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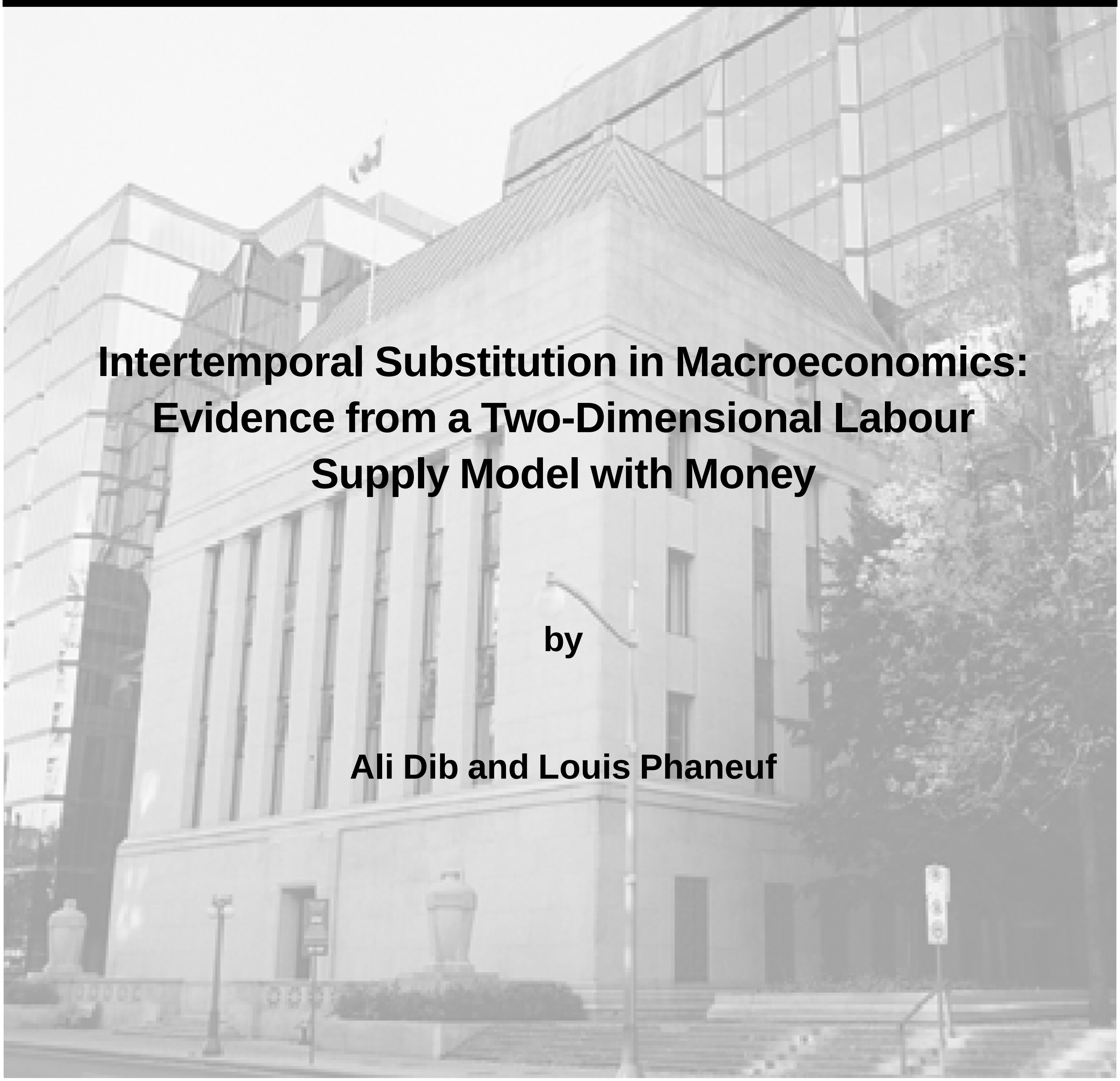

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Abstract

The hypothesis of intertemporal substitution in labour supply has a history of empirical failure when confronted with aggregate time-series data. The authors show that a two-dimensional labour supply model, adapted to an environment with money as originally proposed by Lucas and Rapping (1969) and Lucas (1972), performs very well. The overidentifying restrictions implied by the model are far from rejected. The estimated parameters of preferences are generally stable and meaningful. Furthermore, the estimated wage elasticities of labour supply are much higher than previously found in the literature.

JEL classification: C52, E24, E32, J22
Bank classification: Business fluctuations and cycles; Labour markets; Econometric and statistical methods

Résumé

La confrontation empirique avec les séries chronologiques macroéconomiques aboutit habituellement à une réfutation de l'hypothèse de substitution intertemporelle d'offre de travail. Les auteurs montrent qu'un modèle bidimensionnel d'offre de travail avec monnaie, tel que celui proposé par Lucas et Rapping (1969) et Lucas (1972), donne d'excellents résultats. Les contraintes de suridentification qu'implique le modèle ne sont pas rejetées par les données, et les estimations des paramètres relatifs aux préférences sont généralement stables et sensées. De plus, les valeurs calculées pour l'élasticité de substitution intertemporelle de l'offre de travail par rapport aux variations temporaires des taux de salaire sont très supérieures à celles que l'on trouve dans la littérature.

Classification JEL : C52, E24, E32, J22
Classification de la Banque : Cycles et fluctuations économiques; Marchés du travail; Méthodes économétriques et statistiques

1. Introduction

Following the seminal work of Lucas and Rapping (1969), a large class of macroeconomic models have relied on the hypothesis of intertemporal elasticity of substitution to explain fluctuations in aggregate employment.[1] This hypothesis claims that the cyclical variations in employment and wages result from the optimal decisions of a representative household that substitutes hours worked intertemporally in response to transitory movements in wage and interest rates. Thus, in these models, cyclical employment fluctuations are modelled as movements along a labour supply curve. Paradoxically, studies that use aggregate data to test the hypothesis of intertemporal substitution in labour supply (ISLS) find, in general, no supportive evidence, and often reach negative conclusions. The evidence found by Mankiw, Rotemberg, and Summers (1985) is typical of the problems encountered with the ISLS approach over the years: the overidentifying restrictions implied by the theory are almost always rejected, the estimated parameters of preferences are highly unstable, and the utility function is often not concave, leading to elasticities of the wrong sign.[2] Hence, this class of models must rely on selected microeconomic evidence for justification of the ISLS hypothesis.[3]

Our main objective in this paper is to show that most problems previously encoun-

[1]This includes real business cycle models, dynamic general-equilibrium (DGE) models with sticky nominal prices, models of labour market search, and limited-participation models, among others. In these theoretical models, fluctuations in aggregate employment are modelled as movements along a labour supply curve.

[2]Alogoskoufis (1987) obtains more encouraging results estimating an equation for log-linear labour supply in which work effort is measured by the number of workers (extensive margin), rather than by the hours worked per person (intensive margin). However, no formal attempt is made at explicitly modelling optimal choices at the two margins. Eichenbaum, Hansen, and Singleton (1988) show that a model of aggregate consumption and leisure decisions in which preferences are non-time separable is more favourable to the representative agent framework. Still, they find substantial evidence against the overidentifying restrictions implied by their model.

[3]Card (1994) concludes that microeconomic evidence does not support the ISLS hypothesis either.

tered by empirical studies of intertemporal Euler equations can be overcome when assuming that the representative household's preferences are defined over expected streams of consumption, leisure at the intensive margin, leisure at the extensive margin, and real money balances. Nevertheless, in standard ISLS models, such as those tested by Mankiw, Rotemberg, and Summers (1985), the representative household derives utility only from expected streams of consumption and a single measure of leisure. In this case, leisure is defined as the difference between total available hours in a period and the per capita total hours worked by the civilian labour force in the same period. Furthermore, most previous studies exclude money from their analysis.[4]

The two-dimensional labour supply framework is partly motivated by the fact that movements in employment rates for a given labour force are cyclically more important than movements in labour force participation. For instance, Hall and Lilien (1986) decompose actual movements in employment into the sum of changes in labour force participation and the fraction of week workers in the labour force. They show that the first component contributed 30 per cent aggregate employment movements during the postwar period and that the second component contributed close to 70 per cent. Bils and Cho (1994) also find postwar evidence indicating that a 1 per cent deviation from trend in employment has resulted, on average, from a 0.2 per cent change in the fraction of individuals who worked during the year and from a 0.8 per cent change in the weeks at work during the year for a given sized workforce. Moreover, they find microeconomic evidence using the Michigan Panel Study of Income Dynamics (PSID) that supports the distinction between leisure time in workweeks and weeks off in the year.

Therefore, while we do not try to model the participation decision explicitly, our framework is built on the assumption that weekly hours worked and weeks worked in

[4]Introducing money into the model adds an additional explicative variable and allows the derivation of an additional dynamic Euler equation associated with real money balances.

a quarter are imperfect substitutes to the representative household. In related work, Rogerson and Rupert (1991) use microeconomic data from the PSID for married males between the ages of 25 and 65 for the years 1976–82 to assess the household's willingness to substitute work intertemporally. In their model, workers choose weeks of work and hours of work per week. Focusing on the choice of weeks, they show that allowing some individuals to be at a corner solution for weeks worked, as a result of working year round, may substantially increase the intertemporal substitution of labour supply.

There are four main areas in which our approach differs from that of Rogerson and Rupert: (i) we employ aggregate time series rather than microeconomic data, (ii) we provide estimates of the preferences parameters, (iii) we formally test the overidentifying restrictions implied by the theoretical models, and (iv) we do not focus on individuals who are at a corner solution for weeks worked. Estimates of the parameters of preferences are recovered from the intertemporal Euler equations, which are jointly estimated using postwar U.S. aggregate data.

In addition, we assume, while estimating the intertemporal Euler equations, that the representative household can hold different types of riskless and/or risky assets: namely, bonds, shares, or both. We also examine the sensitivity of our findings to different measures of wages. Finally, in an effort to better identify the factors behind our main findings, we compare the results of the two-dimensional ISLS models with money with those of alternative ISLS models, including one-dimensional ISLS models with and without money, and two-dimensional ISLS models without money.

Our main findings can be summarized as follows. First, we find that the distinction between leisure in the workweeks and in non-working weeks is strongly supported by aggregate time-series data; each type of leisure contributes substantially to the representative household's utility according to their estimated shares in the utility function.

The inclusion of real money balances in the utility function is also supported empirically. Most importantly, the overidentifying restrictions implied by two-dimensional ISLS models with money easily survive statistical tests. These findings are not sensitive to specific measures of asset returns and nominal wages.

We find that the labour supply elasticity with respect to transitory movements in wages is higher for the weekly hours than for the weeks worked. Combining these two elasticities, our model delivers a wage elasticity of labour supply for total hours worked that, at the lowest, is 1.54 and can be as high as 2.15. In comparison, the highest wage elasticity of labour supply previously found with aggregate time-series data was around unity (Alogoskoufis 1987). We also find that asset returns have a significant independent influence on total hours worked.

In contrast, ISLS models that feature only one type of leisure, whether they include money or not, do not perform well; their problems range from non-concavity of the estimated utility functions to systematic rejection of the overidentifying restrictions implied by these models. The two-dimensional ISLS models that exclude money are also systematically rejected, even though they perform better than one-dimensional ISLS models.

We believe that these findings have special significance in light of the original work of Lucas and Rapping (1969) and Lucas (1972), who advocate a competitive theory of the labour market combined with an environment that accounts for money.

The rest of this paper is organized as follows. Section 2 constructs the two-dimensional ISLS model with money and the alternative ISLS models. Section 3 describes the econometric methods and data used to estimate the models. Section 4 reports the empirical results of the two-dimensional ISLS model with money and compares them with those of alternative ISLS models. Section 5 reports the intertemporal elasticities implied by the estimated two-dimensional ISLS models with money. Section 6 offers concluding remarks.

2. The Models

2.1 A two-dimensional ISLS model with money

Our framework is inspired by the models developed in Bils and Cho (1994) and Cho, Merrigan, and Phaneuf (1998). Consider an economy inhabited by a large number of identical households whose preferences are defined over expected streams of consumption, c_t, leisure in the workweeks, l_{1t}, leisure in the non-working weeks, l_{2t}, and real money balances, m_t. The representative household maximizes the following lifetime expected discounted utility:

$$E_t \sum_{t=0}^{\infty} \beta^t u\left(c_t, l_{1t}, l_{2t}, m_t\right), \tag{1}$$

where $u_c, u_{l_1}, u_{l_2}, u_m > 0$ and $u_{cc,} u_{l_1 l_1,} u_{l_2 l_2}, u_{mm} < 0$, β is the rate of time discount and E_t denotes the mathematical expectation.

Money holding generates a positive utility, since it facilitates consumption and reduces the time allocated for shopping. Money in the utility function also allows derivation of an extra dynamic Euler equation associated with the choice of the real balances, which implies more dynamics in the model.[5]

In each period, the representative household's total time endowment is a product of the number of weeks, E, and the hours available in the week, H, with both E and H taken as given. The representative household allocates its time during the workweeks, e_t, to work h_t (the weekly hours per worker), leisure l_{1t}, and a fixed time cost associated with commuting, τ. In non-working weeks, time is entirely devoted to leisure, l_{2t}. Hence,

[5] Feenstra (1986) shows the functional equivalence between liquidity costs and the utility of money.

leisure in the workweeks is given by

$$l_{1t} = (H - h_t - \tau)\, e_t, \tag{2}$$

and leisure in non-working weeks is given by

$$l_{2t} = (E - e_t)\, H. \tag{3}$$

The representative household ranks alternative streams of consumption, leisure in the workweeks, leisure in non-working weeks, and real money balances, using the following constant relative risk aversion (CRRA) utility function[6]:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(c_t^{\alpha_c} l_{1t}^{\alpha_{l1}} l_{2t}^{\alpha_{l2}} m_t^{\alpha_m}\right)^{1-\sigma} - 1}{1-\sigma} \right], \tag{4}$$

where $\alpha_c + \alpha_{l1} + \alpha_{l2} + \alpha_m = 1$. Concavity requires that $\alpha_c, \alpha_{l1}, \alpha_{l2}$, and α_m have positive signs, and that the product of each of these exponents with $(1-\sigma)$ be less than unity. Eichenbaum, Hansen, and Singleton (1988) describe in more detail some desirable characteristics of the above form of the utility function.

The representative consumer's allocations must satisfy the following sequence of budget constraints:

$$p_t c_t + p_t m_t + b_t + s_t \leq w_t h_t e_t + r_{bt} b_{t-1} + r_{st} s_{t-1} + p_{t-1} m_{t-1} + tr_t, \tag{5}$$

where p_t is the price of the consumption good in period t, b_t and s_t are bonds and shares (riskless and risky assets, respectively) purchased in period t, w_t is the after-tax wage rate, r_{bt} is the after-tax riskless asset return, $r_{st} = \frac{p_{st}+d_{st}}{p_{st-1}}$ is the after-tax risky asset return, p_{st} is the price of shares, d_{st} is the dividends earned by shares in period t,

[6]Eichenbaum, Hansen, and Singleton (1988) discuss the advantages of working with this class of preferences.

and tr_t is a lump-sum money transfer. The budget constraint (5) is specified as if the representative consumer holds bonds and shares. In deriving the intertemporal Euler equations below, however, we assume that the representative consumer can possibly hold bonds, shares, or both.

The representative household chooses c_t, h_t, e_t, m_t, b_t, and s_t that maximize expected total discounted utility (4) subject to (5), while taking into account (2) and (3). The first-order conditions are:

$$\alpha_c \left(c_t^{\alpha_c} l_{1t}^{\alpha_{l1}} l_{2t}^{\alpha_{l2}} m_t^{\alpha_m}\right)^{1-\sigma} c_t^{-1} - \lambda_t p_t = 0, \tag{6}$$

$$\alpha_{l1} \left(c_t^{\alpha_c} l_{1t}^{\alpha_{l1}} l_{2t}^{\alpha_{l2}} m_t^{\alpha_m}\right)^{1-\sigma} l_{1t}^{-1} - \lambda_t w_t = 0, \tag{7}$$

$$\alpha_{l2} \left(c_t^{\alpha_c} l_{1t}^{\alpha_{l1}} l_{2t}^{\alpha_{l2}} m_t^{\alpha_m}\right)^{1-\sigma} l_{2t}^{-1} - \lambda_t w_t (1 - \frac{\tau}{H}) = 0, \tag{8}$$

$$\alpha_m \left(c_t^{\alpha_c} l_{1t}^{\alpha_{l1}} l_{2t}^{\alpha_{l2}} m_t^{\alpha_m}\right)^{1-\sigma} (m_t p_t)^{-1} - \lambda_t + \beta E_t \lambda_{t+1} = 0, \tag{9}$$

$$\beta E_t \lambda_{t+1} r_{bt+1} - \lambda_t = 0, \tag{10}$$

$$\beta E_t \lambda_{t+1} r_{st+1} - \lambda_t = 0, \tag{11}$$

where λ_t is the multiplier associated with the intertemporal budget constraint, which also represents the marginal utility of wealth at date t.[7]

Assuming that λ_t follows a martingale process (see MaCurdy 1985), we can derive

[7]From equation (9), we can derive the standard money-demand function in which real balances depend on consumption and nominal interest rates.

the following Euler equations:

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\left(\frac{l_{1t+1}}{l_{1t}}\right)^{\alpha_{l1}}\left(\frac{l_{2t+1}}{l_{2t}}\right)^{\alpha_{l2}}\right]^{1-\sigma}\right.$$
$$\left.\times\left(\frac{c_{t+1}}{c_t}\right)^{-1}\frac{p_t r_{jt+1}}{p_{t+1}}-1\right\} = 0, \qquad (12)$$

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\left(\frac{l_{1t+1}}{l_{1t}}\right)^{\alpha_{l1}}\left(\frac{l_{2t+1}}{l_{2t}}\right)^{\alpha_{l2}}\right]^{1-\sigma}\right.$$
$$\left.\times\left(\frac{l_{1t+1}}{l_{1t}}\right)^{-1}\frac{w_t r_{jt+1}}{w_{t+1}}-1\right\} = 0, \qquad (13)$$

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\left(\frac{l_{1t+1}}{l_{1t}}\right)^{\alpha_{l1}}\left(\frac{l_{2t+1}}{l_{2t}}\right)^{\alpha_{l2}}\right]^{1-\sigma}\right.$$
$$\left.\times\left(\frac{l_{2t+1}}{l_{2t}}\right)^{-1}\frac{w_t r_{jt+1}}{w_{t+1}}-1\right\} = 0, \qquad (14)$$

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\left(\frac{l_{1t+1}}{l_{1t}}\right)^{\alpha_{l1}}\left(\frac{l_{2t+1}}{l_{2t}}\right)^{\alpha_{l2}}\right]^{1-\sigma}\right.$$
$$\left.\times\left(\frac{c_{t+1}}{c_t}\right)^{-1}\frac{p_t}{p_{t+1}}+\frac{\alpha_m c_t}{\alpha_c m_t}-1\right\} = 0, \qquad (15)$$

where r_{jt+1} ($j = b$, s, or both) denotes the type of assets held by the representative consumer. If $j = b$, the representative consumer holds only riskless assets. Hence, there are four Euler equations that can be estimated jointly in order to recover the preference parameters of the two-dimensional ISLS model with money. The same applies if $j = s$, so that the representative consumer holds only risky assets. If $j = b$ and s, the representative consumer holds both riskless and risky assets, implying that there are seven Euler equations to estimate jointly.

Conditions (12)–(14) stipulate that the marginal cost of a unity of consumption or of an hour of both types of leisure in period t must be equal to the expected marginal benefit in period $t+1$. Condition (15) implies that the representative household compares its marginal utility of holding an additional dollar in period t with the marginal disutility of not consuming this dollar in the current period versus the expected discounted marginal utility of consumption in the future. Note that the inclusion of money in the model implies the derivation of an additional Euler equation, equation (15), and considers real balances as an additional explicative variable in each Euler equation.

2.2 Alternative ISLS models

Since our empirical work entails a systematic comparison of two-dimensional ISLS models with money with alternative ISLS models, we briefly describe the one-dimensional ISLS model without money (or standard model), the one-dimensional ISLS model with money, and the two-dimensional ISLS model without money. For simplicity, we provide only the intertemporal Euler equations derived from these models.

2.2.1 The standard one-dimensional ISLS model (no money)

The one-dimensional ISLS model does not distinguish between leisure in the workweeks and leisure in non-working weeks, using instead the standard definition of leisure time. Furthermore, it does not account for money. In the standard model, the representative household's preferences are described by,

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(c_t^{\alpha_c} l_t^{\alpha_l})^{1-\sigma} - 1}{1-\sigma} \right], \tag{16}$$

where $\alpha_c + \alpha_l = 1$. In the current context, leisure is given by $l_t = (E \times H) - n_t$, with n_t measuring the total hours worked during period t. The representative household faces the following budget constraint:

$$p_t c_t + b_t + s_t \leq w_t n_t + r_{bt} b_{t-1} + r_{st} s_{t-1}. \tag{17}$$

Optimal choices of c_t, n_t, b_t, and s_t are those that maximize expected total discounted utility (16) subject to (17). The Euler equations derived from this optimization problem are:

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{l_{t+1}}{l_t}\right)^{\alpha_l}\right]^{1-\sigma}\left(\frac{c_{t+1}}{c_t}\right)^{-1}\frac{p_t r_{jt+1}}{p_{t+1}}-1\right\} = 0, \tag{18}$$

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{l_{t+1}}{l_t}\right)^{\alpha_l}\right]^{1-\sigma}\left(\frac{l_{t+1}}{l_t}\right)^{-1}\frac{w_t r_{jt+1}}{w_{t+1}}-1\right\} = 0, \tag{19}$$

for r_{jt+1}, $j = b$, s or both. With $j = b$ or s, the model yields two intertemporal Euler equations, while with $j = b$ and s, it delivers four Euler equations.

2.2.2 The one-dimensional ISLS model with money

Assuming that the representative household contemplates only one type of leisure and derives utility from holding real money balances, preferences can be described by

$$E_t\sum_{t=0}^{\infty}\beta^t\left[\frac{(c_t^{\alpha_c} l_t^{\alpha_l} m_t^{\alpha_m})^{1-\sigma}-1}{1-\sigma}\right], \tag{20}$$

where $\alpha_c + \alpha_l + \alpha_m = 1$. With money taken into account, the representative consumer faces the following budget constraint:

$$p_t c_t + p_t m_t + b_t + s_t \leq w_t n_t + r_{bt} b_{t-1} + r_{st} s_{t-1} + p_{t-1} m_{t-1} + tr_t. \tag{21}$$

The representative household's optimization problem consists in choosing c_t, n_t, m_t, b_t, and s_t that maximize (20) subject to (21). The corresponding Euler equations are:

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{l_{t+1}}{l_t}\right)^{\alpha_l}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\right]^{1-\sigma}\left(\frac{c_{t+1}}{c_t}\right)^{-1}\frac{p_t r_{jt+1}}{p_{t+1}}-1\right\} = 0, \tag{22}$$

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{l_{t+1}}{l_t}\right)^{\alpha_l}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\right]^{1-\sigma}\left(\frac{l_{t+1}}{l_t}\right)^{-1}\frac{w_t r_{jt+1}}{w_{t+1}}-1\right\} = 0, \tag{23}$$

$$E_t\left\{\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{\alpha_c}\left(\frac{l_{t+1}}{l_t}\right)^{\alpha_l}\left(\frac{m_{t+1}}{m_t}\right)^{\alpha_m}\right]^{1-\sigma}\left(\frac{c_{t+1}}{c_t}\right)^{-1}\frac{p_t}{p_{t+1}}+\frac{\alpha_m c_t}{\alpha_c m_t}-1\right\} = 0, \tag{24}$$

for r_{jt+1}, $j = b$, s or both. Hence, the one-dimensional model with money yields three Euler equations if $j = b$ or s, and five Euler equations if $j = b$ and s.

2.2.3 Two-dimensional ISLS model (no money)

The third model is one that incorporates the two types of leisure, l_{1t} and l_{2t}, while excluding money. The representative household's preferences are described by,

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(c_t^{\alpha_c} l_{1t}^{\alpha_{l1}} l_{2t}^{\alpha_{l2}})^{1-\sigma} - 1}{1-\sigma} \right], \tag{25}$$

where $\alpha_c + \alpha_{l1} + \alpha_{l2} = 1$. The budget constraint is,

$$p_t c_t + b_t + s_t \leq w_t h_t e_t + r_{bt} b_{t-1} + r_{st} s_{t-1}. \tag{26}$$

The representative household chooses c_t, h_t, e_t, b_t, and s_t that maximize expected discounted utility (25) subject to (26), while taking into account definitions (2) and (3). The intertemporal Euler equations corresponding to this optimization problem are:

$$E_t \left\{ \beta \left[\left(\frac{c_{t+1}}{c_t} \right)^{\alpha_c} \left(\frac{l_{1t+1}}{l_{1t}} \right)^{\alpha_{l1}} \left(\frac{l_{2t+1}}{l_{2t}} \right)^{\alpha_{l2}} \right]^{1-\sigma} \left(\frac{c_{t+1}}{c_t} \right)^{-1} \frac{p_t r_{jt+1}}{p_{t+1}} - 1 \right\} = 0, \tag{27}$$

$$E_t \left\{ \beta \left[\left(\frac{c_{t+1}}{c_t} \right)^{\alpha_c} \left(\frac{l_{1t+1}}{l_{1t}} \right)^{\alpha_{l1}} \left(\frac{l_{2t+1}}{l_{2t}} \right)^{\alpha_{l2}} \right]^{1-\sigma} \left(\frac{l_{1t+1}}{l_{1t}} \right)^{-1} \frac{w_t r_{jt+1}}{w_{t+1}} - 1 \right\} = 0, \tag{28}$$

$$E_t \left\{ \beta \left[\left(\frac{c_{t+1}}{c_t} \right)^{\alpha_c} \left(\frac{l_{1t+1}}{l_{1t}} \right)^{\alpha_{l1}} \left(\frac{l_{2t+1}}{l_{2t}} \right)^{\alpha_{l2}} \right]^{1-\sigma} \left(\frac{l_{2t+1}}{l_{2t}} \right)^{-1} \frac{w_t r_{jt+1}}{w_{t+1}} - 1 \right\} = 0, \tag{29}$$

for r_{jt+1}, $j = b$, s or both. This model delivers three Euler equations if $j = b$ or s, and six Euler equations if $j = b$ and s.

While, in principle, the intertemporal Euler equations could be estimated either individually or jointly, we focus on the joint estimation, given the large number of models considered.

3. Estimation Procedure and Data

This section describes the econometric procedure and data used to estimate the Euler equations of our ISLS models.

3.1 Estimation method

The structural parameters of the ISLS models are estimated using the generalized method of moments (GMM) procedure proposed by Hansen (1982) and Hansen and Singleton (1982). Let $E_t[q(\mathbf{y}_{t+1}, \theta)]$ be a vector of n Euler equations derived from a particular model. The vector $\mathbf{y}_{t+1}$ is composed of stationary variables dated t and $t+1$, while the vector θ is composed of the l structural parameters that we seek to estimate. For a vector $\mathbf{z}_t$ of k instrumental variables included in the information set available in period t, we define a vector of $(n \times k)$ unconditional moment restrictions implied by the model,

$$Ef(\mathbf{y}_{t+1}, \mathbf{z}_t, \theta) = E[q(\mathbf{y}_{t+1}, \theta) \otimes \mathbf{z}_t], \tag{30}$$

where $\otimes$ is the Kronecker product. The sampling equivalence of equation (30) is given by,

$$g_T(\theta) = \frac{1}{T} \sum_{t=1}^{T} f(\mathbf{y}_{t+1}, \mathbf{z}_t, \theta), \tag{31}$$

with $g_T(\theta)$ converging asymptotically towards zero under the null hypothesis that the structural model is well specified. The GMM estimator of the parameter vector (θ_T) is the solution to the following problem:

$$\theta_T = \arg\min_{\theta} \; g_T(\theta)' W_T g_T(\theta), \tag{32}$$

where W_T is a non-negative symmetric weighting matrix. An optimal weighting matrix, W_T^*, is obtained as the inverse of the variance-covariance matrix of the moment conditions evaluated at a consistent first-step estimator; for example, by using the identity matrix as the weighting matrix at the first step. This optimal weighting matrix is consistently estimated using the procedure developed by Newey and West (1994).

The overidentifying restrictions implied by the different models can be tested formally using Hansen's J-statistic if the dimension of the vector of moments is greater than the dimension of the vector of estimated parameters. This statistic is given by:

$$J = T\left\{g_T(\theta)' W_T^* g_T(\theta)\right\}, \tag{33}$$

which asymptotically follows a χ^2 distribution with $nk - l$ degrees of freedom.

The list of instruments used in the estimation of ISLS models is not uniform across studies. For example, Mankiw, Rotemberg, and Summers (1985) use different combinations, including lagged consumption, lagged interest rates, lagged leisure, lagged prices, and lagged wages.[8] Eichenbaum, Hansen, and Singleton (1988) employ the current rates of change of consumption, leisure, and wages, and the current interest rate.

Following Tauchen (1986) and Kocherlakota (1990), we use only current and one-period lagged values of the instrumental variables to estimate the intertemporal Euler equations. Unlike the models that have been tested by Mankiw, Rotemberg, and Summers (1985) and by Eichenbaum, Hansen, and Singleton (1988), our model includes two different measures of leisure, and different measures of asset returns and money. Specifically, we use different subsets of the following instrumental variables: $\{1, \frac{r_{jt}}{Rc_t Rp_t}, \frac{1}{Rc_t Rp_t}$, Rc_t,Rl_{1t}, Rl_{2t}, Rl_t, $Rm_t\}$ (where $Rx_t = x_t/x_{t-1}$).

[8]They occasionally use up to five-period lagged values of the variables.

3.2 Data

The ISLS models are estimated using seasonally adjusted, quarterly data for the period 1960Q1–1993Q4.[9] Aggregate real per capita consumption, c_t, is the sum of consumption expenditures on non-durable goods and services, converted into per capita terms after dividing by the total adult population (age sixteen and over). The aggregate price level, p_t, is the implicit price deflator that corresponds to our measure of consumption expenditures. The rate of return on riskless assets, r_{bt}, is the 3-month Treasury bill rate, expressed in real terms. The rate of return on risky assests, r_{st}, is the value-weighted average of returns on the New York Stock Exchange, also expressed in real terms. The monetary aggregate used to calculate real money balances is M1.

We use two different wage measures. The first one, represented by w_1, is the average hourly compensation in non-agricultural employment. The second, represented by w_2, adheres more closely to the National Income and Product Accounts (NIPA) and is the sum of NIPA definitions of wages and salaries, other labour income, and proprietary income divided by total labour hours.[10] The wage rates and asset returns are both after-tax measures. The representative household's average tax rate is based upon the taxability properties of the various components of disposable income.[11]

[9]Our choice of sample period is justified by the fact that we want to use hours worked from the Household Survey to be consistent with previous studies. This series is unfortunately unavailable after 1993Q4.

[10]Thus, proprietary income is included entirely within labour compensation, although part of this income could represent the return on capital (Dutkowsky and Dunsky 1996).

[11]Specifically, the average tax rate, ω_t, comes from the following disposable income equation:

$$YD_t = (1 - \omega_t)(WS_t + INT_t) + OLY_t + TP_t,$$

where YD is nominal disposable income; WS is the sum of nominal wages and salaries and proprietary income; INT is the sum of total interest, dividends, and rental income less interest paid on household debt; OLY denotes other labour income; and TP represents the nominal transfer payments. Other labour income (which consists primarily of labour benefits) and transfer payments are tax exempt, to

The representative household's quarterly time endowment is 1,456 hours (13 weeks × 112 hours).[12] The weekly average hours worked, h_t, is the hours series from the Household Survey. As in Alogoskoufis (1987), we approximate the working weeks, e_t, by the product of the number of weeks in the quarter and the ratio of the civilian employment to the working population. The working-time cost is set at 6 hours per workweek.[13]

When estimating one-dimensional ISLS models, we measure total hours worked during the quarter n_t by $(hours_t \times emp_t \times 13)/pop_t$, with $hours_t$ representing the average weekly hours, emp_t the weekly employees (total employed labour force), and pop_t the total adult population.

4. Results

We begin by reporting the estimation results obtained from two-dimensional ISLS models with money. We then compare these results with those of alternative ISLS models. Estimates of the parameters of preferences are recovered from the jointly estimated Euler equations. Tables 1 and 2 report the results.

4.1 The two-dimensional ISLS model with money

The preference parameters of two-dimensional ISLS models with money are obtained from the estimated intertemporal Euler equations (12)–(15). Table 1 reports the estimates. The instrumental variables used in estimating the models are listed at the bottom of the table. Each of the three panels in this table reports findings that correspond to

be consistent with IRS tax laws. Solving the equation above for $(1-\omega_t)$ gives the average tax rate (Dutkowsky and Dunsky 1996).

[12] We adjust for sleeping time, so the representative household's daily time endowment is 16 hours.

[13] We have considered a range of 4 to 12 hours for the fixed time cost without any significant impact on the results.

a specific assumption about the holding of assets. Also listed within each panel are the results obtained with the two measures of wages.

The overidentifying restrictions implied by the two-dimensional ISLS models with money are generally not rejected at a conventional confidence level. The estimates of β, α_c, α_{l1}, α_{l2}, α_m, and σ always imply that the concavity conditions are satisfied. Note that the estimates are highly stable when we change the measures of asset returns and wages. In contrast, Mankiw, Rotemberg, and Summers (1985) find that the overidentifying restrictions implied by standard one-dimensional ISLS models are systematically rejected and that the estimated parameters of preferences are highly unstable.

Panel A of Table 1 reports the estimated structural parameters with the representative consumer holding only risky assets, s_t. The estimates of the discount factor, β, are below unity, a finding that is interesting in itself, since most previous empirical studies of intertemporal Euler equations have found estimates of β that are above unity.

Our estimates confirm that the two dimensions of leisure are statistically significant, each type of leisure contributing quite substantially to the household's preferences, as shown by their estimated shares in preferences. The estimated share of leisure in working weeks is 0.3380 when the wage rate is measured by w_1, and 0.3576 when it is w_2. The share of leisure in non-working weeks is 0.3289 with w_1, and 0.3304 with w_2. The estimates of α_c are 0.3308 and 0.3100, respectively. The estimated share of real money balances, while small at 0.0023 or 0.0021, is nonetheless statistically significant. The estimated preference parameter, σ, which is also statistically significant, is 3.8798 with wage rate w_1, and 5.8916 with w_2.

Panel B of Table 1 reports the results obtained under the assumption that the representative household holds only riskless assets, b_t. While these results are not as good as those obtained with the risky assets, they are still encouraging. The overidentifying restrictions are not statistically rejected at a conventional confidence level, but their non-rejection is not as strong as previously. The discount factor, β, is now slightly above unity, as in most empirical studies of intertemporal Euler equations.

The wage measure seems to have a greater impact on the estimated preference shares of consumption and leisure in working weeks. Estimates of α_c are 0.4427 with w_1, and 0.3149 with w_2. The estimates of α_{l1} are 0.2197 and 0.3522, respectively. In comparison, the estimated share of leisure in non-working weeks, α_{l2}, is stable when we change the wage rate, with estimates of 0.3358 and 0.3316, respectively. The preference share of real money balances is 0.0018 or 0.0012, depending on the wage measure, and is statistically significant. The estimates of σ are broadly similar to those obtained with the risky assets, at 3.8996 with wage rate w_1 and 5.9384 with w_2.

Panel C of Table 1 reports the results with the representative household holding riskless and risky assets. By far, the overidentifying restrictions implied by the model are not refuted. The estimates of α_c and α_{l1} are quite stable when the wage rate is changed from w_1 to w_2, with 0.4651 and 0.3903 for α_c, and 0.2152 and 0.2922 for α_{l1}. Estimates of α_{l2} are virtually unchanged at 0.3176 and 0.3158, respectively. The estimated share of real money balances, α_m, is also stable at 0.0013 and 0.0016. Estimates of σ are 4.0440 with w_1 and 5.4495 with w_2.[14]

According to the findings reported in this subsection, it seems that allowing the representative consumer to have preferences defined in terms of consumption, leisure in the workweeks, leisure in non-working weeks, and real money balances results in a better overall fit of U.S. aggregate time-series data. In particular, the overidentifying restrictions implied by the model cannot be rejected and the estimated parameters of

[14]When β was found to be slightly above unity, the corresponding Euler equations were re-estimated, constraining the parameter β to be below unity, with almost no changes in the estimates of the other structural parameters of the model.

preferences are highly stable when we use different measures of asset returns and wages.

4.2 Alternative ISLS models with and without money

It is also possible to assess indirectly the empirical success of the two-dimensional ISLS model with money by estimating alternative versions of the model that feature less theoretical ingredients than in the more general framework. Table 2 reports the results of one-dimensional ISLS models, with and without money, and of two-dimensional ISLS models without money.[15]

Panel A of Table 2 reports the estimates of one-dimensional ISLS models without money (or standard models). The estimated intertemporal Euler equations are (18) and (19). As in Mankiw, Rotemberg, and Summers (1985), Hansen's J-test strongly rejects the overidentifying restrictions implied by the standard models. Assuming that the representative consumer holds riskless and risky assets, the estimate of σ is -2.558, which violates the concavity conditions.

Panel B of Table 2 reports the results of one-dimensional ISLS models with money. The estimated structural parameters are recovered from the Euler equations (22)–(24). The results are still very negative, with overidentifying restrictions that are strongly rejected. The concavity conditions are not satisfied when the representative consumer holds only risky assets or a combination of riskless and risky assets, the estimates of σ being -2.7282 and -6.9859, respectively. Note also that these estimates are highly unstable. While the estimate of α_c is only 0.0438 with the risky assets, it rises to 0.3227 with the riskless assets. Altogether, these negative results constitute strong evidence

[15]Since the results of one-dimensional ISLS models and two-dimensional ISLS models without money are essentially negative, we report only those obtained with wage rate w_1. The alternative models can be estimated using the same set of instruments as in the more general model or different subsets of instruments with the same negative results.

against the one-dimensional ISLS models.

Panel C of Table 2 reports estimates of two-dimensional ISLS models that do not account for money, based on Euler equations (27)–(29). As before, the overidentifying restrictions of the model are strongly rejected. Note also that the exclusion of money from the two-dimensional model greatly affects the estimates of σ, which are now unstable. Indeed, estimates of σ are 51.580 with the risky assets, 4.106 with the riskless assets, and 19.657 with riskless and risky assets held jointly.

Thus, these findings provide indirect empirical support to the claim that the two dimensions of leisure and the presence of real money balances in the utility function are key factors that contribute to the empirical success of the two-dimensional ISLS model with money.

5. Intertemporal Elasticities

Using the estimates reported in Table 1 of the two-dimensional ISLS models with money, we calculate the short-run elasticities of consumption, weekly hours worked, weeks worked, and real money balances with respect to transitory movements in wage rates, asset returns, and prices. To compute these elasticities, we assume that transitory changes in wages, asset returns, and prices have only one-period effects. MaCurdy (1981) assumes that an unanticipated transitory change in the wage rate triggers a wealth effect. Under the assumption that the wealth effect is negligible and has no long-run effect, however, McLaughlin (1995) shows that the constant elasticity of marginal wealth (λ-constant elasticity) is equivalent to the short-run, compensated elasticity of substitution.[16]

Assuming a deterministic environment and a small wealth effect, the elasticities can

[16]With transitory shocks, infinite lifetime, and a low discount rate, which are features of our model, the wealth effect is indeed negligible.

be derived as in Mankiw, Rotemberg, and Summers (1985) and McLaughlin (1995).[17] The Euler equations are first transformed into log-linear systems, and are then differentiated with respect to the log of endogenous and exogenous variables. This gives the following short-run, intertemporal substitution matrix:

$$\left(\frac{\partial \ln y_t}{\partial \ln x_t}\right) = \left(\frac{\partial \ln q_t}{\partial \ln y_t}\right)^{-1} \left(\frac{\partial \ln q_t}{\partial \ln x_t}\right),$$

where y_t is a vector of endogenous variables such that $y_t = (c_t,\ m_t,\ h_t,\ e_t)'$; vector $x_t = (w_t,\ r_{jt+1},\ p_t)'$ is composed of exogenous variables, and vector q_t contains the Euler equations.

Table 3 reports the intertemporal elasticities that are based on the estimates of the two-dimensional ISLS models with money. The estimated short-run elasticities are generally lower than unity, except for the weekly hours of work and the total hours worked. The signs of the elasticities are what the theory predicts.

A transitory rise in wages generates an increase in consumption, weekly hours worked, weeks worked, and real money balances. The wage elasticity of weekly hours worked is in the range of 1.454–1.724 with wage rate w_1, and 1.235–1.444 with w_2. The wage elasticity of working weeks is between 0.360 and 0.426 with w_1, and 0.305 and 0.357 with w_2.

Combining the two elasticities for the weekly hours worked and the working weeks, the wage elasticity of total hours worked falls in the range of 1.814–2.150 with w_1, and 1.540–1.809 with w_2. These elasticities are much higher than those previously reported in the literature using aggregate time-series data.

A transitory increase in asset returns raises labour supply, while reducing both consumption expenditures and real money balances. The asset-return elasticity of total

[17]With this assumption, there is certainty equivalence in the Euler equations, which allows us to ignore the expectation operator (Mankiw, Rotemberg, and Summers 1985; Alogoskoufis 1987).

hours worked lies between 0.476 and 0.634 with w_1, and between 0.268 and 0.288 with w_2. These elasticities are consistent with those obtained by Alogoskoufis (1987).

6. Conclusion

The hypothesis of intertemporal substitution in labour supply has not been very successful when confronted with aggregate time-series data. The findings reported in this paper suggest that some credibility in the ISLS hypothesis may be restored if the representative household enjoys leisure both at the intensive and extensive margins, and if the two-dimensional labour supply framework is adapted to an environment with money, as initially proposed by Lucas and Rapping (1969) and Lucas (1972).

Future work should allow for non-separability of preferences that would accommodate either intertemporal substitution or complementarity of leisure using a two-dimensional framework of the kind we have proposed in this paper.

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Table 1:
Estimates of the Two-Dimensional ISLS Models with Money

	β	α_c	α_{l1}	α_{l2}	α_m	σ	J-stat.
	A. Euler equations with risky asset return (r_{st})						
w_1	0.9971	0.3308	0.3380	0.3289	0.0023	3.8798	27.87
	(0.005)	(0.171)	(0.138)	(0.054)	(0.0012)	(1.778)	(0.22)
w_2	0.9991	0.3100	0.3576	0.3304	0.0021	5.8916	26.99
	(0.005)	(0.104)	(0.085)	(0.033)	(0.0007)	(1.916)	(0.25)
	B. Euler equations with riskless asset return (r_{bt})						
w_1	1.0078	0.4427	0.2197	0.3358	0.0018	3.8996	28.85
	(0.002)	(0.221)	(0.196)	(0.055)	(0.0009)	(1.807)	(0.068)
w_2	1.0092	0.3149	0.3522	0.3316	0.0012	5.9384	26.50
	(0.002)	(0.093)	(0.079)	(0.0320)	(0.0003)	(1.927)	(0.12)
	C. Euler equations with both asset returns (r_{st} and r_{bt})						
w_1	1.0073	0.4651	0.2152	0.3176	0.0013	4.0440	38.14
	(0.001)	(0.203)	(0.185)	(0.037)	(0.0004)	(1.560)	(0.247)
w_2	1.0086	0.3903	0.2922	0.3158	0.0016	5.4495	35.55
	(0.001)	(0.110)	(0.095)	(0.028)	(0.0005)	(1.532)	(0.349)

Notes: Standard errors are in parentheses. P-values are in parentheses under J-statistics; the wage rates w_1 and w_2 are defined in the text. The vectors of instrumental variables, z_t, used to estimate the models are: in A, $z_t = (1, Rc_t, Rm_t, Rl_{1t}, Rl_{2t}, \frac{r_{st}}{Rc_t Rp_t}, \frac{1}{Rc_t Rp_t})'$; in B, $z_t = (1, Rc_t, Rm_t, Rl_{1t}, Rl_{2t}, \frac{r_{st}}{Rc_t Rp_t})'$; in C, z_t=$(1, \frac{1}{Rc_t Rp_t}, Rc_t, Rm_t, Rl_{1t}, Rl_{2t})'$.

Table 2:
Estimates of Alternative ISLS Models

	β	α_c	α_{l1}	α_{l2}	α_m	α_l	σ	J-stat.
				A. Standard ISLS model				
r_s	1.0069	0.4143	-	-	-	0.5857	1.7980	27.28
	(0.030)	(0.201)				(0.201)	(19.26)	(0.0001)
r_b	1.0129	0.2272	-	-	-	0.7728	10.156	26.80
	(0.005)	(0.053)				(0.054)	(4.731)	(0.0001)
$r_{s,b}$	0.9974	0.2942	-	-	-	0.7058	-2.558	28.46
	(0.005)	(0.139)				(0.140)	(4.52)	(0.0008)
				B. One-dimensional ISLS model with money				
r_s	0.9913	0.0438	-	-	0.0055	0.9517	-2.7282	36.70
	(0.009)	(0.447)			(0.057)	(0.478)	(7.4111)	(0.0008)
r_b	1.0098	0.3227	-	-	0.0006	0.6772	6.8063	33.10
	(0.0003)	(0.070)			(0.0001)	(0.070)	(2.762)	(0.0005)
$r_{s,b}$	0.9914	0.2142	-	-	0.0005	0.7857	-6.9859	35.48
	(0.005)	(0.060)			(0.0001)	(0.060)	(4.086)	(0.0034)
				C. Two-dimensional ISLS model (no money)				
r_s	1.0685	0.3718	0.3620	0.3200	-	-	51.580	25.61
	(0.022)	(0.129)	0.068	(0.033)			(23.61)	(0.007)
r_b	1.0057	0.2708	0.3367	0.3925	-	-	4.1062	25.35
	(0.002)	(0.150)	(0.141)	(0.052)			(2.049)	(0.008)
$r_{s,b}$	1.0255	0.3154	0.3441	0.3405	-	-	19.657	30.63
	(0.003)	(0.085)	(0.073)	(0.029)			(7.948)	(0.060)

Notes: Standard errors are in parentheses. P-values are in parentheses under J-statistics; the wage rate is w_1, defined in the text. The instrumental variables used to estimate the alternative models are taken from the following set of variables: $\{1, \frac{r_{jt}}{Rc_t Rp_t}, \frac{1}{Rc_t Rp_t}, Rc_t, Rl_t, Rl_{1t}, Rl_{2t}, Rm_t\}$, $j = b, s$, and $Rx_t = x_t / x_{t-1}$.

Table 3:
Elasticities Implied by the Two-Dimensional ISLS Models with Money

		A. Risky return, r_{st}			*B. Riskless return, r_{bt}*			*C. Both return rates*		
		w_t	r_{t+1}	p_t	w_t	r_{t+1}	p_t	w_t	r_{t+1}	p_t
c_t	w_1	0.495	-0.176	-0.753	0.413	-0.148	-0.669	0.402	-0.132	-0.649
	w_2	0.571	-0.080	-0.741	0.568	-0.076	-0.737	0.500	-0.075	-0.680
m_t	w_1	0.495	-47.85	-0.753	0.413	-80.76	-0.669	0.402	-117.4	-0.649
	w_2	0.571	-51.41	-0.741	0.568	-92.18	-0.737	0.500	-83.29	-0.680
h_t	w_1	1.454	0.508	-0.712	1.690	0.428	-0.952	1.724	0.382	-1.011
	w_2	1.235	0.231	-0.746	1.242	0.220	-0.757	1.444	0.215	-0.922
e_t	w_1	0.360	0.126	-0.176	0.418	0.106	-0.235	0.426	0.094	-0.250
	w_2	0.305	0.057	-0.184	0.307	0.054	-0.187	0.357	0.053	-0.228
$e_t h_t$	w_1	1.814	0.634	-0.888	2.108	0.534	-1.187	2.150	0.476	-1.261
	w_2	1.540	0.288	-0.930	1.549	0.274	-0.944	1.809	0.268	-1.150

Notes: The elasticities are calculated using the estimates of the two-dimensional ISLS model with money reported in Table 1; the wage rates w_1 and w_2 are defined in the text.

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