historical data while it also

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1/ The parameter α is determined with the long-run average of the ratio of labor income to net national income at factor prices. The value of δ is the one commonly used in the real business cycle literature; with it the model mimics the actual long-run average of the investment-output ratio. The value of ω is in the range of the estimates of the intertemporal elasticity of substitution in labor supply $(1/(\omega-1))$ obtained by MaCurdy (1981) and Heckman and MaCurdy (1980,1982). The interest rate r^* is set to the annual equivalent of the value suggested by Kydland and Prescott (1982) for the U.S. economy. The risk-aversion parameter γ is in the range of the estimates obtained by Hansen and Singleton (1983) and Friend and Blume (1975). The value of β is determined using the long-run average of the GNP/GDP ratio and the other parameter values, so as to ensure that in the deterministic steady state the rate of time preference equals r^*.

separates those elements of economic decision-making that are altered by the policy from those that remain unchanged. Thus, a useful model must replicate the properties of observed time series and must also capture the ability that agents have to modify their behavior as the environment changes. The latter property is obviously satisfied by the model studied here, since it allows individuals to reformulate their optimal intertemporal plans as policy changes are introduced. The task of this section is to enquire whether the first property is also satisfied. This is done by undertaking the calibration exercise mentioned earlier and by briefly discussing its results.

The numerical solution of the model follows the methodology suggested in Bertsekas (1976) and employed by Sargent (1980), Greenwood, Hercowitz and Huffman (1988) and, in the context of a similar model as the one studied in this section, by Mendoza (1989b). The procedure, which is described in more detail in the appendix, is based on performing iterations on the value function (9) using a discrete grid of values for domestic capital and foreign assets and the two-point Markov structure of the shocks. Iterations are performed until convergence of the value function is achieved. The state-contingent decision rules for capital and foreign-asset accumulation, associated with the solution of the functional equation (9), are used to calculate the exact stationary joint probability distribution of the state variables of the artificial economy. This probability distribution is in turn utilized to calculate first and second order statistical moments that can be compared with those observed in the actual data, establishing in this manner the ability of the model to mimic the behavior of observed time series.

The unrestricted model of the small open economy is calibrated setting the parameters σ_e=1.285 percent, ρ=0.41 and Φ=0.023. The statistical moments for both this free-trade artificial economy and the actual Canadian data are listed in Table 1. A graph of the stationary marginal probability distribution of domestic capital and foreign assets is produced in Figure 1.

By comparing the moments of variability, persistence and co-movement listed in Table 1, it transpires that the free-trade economy delivers a fairly accurate characterization of the observed stylized facts. 1/ First, the model mimics the observed ranking of variability of all the aggregates listed, approximating closely the percentage standard deviation of each variable. Second, although the model exaggerates the GDP correlations of consumption, savings and labor, it reproduces a similar

1/ A detailed analysis of the ability of the free-trade model to mimic and explain Canadian business cycles is carried out in Mendoza (1989a) and (1989b).

Table 1. Statistical Moments: Canadian Data and Benchmark Economy 1/

Variables	A Canadian Data 1946-1985			B Benchmark Economy Free Trade		
	σ 2/	ρ 3/	ρy 4/	σ 2/	ρ 3/	ρy 4/
(1) GDP	2.810	0.615	1.000	2.807	0.614	1.000
(2) GNP	2.950	0.643	0.995	2.864	0.616	0.994
(3) C	2.460	0.701	0.586	2.140	0.688	0.943
(4) S	7.306	0.542	0.662	5.635	0.602	0.923
(5) I	9.820	0.314	0.639	10.028	-0.045	0.554
(6) K	1.380	0.649	-0.384	1.364	0.705	0.594
(7) L	2.020	0.541	0.799	1.929	0.614	1.000
(8) $-r^*A$	15.250	0.727	-0.175	15.672	0.971	-0.046
(9) TB/Y	1.875	0.623	-0.129	1.901	0.018	-0.019
	CORR(S,I) = 0.434			CORR(S,I) = 0.585		

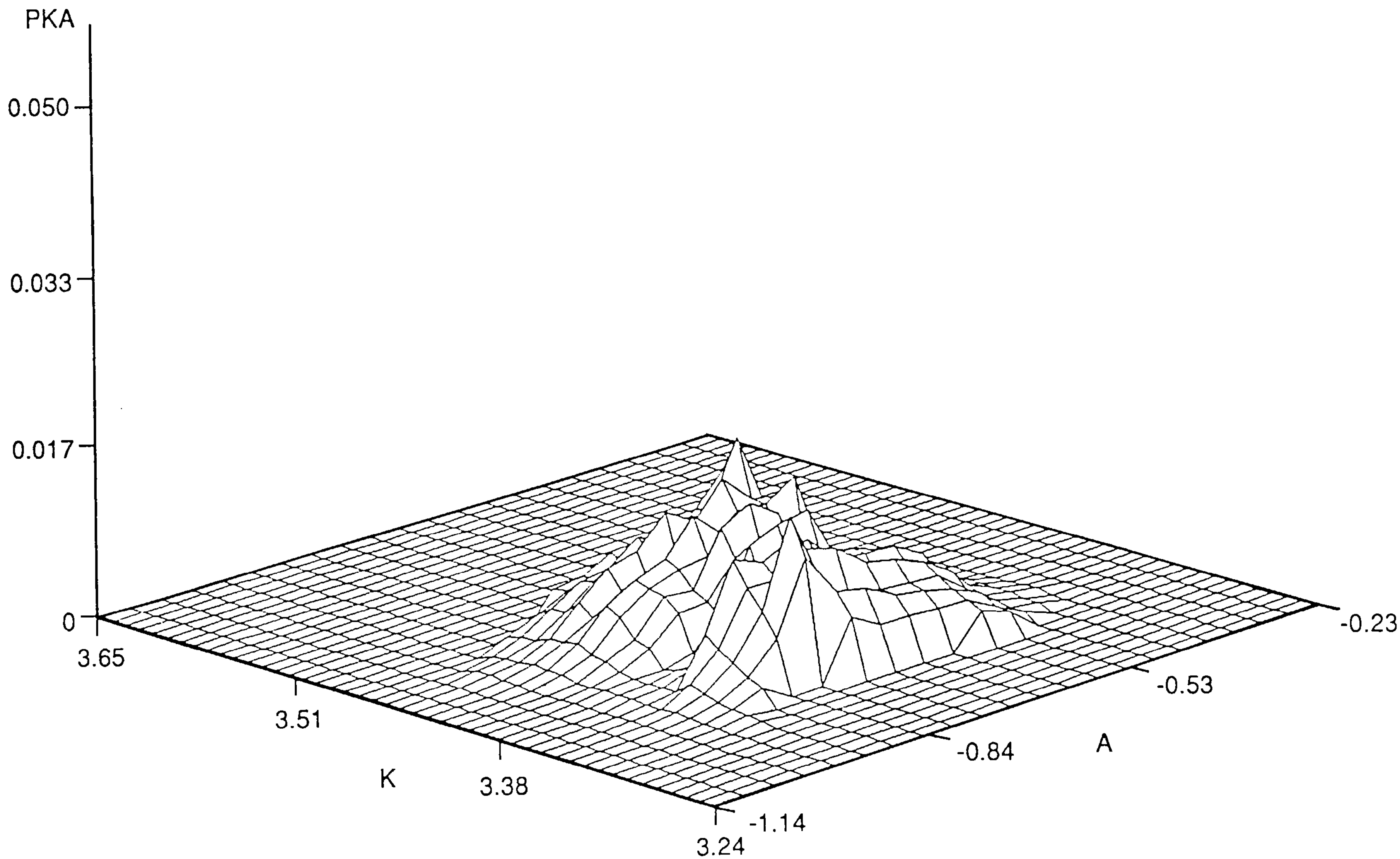
1/ The data are measured in per-capita terms of the 15+ population, logged and detrended with a quadratic time trend. 1)-3), 5) and 8) are aggregates from national income accounts. 6) are total end-of-period net stocks of fixed non-residential industrial capital. Labor is an index of man hours worked by paid workers. Savings is generated as investment plus the balance of trade, which corresponds to the difference between GDP minus consumption. The alternative definition of savings (investment plus the current account) corresponds to GNP minus consumption and is not utilized here to isolate the effects of fluctuations in GDP from the effects of changes in foreign interest payments. All data corresponds to real observations based on 1981 dollars and were obtained from the CANSIM data retrieval.

2/ Percentage standard deviation.

3/ First-order autocorrelation coefficient.

4/ Coefficient of correlation with GDP.

FIGURE 1
Limiting Probability Distribution of Capital and Foreign Assets in the Benchmark Economy



pattern of procyclical and countercyclical movements as that observed in the data, as well as the correlation between savings and investment. 1/ 2/ Third, the model also approximates the ranking of first-order serial autocorrelation coefficients, although it underestimates the persistence of investment and the trade-balance-output ratio.

It is important to emphasize that this benchmark model possesses the ability to mimic some of the moments that characterize foreign interest payments and the ratio of the trade balance to output. In particular, although Canada is a net debtor for which debt service is not relatively large--about 2 percent of GDP on average--it is also a country that participates actively in world financial markets--debt service fluctuates countercyclically about 15 percent on average, which is more variability than that experienced in any other major macro-aggregate. From the perspective of the model, these observations indicate that individuals rationally choose to participate in world capital markets in a manner such that foreign debt exhibits 15.7 percent standard deviation, 0.97 first-order autocorrelation and -0.05 correlation with domestic output. 3/ These statistical moments are the result of lifetime utility-maximizing decisions formulated in a distortion-free environment, and therefore they represent an economic condition in which welfare is maximized.

The rest of the paper studies what happens when the free-trade environment is modified by a government that dislikes fluctuations in the balance of trade, and imposes capital controls in order to eliminate them or to achieve larger trade surpluses. The distortion-free nature of the benchmark economy suggests that capital controls and trade-balance targets are bound to introduce additional restrictions that will necessarily reduce welfare. Thus, the experiment is designed to provide policy-makers with an alternative assessment of a policy that may appear as optimal from the perspective of a different model. Examples of models that have defended strongly the argument that larger trade surpluses per se are a desirable goal for economic policy can be traced back to the merchantilist school. The IS-LM-BP prototype developed in the 1960s and 1970s predicts

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1/ The model predicts almost perfect positive correlation between C, S and GDP because the small open-economy assumption, along with the non-random interest rate, eliminates the intertemporal consumption-substitution effect. Also, L exhibits the same persistence and output correlation as GDP because of the Cobb-Douglas structure of the production function and the instantaneous-utility and time-preference functions defined in (2) and (3).

2/ The negative correlation between K and GDP observed in Canadian data is a puzzle that is also present in U.S. data and that appears to be related to measurement errors (see Kydland and Prescott, 1982).

3/ The stochastic processes of debt service, the current account and the balance of trade exhibit the same characteristics of variability, co-movement and persistence because the model assumes that the interest rate is non-random and trade imbalances all completely financed with the accumulation of debt.

that the achievement of larger trade surpluses induces an expansion of domestic income, which may be offset or magnified depending on the flexibility of the exchange rate.

IV. Simulations for Economies with Capital Controls

The previous section provided evidence illustrating that the unrestricted model is a useful benchmark for dynamic policy analysis. The goal now is to investigate the effects of introducing a policy that restricts foreign-asset trading in order to stabilize the balance of trade at some target level. This policy is enforced by imposing a tax, or subsidy, on foreign interest income. The revenue from this tax is rebated to agents through lump-sum transfers. This section begins by studying the effects of the policy on economic activity, as expressed by the resulting changes in some of the statistical moments of the main macro-aggregates. The welfare effect of the policy is then analyzed by looking at alternative welfare measures, based on compensating variations of stationary consumption paths that correspond to lifetime utility-maximizing values. This section concludes by considering the feasibility of the policy, which is studied by computing the tax-strategy that the government must follow to successfully achieve its trade-balance target.

1. Effects on Economic Activity

The effects that a policy of imposing capital controls to stabilize the balance of trade can cause on economic activity are arrived at by numerically solving the policy-restricted version of the model. As discussed in Section II, the policy takes the form of a restriction on foreign-asset accumulation according to which $A_{t+1} = \hat{A}$ for all t. The solution method to be applied is the same, except that the domestic capital stock is the only choice variable and the model does not have to be calibrated. Note that although the grid of possible initial values for the holdings of foreign assets includes the same elements as before, it collapses to the single point $\hat{A}$ exactly one period after the policy is implemented. Alternatively, the target value of foreign assets could be allowed to depend upon the state-of-the-world, so that the same methodology could be used to study a different situation in which capital controls were state contingent.

In order to obtain a more complete evaluation of the effects of the policy on economic activity, four different strategies have been considered. In the first case the government simply picks $\hat{A}$ so as to stabilize the balance of trade at its mean value observed in the benchmark economy. In the other three cases, $\hat{A}$ is adjusted so as to deliver trade-balance surpluses approximately 12, 30 and 60 percent higher than the average obtained in the free-trade economy. Recall that, once capital controls are introduced, balance-of-payments equilibrium implies that the value of $\hat{A}$ is linked to the trade balance by the equality $TB_t=-r^*\hat{A}$. Thus, a large long-run trade surplus is associated with a high level of foreign debt because sufficient net exports must be generated to meet the debt commitment.

Panels A-E of Table 2 list the means, standard deviations and GDP correlations of the variables in the benchmark economy and in each of the restricted economies. The long-run effects of the policy on economic activity are analyzed by comparing the moments of the unrestricted economy with the moments of the restricted economies. The general result obtained from this analysis is that capital controls, as a means of stabilizing the balance of trade at some target level, do not have substantial effects on various indicators of economic activity.

Consider first the average values listed in column I of each panel. As can be observed, the policy in question has minimal effects on the mean values of all non-controlled variables. Although the results indicate that the average of each aggregate, except consumption, increases slightly as the trade-balance target is raised, these increments are relatively small. Furthermore, the largest drop in average consumption that the policy can cause is only 0.5 percent, and that occurs when the trade-balance target is set 60 percent higher than the mean trade-balance of the benchmark economy. In fact, as column I in panels A and B shows, if the government concentrates only on stabilizing the balance of trade at the level it has in the free-trade economy, the average values of all aggregates are practically the same as in the benchmark economy.

The standard deviations listed in column II of each panel illustrate two findings. 1/ First, when capital controls are introduced to stabilize the balance of trade at its mean value in the benchmark economy, the only noticeable changes in the variability of the aggregates affect savings, investment and the domestic capital stock. Since in the restricted economy changes in savings are equivalent to changes in investment, the standard deviation of these two variables is identical. Restricting foreign-asset trading reduces the standard deviation of investment from 0.034 to 0.017. In contrast, the variability of the domestic capital stock increases from 0.046 to 0.064. These changes are consistent with the fact that, by controlling the option of using international trade as a means for the optimal intertemporal allocation of consumption through the cycle, the government forces the dynamics of investment and the capital stock to behave as in a closed economy. Changes in K must now respond to consumption-smoothing and consumption-substitution effects, instead of depending on fluctuations in the relative returns of capital and foreign assets. Therefore, movements in capital accumulation face an increasing supply price of the capital stock, and hence the variability of investment is smaller than in a small open economy--where the supply price of K is a constant at the level of the world's interest rate.

The second finding from comparing the standard deviations is that increasing the trade-balance target, or reducing the value of $\hat{A}$, does not affect the variability of the aggregates, relative to the initial situation

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1/ Standard deviations, instead of percentage standard deviations, have been considered in order to abstract from the effects of changes in the mean of each variable that may not affect their variance.

Table 2. Statistical Moments for Alternative Artificial Economies 1/

	A Benchmark Economy Free Trade			B Restricted Economy 0 Percent Trade-Balance Improvement			C Restricted Economy 12 Percent Trade-Balance Improvement			D Restricted Economy 30 Percent Trade-Balance Improvement			E Restricted Economy 60 Percent Trade-Balance Improvement		
	μ	σ	ρ_y	μ	σ	ρ_y	μ	σ	ρ_y	μ	σ	ρ_y	μ	σ	ρ_y
GDP	1.487	0.042	1.000	1.487	0.042	1.000	1.492	0.042	1.000	1.497	0.042	1.000	1.507	0.042	1.000
GNP	1.459	0.042	0.994	1.458	0.042	1.000	1.460	0.042	1.000	1.460	0.042	1.000	1.461	0.042	1.000
C	1.119	0.024	0.943	1.119	0.027	0.976	1.118	0.027	0.976	1.116	0.027	0.977	1.114	0.027	0.977
S	0.368	0.021	0.923	0.368	0.017	0.939	0.373	0.017	0.939	0.381	0.017	0.940	0.393	0.017	0.941
I	0.340	0.034	0.554	0.340	0.017	0.939	0.342	0.017	0.939	0.343	0.017	0.940	0.347	0.017	0.941
K	3.399	0.046	0.594	3.397	0.064	0.544	3.415	0.064	0.543	3.434	0.064	0.542	3.472	0.064	0.539
L	1.008	0.019	1.000	1.008	0.020	1.000	1.010	0.020	1.000	1.012	0.020	1.000	1.017	0.020	1.000
-A	0.711	0.111	-0.046	0.708	0.000	0.000	0.795	0.000	0.000	0.926	0.000	0.000	1.142	0.000	0.000
TB	0.028	0.028	0.009	0.028	0.000	0.000	0.032	0.000	0.000	0.037	0.000	0.000	0.046	0.000	0.000
	CORR(S,I) = 0.585			CORR(S,I) = 1.000			CORR(S,I) = 1.000			CORR(S,I) = 1.000			CORR(S,I) = 1.000		

1/ The moments listed are the mean (μ), standard deviation (σ) and correlation with GDP (ρ_y).

in which trade is stabilized at its average value in the benchmark economy. Thus, the standard deviations appear to be independent of the size of the desired adjustment in the balance of trade. Individuals simply scale down their average consumption and experience a similar pattern of fluctuations around this new mean.

The correlations with GDP listed in column III of panels A-E illustrate similar observations as the standard deviations. First, when controls are introduced to stabilize the balance of trade, the only noticeable change is that the correlation between investment and output increases substantially from 0.554 to 0.939. This is to be expected because, as discussed above, changes in savings have to be undertaken by changing investment, and also because the disturbances considered are not large and persistent enough to cause strong consumption-substitution effects. Thus, investment is essentially used as a means to smooth consumption, and hence it exhibits high positive correlation with domestic output. The second observation is that the GDP correlations also appear to be independent of the size of the trade-balance surplus target.

Since the only moments affected by the size of the trade-balance target are the means, it is possible to conclude that the policy under consideration has the effect of shifting the stationary distribution of K and e without affecting its variance. This conclusion is reaffirmed by the graphs of the marginal limiting distribution of the capital stock produced in Figures 2-5. Increasing the trade-balance surplus target displaces this distribution rightwards, without noticeably affecting it in any other way. The direction of this displacement results from the fact that a higher trade-balance surplus reduces consumption in the deterministic stationary equilibrium, and hence it reduces the long-run rate of time preference. This in turn implies that the steady-state capital stock, consistent with an equality between the marginal productivity of capital and the rate of time preference, is higher.

To conclude, the analysis of Table 2 suggests that capital controls, used to target the balance of trade, do not have substantial effects on the equilibrium stochastic process of the economy. Although the dynamics of savings work in an entirely different manner, with investment instead of foreign assets being used as the anchor to smooth consumption, the final result is that output, consumption and the supply of labor behave in almost the same manner. The shocks that enable the benchmark model to mimic Canadian business cycles are not large and persistent enough to allow capital controls to seriously harm the ability of individuals to smooth consumption through the cycle. The important question, however, is how much welfare is lost by imposing this apparently neutral policy. This issue is analyzed next.

2. Effects on Economic Welfare

A set of alternative measures have been formulated in an attempt to determine the welfare effect of the policy under study. Following Lucas (1987), these welfare measures are based on compensating variations of constant-consumption paths. These compensating variations are calculated as follows. The solution of the dynamic programming problems for both the benchmark free-trade economy and the restricted economies includes a solution for the value function, $V^{u}(K,A,e)$ and $V^{r=\hat{A}}(K,A,e)$ respectively. Solutions for these two value functions are calculated for each triple (K,A,e) in the state space K×A×E. Using the Stationary Cardinal Utility function presented in equation (1), it is possible to write a non-linear equation that spells out a constant-consumption path that yields the same lifetime utility expressed by each $V^{u}(K,A,e)$ and each $V^{r=\hat{A}}(K,A,e)$. The level of constant consumption associated with each $V^{r=\hat{A}}(K,A,e)$ is lower than the one that represents each $V^{u}(K,A,e)$ because the former constitute more constrained representations of a distortion-free environment. The percentage difference between these two consumption levels, for each triple in the state space and for each of the four values of Â considered, is a compensating variation that reflects the welfare loss induced by the policy.

Table 3 presents four alternative measures of the percentage welfare loss for each restricted economy. The first measure considers that for a given Â there is a V^{u} and a $V^{r=\hat{A}}$ for each (K,A,e) and thus focuses on the compensating variations for each state of nature. From these point-wise comparisons, the maximum and minimum percentage welfare losses are listed in columns I and II of the table. It is difficult to establish a general judgement of the long-run welfare effect of the policy in this way because point-wise comparisons ignore the long-run probability associated with each state of nature. For example, in the case where the trade balance is stabilized at its average value in the benchmark economy, a 35 percent welfare loss occurs if the economy is at the lowest K, the lowest A and the low value of e when the policy is implemented. But, according to the joint limiting distribution of the state variables in the free-trade economy, the long-run probability of starting out from such a situation is infinitesimal (see Figure 1). In general, the largest welfare losses occur when the initial A, at the date the capital controls are introduced, is driven the longest way to reach Â. But this implies that the initial A must have been located at one of the extremes of the foreign-asset grid, and thus the odds of having to implement the policy when the economy is in that particular situation are null.

More illustrative than maximum and minimum welfare losses are the measures that condense the information provided by all the compensating variations and their associated long-run probabilities. Two measures of this kind are provided in columns III and IV of Table 3. Column III presents an expected percentage welfare loss calculated using the long-run probability of occurrence of each triple (K,A,e) in the free-trade economy. This measure is referred to as the ex ante welfare loss because it considers the odds of introducing the policy when the economy is situated at some triple (K,A,e) in the free-trade economy. In contrast, column IV lists an expected welfare loss calculated using the limiting distribution of the state variables in each restricted economy. This ex post welfare loss considers the long-run probability of the restricted economy being at some state (K,Â,e) and compares the welfare level obtained in this environment with what similar triples would have provided if trade had not been

Limiting Probability Distribution of the Capital Stock in the Restricted Economy with 0 Percent Increment in Trade Surplus

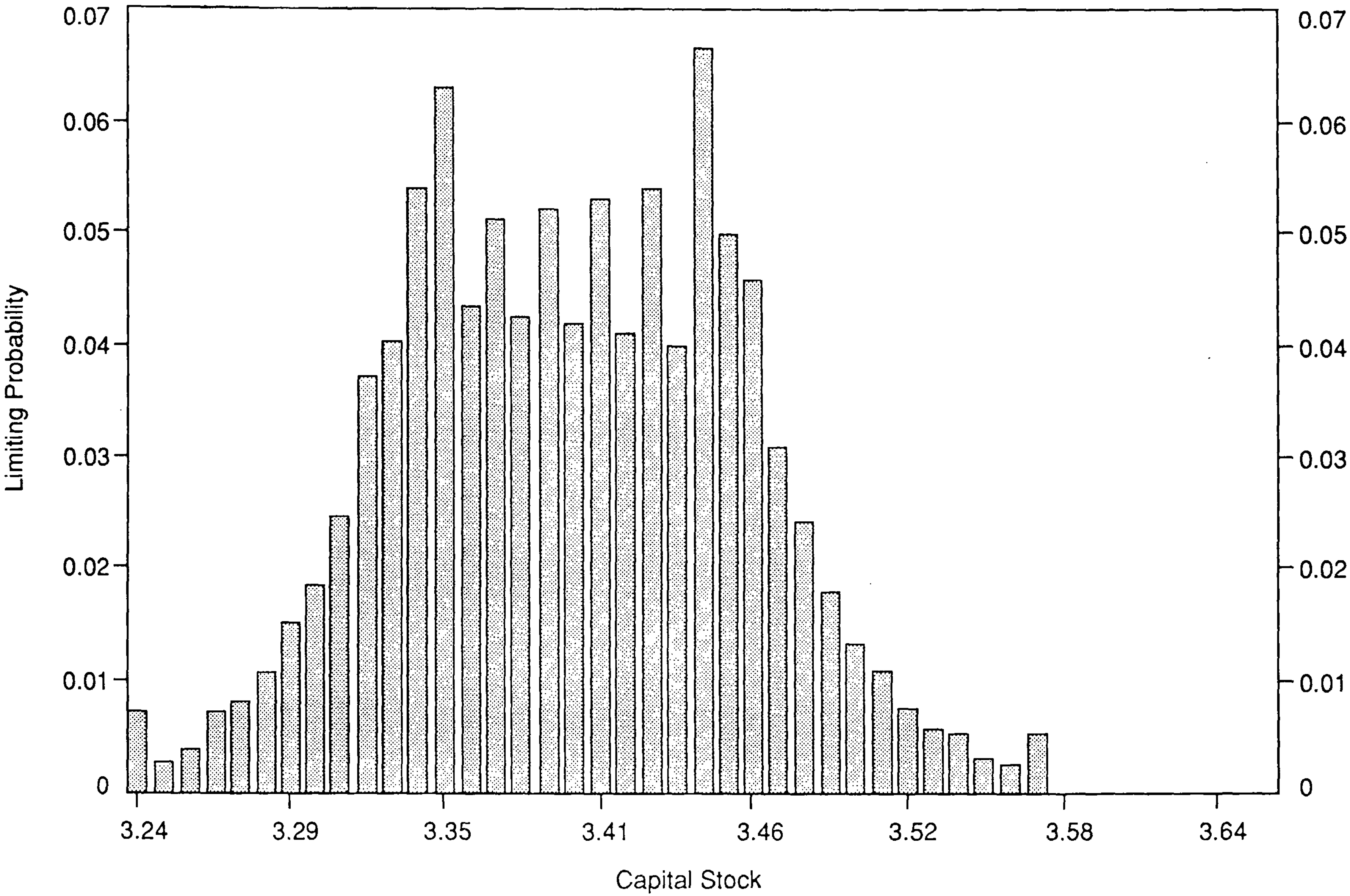

FIGURE 3
Limiting Probability Distribution of the Capital Stock in the Restricted Economy with 12 Percent Increment in Trade Surplus

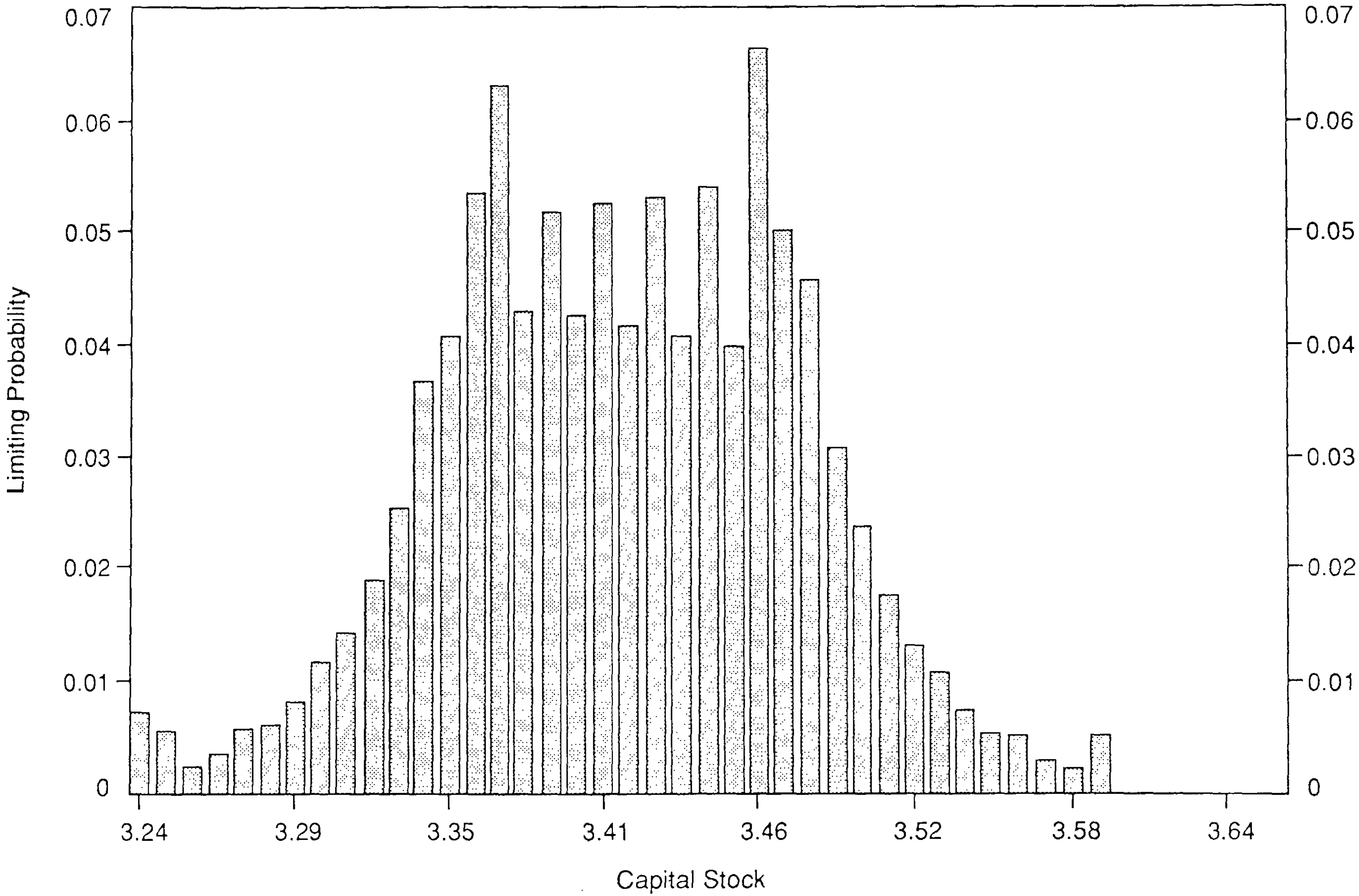

FIGURE 4

Limiting Probability Distribution of the Capital Stock in the Restricted Economy with 30 Percent Increment in Trade Surplus

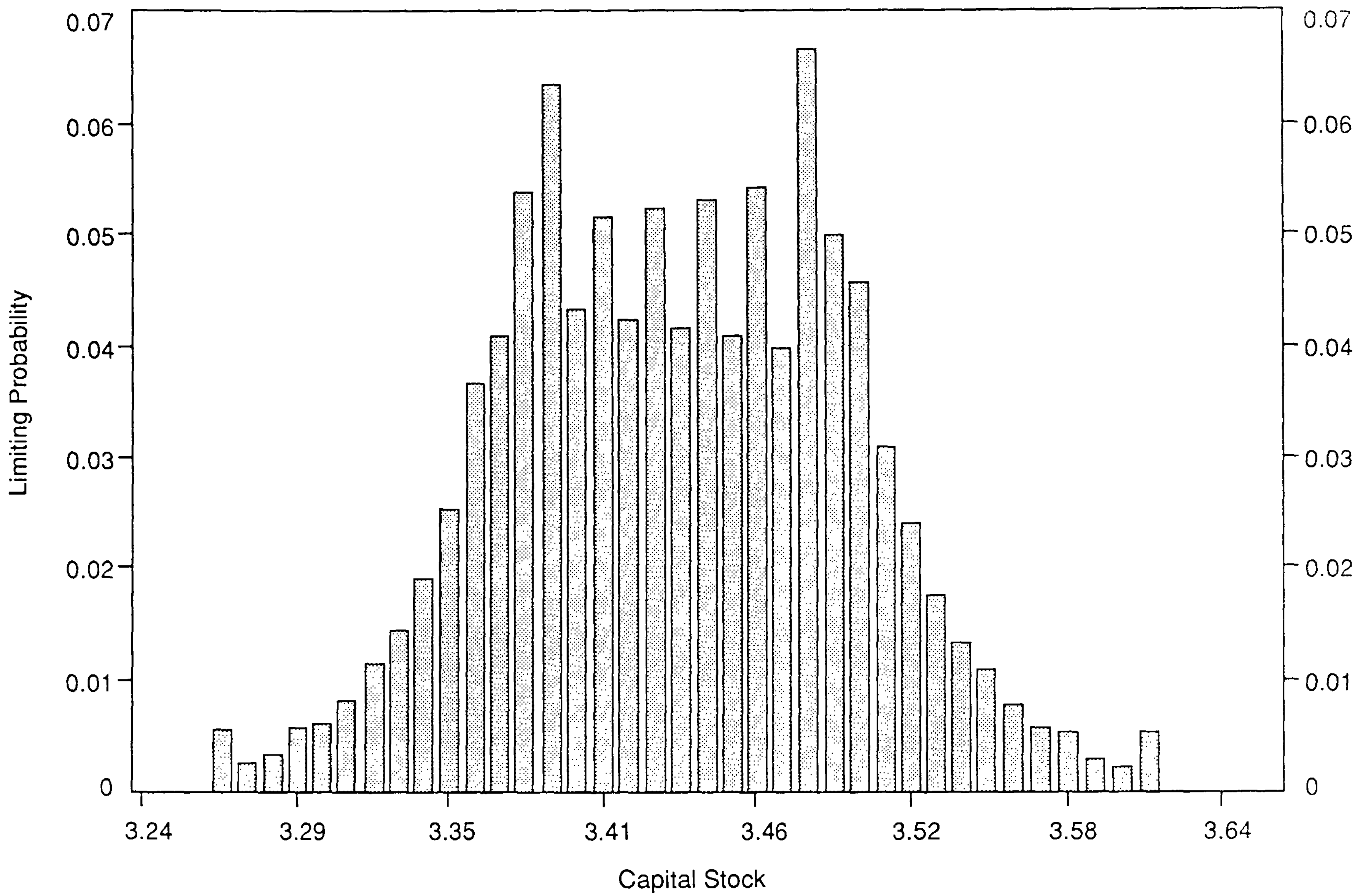

FIGURE 5

Limiting Probability Distribution of the Capital Stock in the Restricted Economy with 60 Percent Increment in Trade Surplus

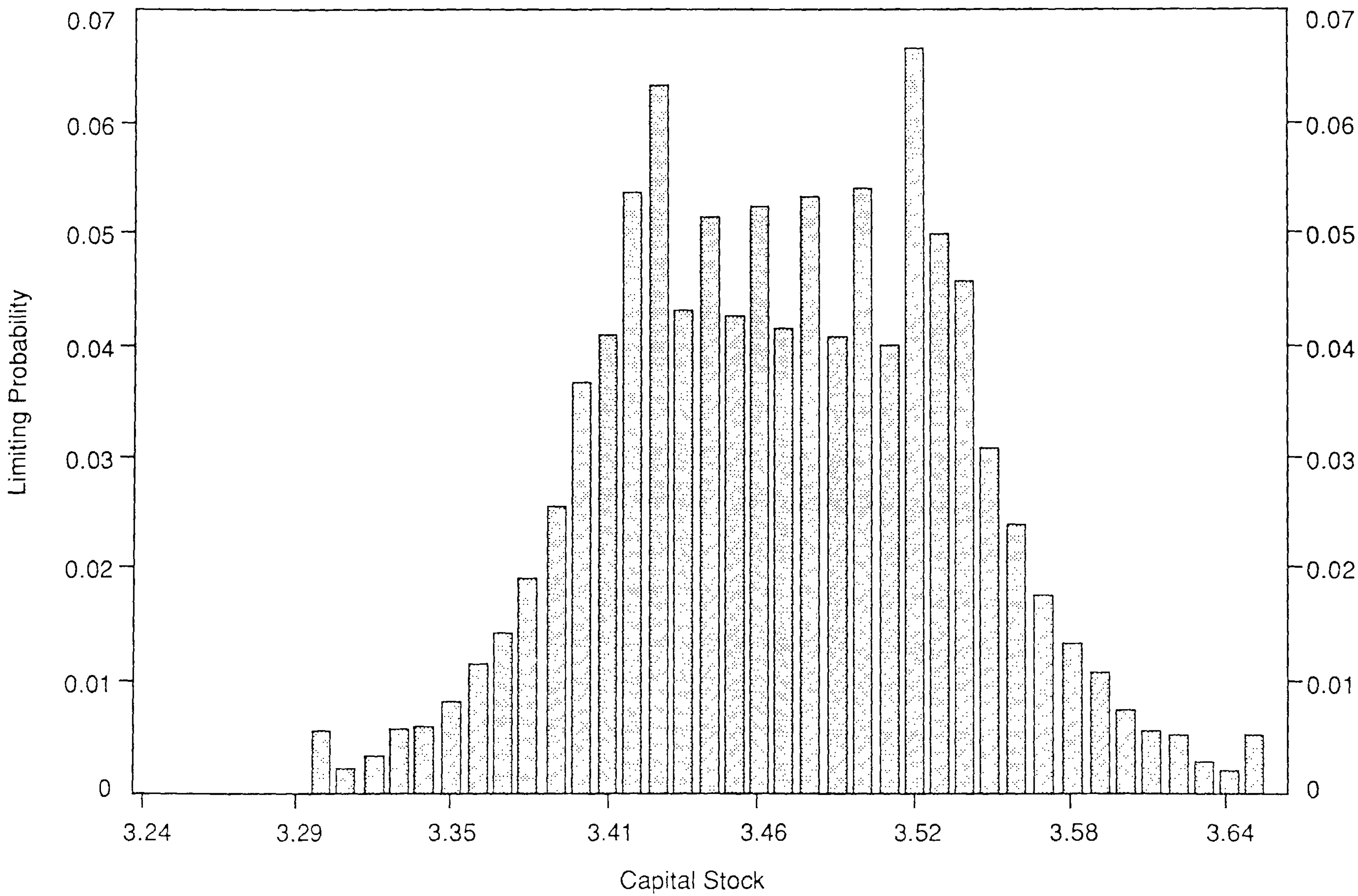

Table 3. Long-Run Welfare Effects of Stabilizing the Balance of Trade

Change in the Trade Balance 1/	Percentage Welfare Loss: I Maximum 2/	II Minimum 2/	III Ex Ante 3/	IV Ex Post 4/
0	35.00	0.006	0.019	0.008
12	7.00	0.006	0.022	0.009
30	2.15	0.009	0.072	0.015
60	3.29	0.016	0.386	0.038

1/ As a percentage of the mean of the balance of trade in the benchmark economy.

2/ Based on point-wise comparisons of the value function for each triple in the state space.

3/ Expected percentage welfare loss calculated with the stationary probability distribution of the benchmark economy.

4/ Expected percentage welfare loss calculated with the stationary probability distribution of the corresponding restricted economy.

controlled. The ex ante welfare loss is a more accurate measure to the extent that it captures the average welfare cost induced by moving the economy from a free-trade environment to a restricted-trade regime. The ex post welfare loss consistently underestimates the ex ante loss for each value of Â studied.

Considering the ex ante measure, Table 3 suggests that the welfare losses associated with capital controls are fairly small. If the government sets Â so as to stabilize the trade balance at its mean value in the benchmark economy, the welfare loss is only 0.019 percent. Even when the policy is designed so as to achieve a 60 percent trade-balance improvement, the loss in welfare measured in terms of constant consumption is only 0.386 percent.

The small welfare costs associated with the imposition of capital controls and the stabilization of the balance of trade are consistent with the findings of Lucas (1987) for the welfare cost of business cycles. He found that when the risk-aversion parameter is set to 1 or 5 and the standard deviation of the log of consumption is set to 0.013 or 0.039, the largest cost of consumption instability is about 0.38 percent. 1/

The interpretation of this result is also consistent with the arguments of Lucas. The disturbances that allow the artificial economy to mimic the regularities of post-war Canadian business cycles are not large and persistent enough to result in significant welfare losses. Risk-averse individuals wish to insure themselves against the risk of domestic shocks by participating in the world's financial market, but since this risk is very small, not having unrestricted access to the world market does not hurt them very much. In fact, if the productivity or terms-of-trade disturbances are increased from 1.285 percent to 2.3 percent, so that business cycles of the order of 5.0 percent standard deviation in GDP are generated, the ex ante welfare loss for the case of a 30 percent trade-balance improvement rises from 0.072 percent to only 0.166 percent. Thus, it appears that fairly large shocks and business cycles would be required for the policy to reduce welfare by a large amount. A similar result was also obtained by Cole and Obstfeld (1989). They obtained results showing that under certain specifications of tastes and technology, individuals can attain welfare-maximizing equilibria even when trade in international assets is forbidden.

It is very important to mention that the apparent neutrality of capital controls in this model is not a general result. The model focuses on the role of international trade as a vehicle to optimally allocate consumption through the business cycle in a representative-agent small open economy. It does not consider other instances of international economic relations, such as the role of technological transfers in long-run growth and the gains from trade for heterogenous agents or multi-sector economies

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1/ The analysis by Lucas (1987) was performed by applying a stochastic consumption stream, with trend and cycle components, to an isoelastic, time-separable utility function.

with traded and non-traded goods, in which depriving individuals or sectors from unrestricted access to world markets could have harmful effects. Moreover, the model adopts parameter values from an economy in which net foreign interest payments are only about 2 percent of GDP on average, which suggests that foreign debt may not play a role as critical as in other economies. Still, the investigation is a useful starting point because it illustrates that under these particular conditions, the welfare costs associated with capital controls and the stabilization of the balance of trade are quite modest.

3. The Government's Fiscal Strategy

The numerical methods applied in this paper can also be used to design one fiscal strategy that the government could follow to successfully implement the policy under consideration. By charging the appropriate tax on foreign interest income, rebating the revenue as a lump-sum transfer, the government can induce individuals to hold the target level of foreign assets $\hat{A}$. Under this fiscal regime, the dynamic programming problem that characterizes the free-trade economy includes the following resource constraint:

$$C_t = \exp(e_t) K_t^{\alpha} \hat{L}_t^{(1-\alpha)} - (\frac{\Phi}{2}) (K_{t+1} - K_t)^2 - K_{t+1} + K_t(1-\delta) + \big(1 + r^*(1-\tau_t)\big)A_t - A_{t+1} + T_t. \tag{12}$$

Where τ_t is the percentage tax on foreign interest income and T_t is a lump-sum transfer. The government sets $T_t = r^* \tau_t A_t$, but individuals take both the tax and the transfer as exogenously given.

The procedure utilized to calculate the schedule of taxes and transfers that enables the government to set $A_{t+1} = \hat{A}$, starting from any initial triple (K_t, A_t, e_t), is the following. First, the solution to the dynamic programming problem of the restricted version of the model delivers an optimal, state-contingent decision rule for domestic capital accumulation, $K_{t+1}(K_t, A_t = \hat{A}, e_t)$, that combined with the budget constraint in (9) and the equilibrium condition for intertemporal consumption determines the rate of return of a risk-free asset r_t in the economy with capital controls:

$$\frac{U_C^{r=\hat{A}}(t)}{\left[\exp(-v(t)) E\left\{U_C^{r=\hat{A}}(t+1)\right\}\right]} = 1 + r_t \tag{13}$$

Here, $U_C^{r=\hat{A}}(t)$ is the lifetime marginal utility of consumption at date t. This marginal utility includes not only the instantaneous marginal utility, but also the marginal change in the rate of time preference and its effect on the valuation of expected future consumption benefits.1/

Next, when interest-income taxes are introduced into the free-trade economy, optimizing individuals allocate consumption so as to equate the marginal rate of substitution between C_t and C_{t+1} with its effective intertemporal relative price $1+r^*(1-\tau_t)$. Therefore, considering that (13) determines the intertemporal relative price of consumption that must prevail in a free-trade environment if A_{t+1} is to be set at $\hat{A}$, it follows that when the government sets τ_t so as to make $1+r^*(1-\tau_t)=1+r_t$, it will succeed in implementing the capital controls. This implies that the government's fiscal strategy is to set $\tau_t=1-r_t/r^*$ and $T_t=\tau_t r^* A_t$. By rebating the proceeds of the tax in the form of a lump-sum transfer, the government ensures that no alterations in the value of initial wealth are caused, and hence that no other changes in the behavior of the aggregates than the ones discussed in part 1 of this section will take place.

Clearly, since r_t depends on the initial state (K_t,A_t,e_t), the tax or subsidy that needs to be charged or paid is also state contingent. Thus, although the individuals take the tax rate as given, this is in fact a random variable. Table 4 presents some of the statistical moments that characterize the stochastic process of the schedule of taxes on foreign interest income for each $\hat{A}$ target. Graphs illustrating the complete tax schedule for the cases of 30 and 60 percent trade-balance improvements under favorable and unfavorable disturbances are produced in Figures 6-9.

The mean values listed in the first row of Table 4 suggest that the average tax rate increases with the size of the desired improvement in the trade-balance surplus. If the goal is to stabilize the balance of trade at its average value in the benchmark economy, so that in fact $\hat{A}$ is at the center of the marginal limiting distribution of foreign assets in the free-trade economy, the average tax rate is close to zero. As the capital controls are tightened, the mean tax rises gradually to reach about 3 percent in the case that a 60 percent trade-balance improvement is desired. Thus, on the average, the taxes or subsidies required to enforce capital controls and stabilize the balance of trade appear to be small, regardless of the desired trade-balance goal.

The analysis of the average tax rates contrasts with the tax rates depicted in Figures 6-9. The reason is that these graphs plot the required tax, or subsidy, that needs to be imposed to implement the policy starting from every possible initial state of nature contained in the state space. For example, if in the case that a 60 percent trade-balance improvement is desired the economy starts at K=3.65, A=-0.23 and experiences a favorable productivity shock, Figure 6 shows that approximately a 63 percent tax rate

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1/ Since the percentage standard deviation of the subjective discount factor in the four restricted-trade economies is less than 0.01 percent, the impatience-effect caused by changes in the rate of time preference is likely to be very small.

Figure 6. Tax Rates With Favorable Shock for a 60 Percent Increment in Trade Surplus

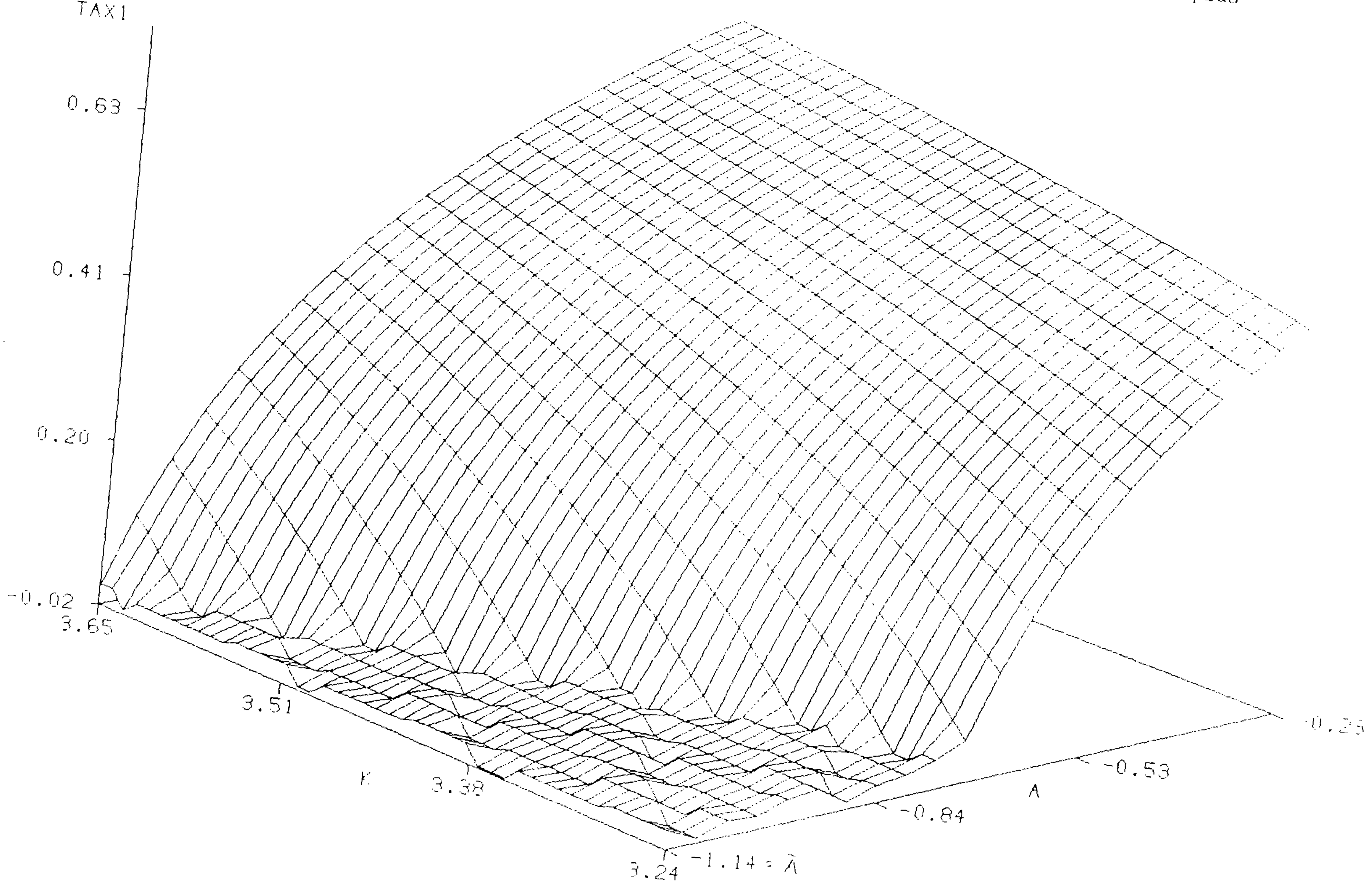


Figure 7. Tax Rates With Unfavorable Shock for a 60 Percent Increment in Trade Surplus

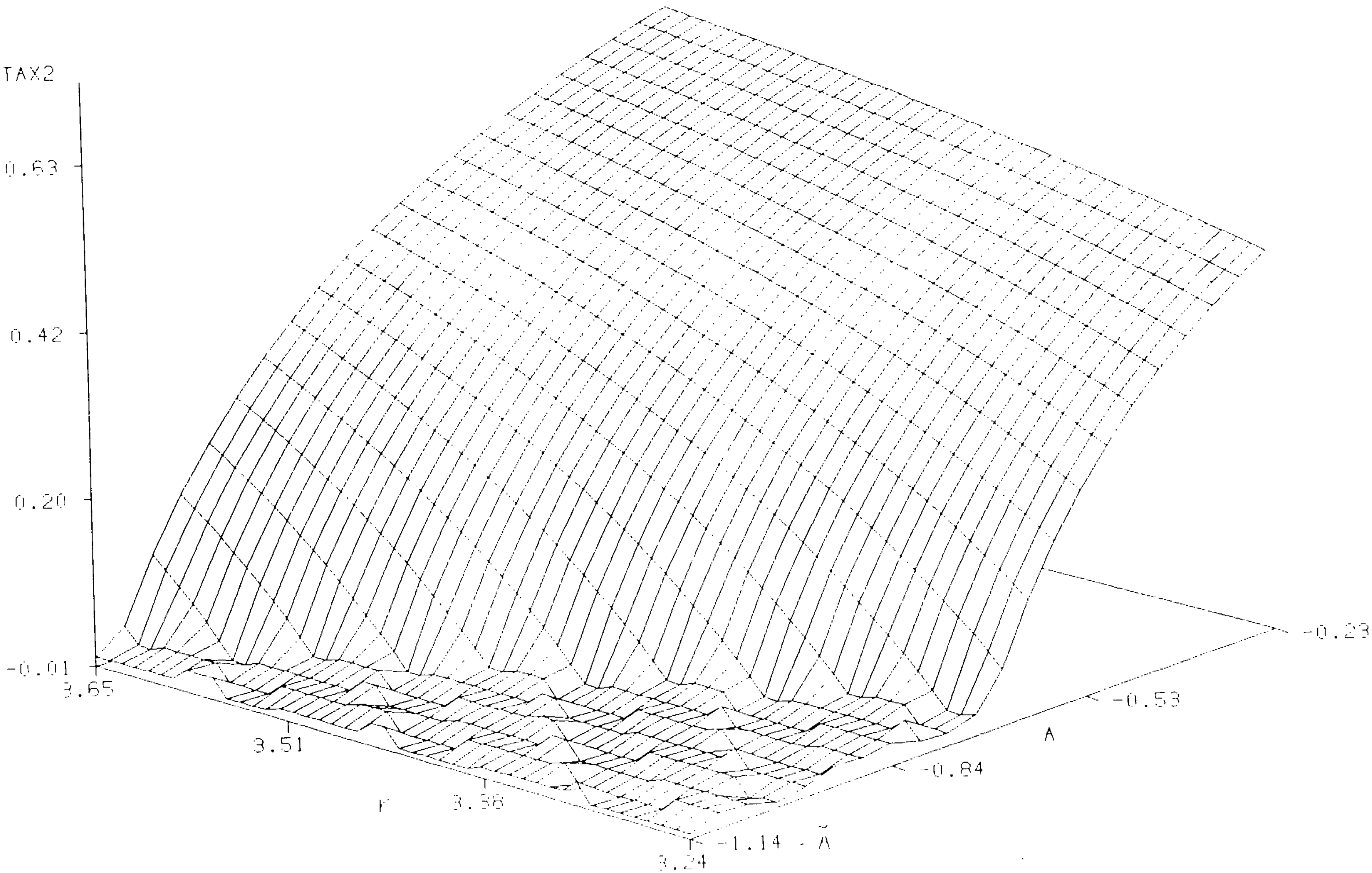


Figure 8. Tax Rates with Favorable Shock for a 30 Percent Increment in Trade Surplus

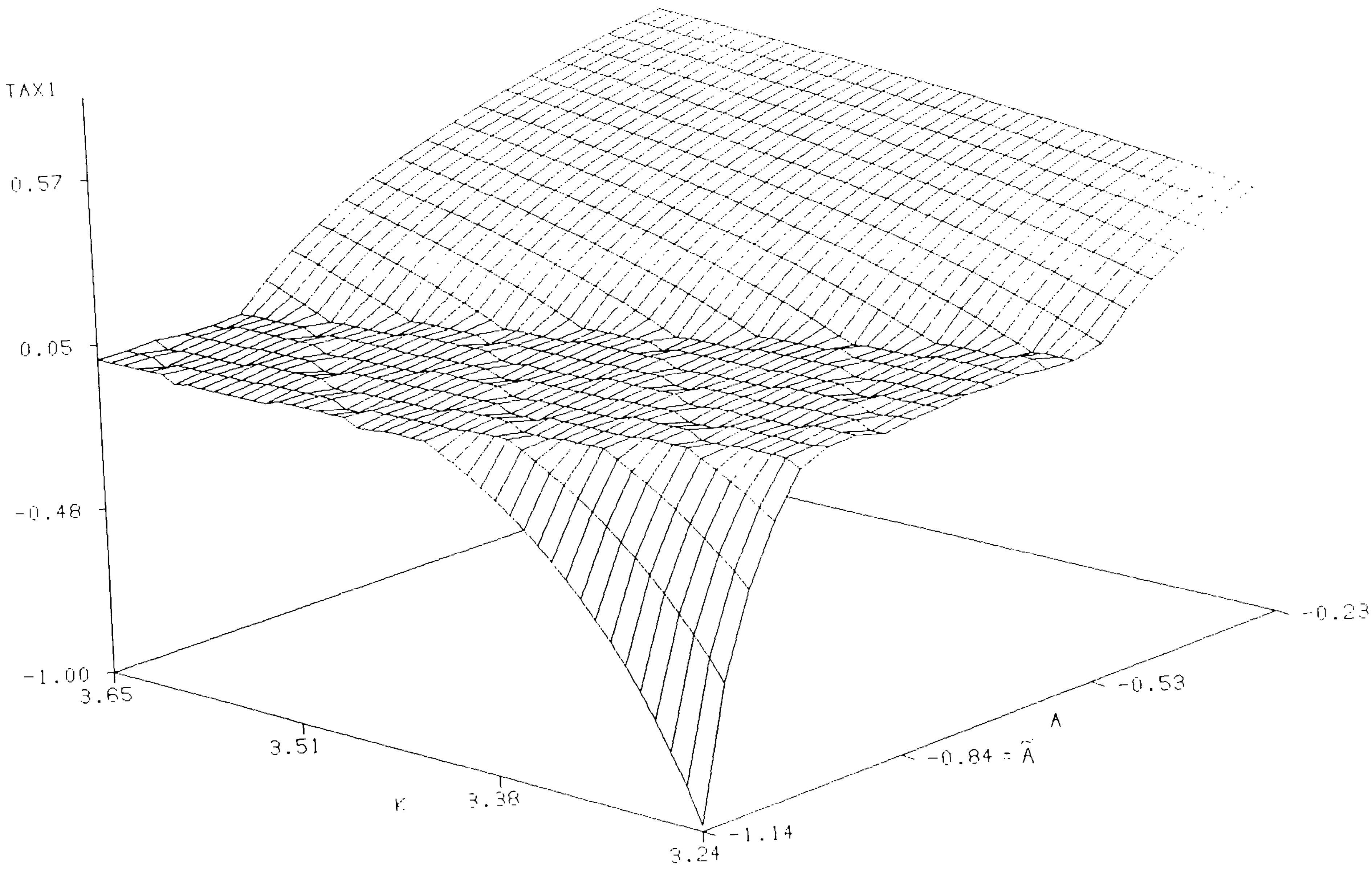


Figure 9. Tax Rates With Unfavorable Shock for a 30 Percent Increment in Trade Surp...

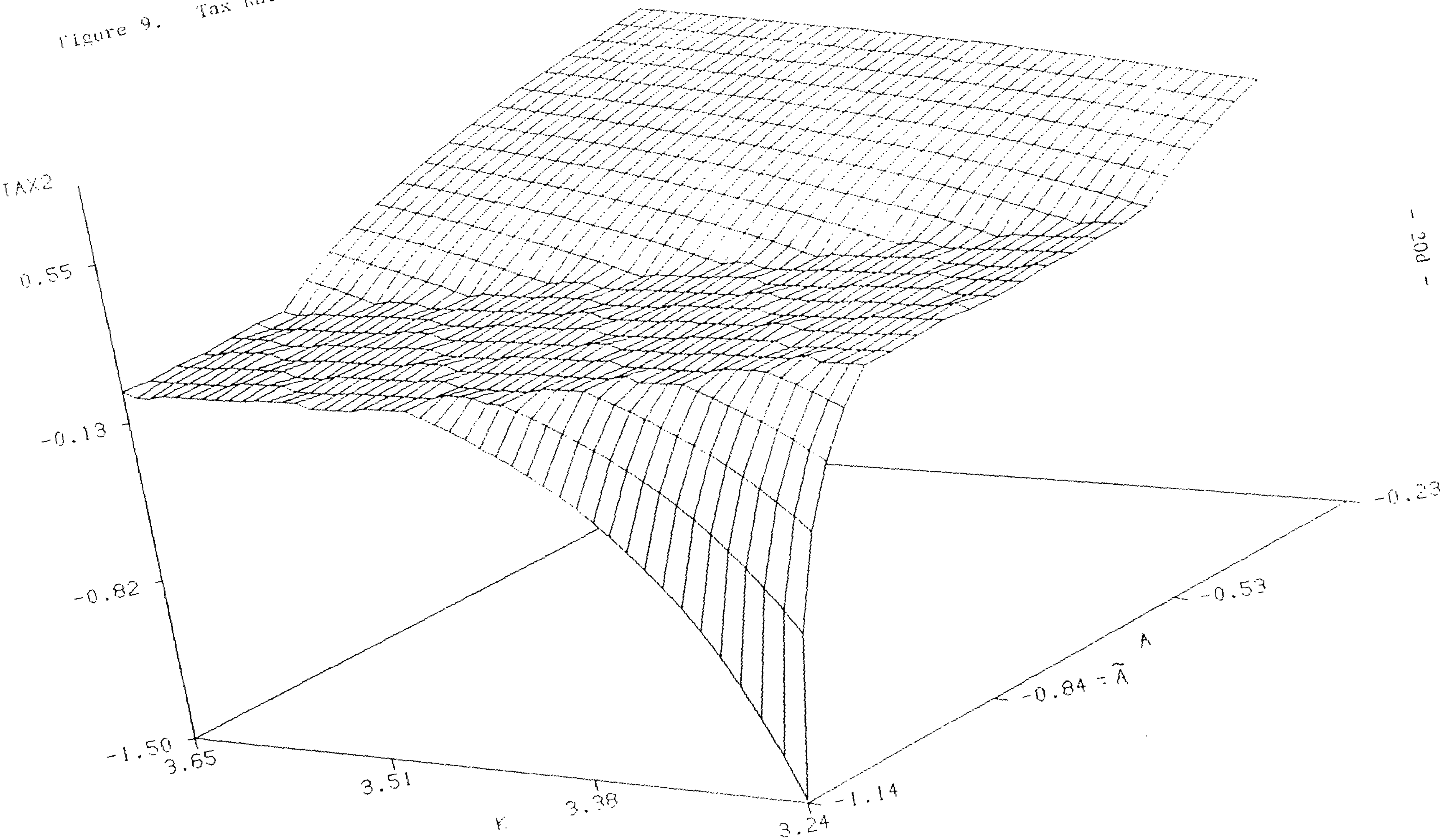


Table 4. *Statistical Moments that Characterize the Stochastic Process of the Foreign Interest Income Tax*

	Percentage Change in the Balance of Trade 1/			
	I	II	III	IV
Statistical Moments	0	12	30	60
Mean	-0.0002	0.0054	0.0145	0.0292
Standard deviation	0.1672	0.1681	0.1690	0.1704
First-order autocorrelation	-0.0691	-0.0712	-0.0729	-0.0758
Correlation with GDP	-0.1403	-0.1294	-0.1173	-0.0932

1/ As a percentage of the mean of the balance of trade in the benchmark economy.

must be imposed. However, this high tax rate need only be imposed for one period, because the next date the economy starts at $A=\hat{A}=-1.14$ and will never deviate from this coordinate in the foreign-asset holding grid. In the long run, only points where $A=\hat{A}$ have non-zero probability of occurrence, so that the one-time large taxes or subsidies have no effect on the statistical moments reported in Table 4. In fact, as the four graphs illustrate, around the area where $A=\hat{A}$, the schedule of taxes is always relatively flat and close to zero.

The standard deviations and first-order autocorrelation coefficients reported in Table 4 indicate that the limiting distribution of the foreign interest-income tax approximately preserves its variability and persistence as the trade-balance target is raised. There is, however, a tendency for the standard deviation to increase by a very small amount and for the first-order autocorrelation coefficient to fall slightly. In general, the standard deviation appears somewhat large compared with that of the macro-aggregates listed in Table 2, but the serial autocorrelation is very close to zero in all four cases reported.

The output-correlation coefficients listed in the last row of Table 4 indicate that the tax exhibits weakly countercyclical behavior. This result appears to follow from the weak countercyclical time-path of the trade balance in the benchmark economy (see Table 1). The negative correlation between τ and GDP increases from -0.14, in the case in which no trade-balance improvement is planned, to -0.09 in the case in which a 60 improvement is the goal.

This analysis of the government's fiscal strategy suggests that, in the long run, the authorities can achieve their goal of restricting foreign-asset trading to stabilize the balance of trade in a relatively easy manner. Although some high taxes or subsidies may be needed initially, in the stochastic steady-state the tax on foreign interest income has a low mean, a constant variance, is almost serially uncorrelated and exhibits weakly countercyclical behavior.

V. Concluding Remarks

This paper analyzes, within the context of a dynamic stochastic model of a small open economy, the macroeconomic effects of a policy that utilizes capital controls to stabilize the balance of trade. The effects of this policy on economic activity and economic welfare are determined by employing numerical techniques recently applied in closed-economy dynamic macro-economic models. The same numerical methods are also used to design a fiscal strategy that would allow the government to successfully implement the policy.

The quantitative results indicate that capital controls or trade-balance targeting have almost no effect on the equilibrium stochastic processes that describe output, consumption and the supply of labor. However, the dynamic processes of savings, investment and the capital stock are significantly altered because once foreign-asset trading is restricted, the domestic capital stock is the only vehicle that can be used to reallocate consumption intertemporally. The analysis also shows that the policy has minimal welfare effects, measured in terms of percentage changes in constant-consumption paths. These results suggest that as the kind of productivity or terms-of-trade disturbances that could explain observed business cycles in post-war Canada are small and transitory, such a policy would not cause large changes in the evolution of some of the macro-aggregates and the level of welfare. The analysis of a feasible fiscal strategy, which induces individuals to comply with capital controls by taxing foreign interest income, suggests that capital controls may require high tax rates only when the policy is introduced and that in the long-run minimal tax rates suffice.

These results are robust to changes in the desired target level of foreign-asset holdings or the surplus in the balance of trade, and are also robust to the magnification of business cycles for up to twice the variability of GDP observed in actual data. However, the apparent neutrality of capital controls cannot be regarded as a general result because it only applies to a framework in which the role of international trade is to allow individuals to smooth consumption during economic fluctuations. Further research to incorporate other important functions of world trade is necessary, especially to introduce the gains from trade in economies with a non-traded goods sector and heterogenous agents and the role of international technological transfers in long-run growth.

Numerical Solution of the Model

This appendix describes the method used to solve the dynamic programming problem and calculate the stationary probability distribution for the restricted and unrestricted artificial economies. The method follows a procedure suggested in Bertsekas (1976) and employed by Sargent (1980) and Greenwood, Hercowitz and Huffman (1988), it takes advantage of the contraction property of value-function iteration and uses a discrete grid of points to approximate the state space.

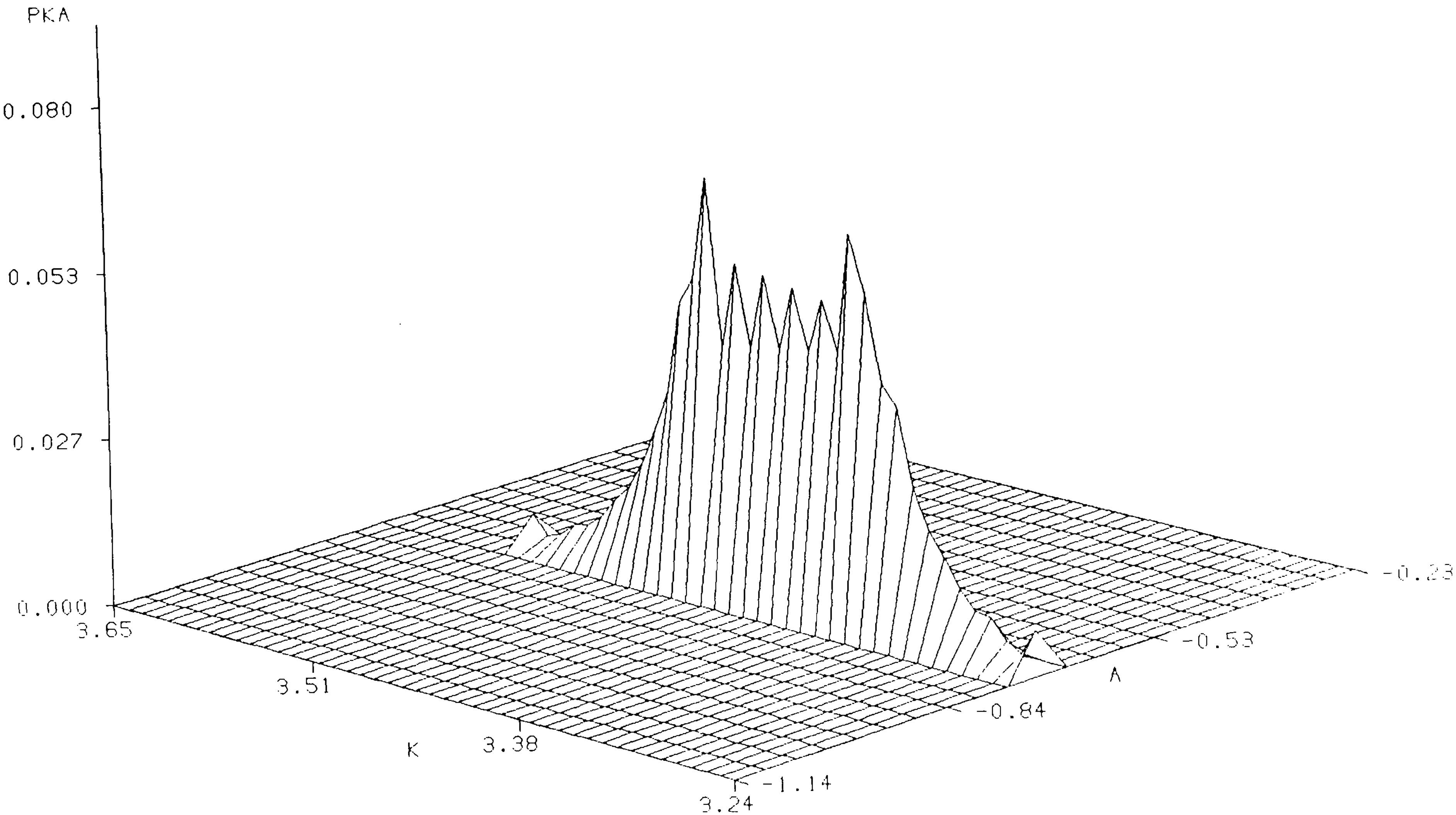
In this case, two evenly-spaced grids containing the values of domestic capital $K=\{K_1,\ldots,K_M\}$ and foreign assets $A=\{A_1,\ldots,A_N\}$ need to be defined. Thus, the initial state space of the artificial economies is given by the set $K \times A \times E$ that contains 2MN elements. The next step is to construct an algorithm that performs successive iterations in the functional equation (9). The algorithm iterates on (9) starting from the initial guess $V(K_t,A_t,e_t) = 0$, using the set of numbers included in $K \times A \times E$. Since the functional equation typically behaves as a contraction mapping, the sequence of iterations converges to a function that solves the equation (i.e. the value function). In cases in which welfare measures are not needed, the iteration process can be stopped when the sequences of optimal state-contingent decision rules for domestic capital and foreign assets converge.

The decision rules resulting from the solution of the functional equation are combined with the conditional probabilities π_{sr}, for s,r=1,2, to define the one-step transition probabilities of moving from any initial triple of domestic capital, foreign assets and the technological disturbances to any other such triple in one period. These transition probabilities are condensed in a matrix P of dimensions (2MN×2MN), which is used to calculate the stationary probabilities of each triple (K, A, e). The long-run probabilities are calculated by iterating on the sequence $p^1=p^0P$, where p^0 is an initial-guess vector of dimensions (1×2MN) and p^1 is a vector of identical dimensions that is used as the new guess in the following iteration. These iterations eventually converge to a unique fixed point p^*, which is the joint limiting probability distribution of K, A and e that characterizes the stochastic steady state of the economy. This distribution is used to compute population moments of variability, co-movement and persistence of all endogenous variables in the artificial economies.

The numerical simulations were carried out using an ETA-10P super-computer with a Vector-Fortran compiler. **K** contained 45 elements and **A** 22, so that the state space $K \times A \times E$ included 1980 combinations and the state-transition probability matrix contained 1980^2 elements.

The solution of the model in the case of the artificial economies in which capital controls are in place is simplified because the capital stock is the only choice variable. In the first period, when the controls have just been introduced, the economy may start from any point in $K \times A \times E$, but after that date the state space collapses to $K \times \hat{A} \times E$. Thus, the decision rule with respect to foreign-asset holdings is predetermined to be $\hat{A}$ at any date. As a result, the long-run probability distribution of capital, foreign assets and the shocks is concentrated in the coordinate where $\hat{A}$ is found (see Figure A1 for the case of a 0 percent trade-balance improvement in which $\hat{A}$ is the 11th point in the **A** grid).

Figure A1. Marginal Probability Density of Capital and Foreign Assets in the Restricted Economy:
0 Percent Trade-Balance Improvement



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