



American Finance Association

Decision Frequency and Synchronization Across Agents: Implications for Aggregate Consumption and Equity Return

Author(s): Anthony W. Lynch

Source: *The Journal of Finance*, Vol. 51, No. 4 (Sep., 1996), pp. 1479-1497

Published by: Blackwell Publishing for the American Finance Association

Stable URL: <http://www.jstor.org/stable/2329401>

Accessed: 25/11/2009 10:19

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at <http://www.jstor.org/page/info/about/policies/terms.jsp>. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at <http://www.jstor.org/action/showPublisher?publisherCode=black>.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.



Blackwell Publishing and American Finance Association are collaborating with JSTOR to digitize, preserve and extend access to *The Journal of Finance*.

<http://www.jstor.org>

Decision Frequency and Synchronization Across Agents: Implications for Aggregate Consumption and Equity Return

ANTHONY W. LYNCH*

ABSTRACT

This article examines a model in which decisions are made at fixed intervals and are unsynchronized across agents. Agents choose nondurable consumption and portfolio composition, and either or both can be chosen infrequently. A small utility cost is associated with both decisions being made infrequently. Calibrating returns to the U.S. economy, less frequent and unsynchronized decision-making delivers the low volatility of aggregate consumption growth and its low correlation with equity return found in U.S. data. Allowing portfolio rebalancing to occur every period has a negligible impact on the joint behavior of aggregate consumption and returns.

A CORNERSTONE OF MODERN asset pricing theory is the intertemporal capital asset pricing model (I-CAPM) of Merton (1973) which assumes that individuals make consumption and portfolio-rebalancing decisions continuously. In a representative-agent economy, the I-CAPM implies that the Beta with respect to the marginal utility of aggregate consumption can explain the cross-section of expected asset returns (Breedeen (1979) and Grossman and Shiller (1982)). Empirically, this consumption CAPM (C-CAPM) performs poorly for U.S. data (see Hansen and Singleton (1982, 1983) and Breedeen, Gibbons, and Litzenberger (1989)).

In contrast to the behavior implied by Merton's I-CAPM, casual observation suggests that individuals do not make consumption or portfolio rebalancing decisions continuously. Additionally, decision-making does not appear to be synchronized across agents. These two features of consumer behavior are likely to affect the joint distribution of aggregate consumption and stock returns and thus may help to explain the documented deviations from the C-CAPM. Recent research helps us to understand how an individual makes less frequent decisions when confronted by adjustment costs (see Constantin-

* New York University. This article is a revision of a chapter from my PhD thesis at the University of Chicago. My committee members, John Cochrane, Kent Daniel, Eugene Fama, Ken French, Lars Hansen, and especially my chairman George Constantinides are thanked for their comments and encouragement. Pierluigi Balduzzi, Kobi Boudoukh, Steve Davis, Ned Elton, Antti Ilmanen, Johnny Liew, Guillermo Mondino, Matthew Richardson, Thomas Sargent, Robert Whitelaw, and participants at workshops at the University of Chicago, Duke University, University of Illinois at Champaign, Ohio State University, Harvard University, UCLA, University of Southern California, University of Texas at Austin, and New York University provided many helpful comments. The referee and René Stulz, the editor, are thanked for comments that greatly improved the exposition of the article. All remaining errors are mine.

ides (1986) and Davis and Norman (1990) for portfolio rebalancing, and Grossman and Laroque (1990) for durable goods purchases). However, it is difficult to characterize aggregate behavior and the cross-section when individuals are using these state-dependent decision rules (see Caballero (1992) and (1993) for recent progress on these issues).

This article considers a stylized model in which the consumption and portfolio composition decision intervals of individuals are assumed to be constant through time (though not necessarily the same), possibly longer than one period, and not synchronized across agents.¹ In contrast to the transaction cost models mentioned above, characterizing the cross-section is straightforward, as individuals fall into classes that depend on when they make decisions. The cross-sectional distribution allows the separate effects of less frequent decision-making and of nonsynchronicity on the joint distribution of aggregate consumption and asset returns to be assessed. The decision structure preserves the model's tractability irrespective of whether both consumption and portfolio rebalancing decisions are made infrequently or only one is made infrequently. The article focuses on a version of the model in which both decisions are made infrequently (the staggered decision interval (SDI) model).

Although not modeled explicitly, constant decision intervals arise when it is costly to gather information and solve optimization problems. Duffie and Sun (1990) present a model of this type and show that if utility is of the power form, the risky asset return follows a geometric Brownian motion and transaction costs are proportional to wealth, the optimal decision interval is a constant. This type of decision structure can be contrasted with the state-dependent decision structures discussed above, which are induced by costless information processing and proportional adjustment costs. My model assumes people minimize information processing costs by reacting to wealth shocks only at fixed intervals. In contrast, these models assume people continually update their wealth in deciding whether to make an adjustment. Little evidence exists as to which is a better descriptor of individual behavior.

Although there are common forces causing individuals' behavior to be synchronized, the model recognizes that idiosyncratic considerations cause some people to be out of synch with the majority. For example, agents may make annual decisions after annual income shocks, which occur in different months across individuals. Also, individuals receiving a tax refund prefer to make decisions in January, while those owing taxes wait until April. Although the SDI economy considered below treats the decision classes symmetrically, it would be straight-forward to allow the classes to be of unequal sizes. Doing so would introduce seasonality into consumption moments and could potentially explain the seasonal patterns which exist in U.S. nonseasonally-adjusted consumption numbers (see Ferson and Harvey (1992)).

¹ Although addressing a different set of issues, this model is in the spirit of Rotemberg (1984) and Grossman and Weiss (1983) who examine the effects of monetary policy using a model in which individuals visit the bank infrequently and in a staggered fashion.

The article presents several new results that are obtained by simulating economies with linear production technologies. Throughout, the processes followed by the risky return and the riskless rate remain the same and are calibrated to the U.S. economy. The first result concerns the effect of infrequent and unsynchronized decision-making on the relation between aggregate consumption and risky asset returns. Less frequent and unsynchronized consumption and rebalancing decision-making (the SDI model) causes reductions in the volatility of aggregate consumption growth at monthly frequencies and in its correlation with equity return at monthly, quarterly, and annual frequencies. With a relative risk aversion coefficient of 10, the volatility of monthly aggregate consumption growth is lower than the data for a decision interval as short as 6 months. The implication is that this model can explain the equity premium puzzle documented for the U.S. economy (Mehra and Prescott (1985)).²

The second result (documented in an appendix available from the author) relates to the separate effects of consumption and portfolio rebalancing decisions being made infrequently. If only the consumption decision is made less frequently, the moments for aggregate consumption growth are virtually identical to those obtained when both decisions are made less frequently. Conversely, if only the portfolio rebalancing decision is made infrequently, the moments are similar to those obtained when both decisions are made every period.

Third, the incremental impact of the nonsynchronicity is directly assessed by comparing the moments for aggregate consumption growth in an SDI model with those for the consumption of a chosen class in the same economy. Decision nonsynchronicity across agents is found to cause volatility reductions at low frequencies.

Fourth, the article considers the impact of less frequent and unsynchronized decision-making in an SDI model, as the data frequency is varied relative to the decision interval. For a given decision interval, the largest volatility reductions (relative to the monthly decision-making case) are for the highest frequency data, with the reductions declining to almost zero as the data frequency approaches the decision interval. In contrast, the corresponding reductions in aggregate consumption growth's correlation with risky asset return are large for all data intervals shorter than or equal to the decision interval. For data intervals longer than the decision interval, the correlation reductions slowly become smaller as the data interval increases.

² The equity premium puzzle says that aggregate consumption is too smooth and not sufficiently correlated with equity returns to explain the magnitude of the equity premium for reasonable relative risk aversion values. Grossman and Laroque (1990) were the first to use consumption adjustment costs (specifically for durable goods) to generate an equity premium puzzle. Other explanations include borrowing and short sale restrictions and asset market transaction costs (see He and Modest (1995), Luttmer (1992), and Cochrane and Hansen (1992)), and idiosyncratic and uninsurable labor income risk (see Mankiw (1986), Lucas (1994), Telmer (1993), and Heaton and Lucas (1994)).

The fifth result pertains to the impact on low frequency data when agents in a representative-agent economy (RA model) make decisions more frequently than the measurement interval. It is found that when agents make decisions monthly rather than annually, the volatility of annual aggregate consumption growth declines by about 20 percent. This percentage decline can be viewed as a direct measure of the effect of temporal aggregation.³

Finally, the utility cost of less frequent consumption and portfolio rebalancing decision-making is found to be very small. If an individual was making decisions every 6 (12) months, she would not give up more than 0.5 percent (1 percent) of her wealth as a once-only cost to be allowed to make decisions every month. Importantly, very small costs are associated with decision intervals that are able to significantly reduce aggregate consumption growth volatility and its correlation with equity return.⁴

The model presented in this article has several potential applications. The asset pricing implications are susceptible to empirical testing using aggregate consumption (see Lynch (1994) for a discussion and some results). As discussed above, seasonalities in consumption can be generated by such a model. Finally, the model is likely to be useful for analyzing the impact of infrequent and unsynchronized decision-making on monthly asset return autocorrelations.

The article is organized as follows. Section I describes the economy that is calibrated, while simulation details and the data used to calibrate the economy are described in Section II. The issues addressed and the simulation results are presented in Section III. Section IV considers the utility cost of less frequent decision-making. Section V concludes.

I. The Models

The next subsection describes the overlapping generations staggered decision interval (SDI) economy, while the second subsection describes the analogous representative-agent (RA) economy. Throughout the analysis the temporal unit of measure is a month; so one period is equal to one month.

A. An Overlapping Generations Staggered Decision Interval (SDI) Model

In the SDI economy, each agent makes consumption and portfolio rebalancing decisions every T periods, but decision-making is not synchronized across agents. Consequently, there are T classes of agent where class membership depends on when an individual makes her decisions. Figure 1 shows the decision timing for each of the T classes. With $T = 1$ in this model, nonsyn-

³ Temporal aggregation has also been considered by Christiano, Eichenbaum, and Marshall (1991), Ermini (1989a and b), Grossman, Melino, and Shiller (1987), Heaton (1993), and Longstaff (1989).

⁴ See Caballero (1992), Cochrane (1989), and Marshall (1993) who present utility cost calculations for various forms of near rationality and Constantinides (1986), who examines the impact of proportional asset market transaction costs on an individual's utility.

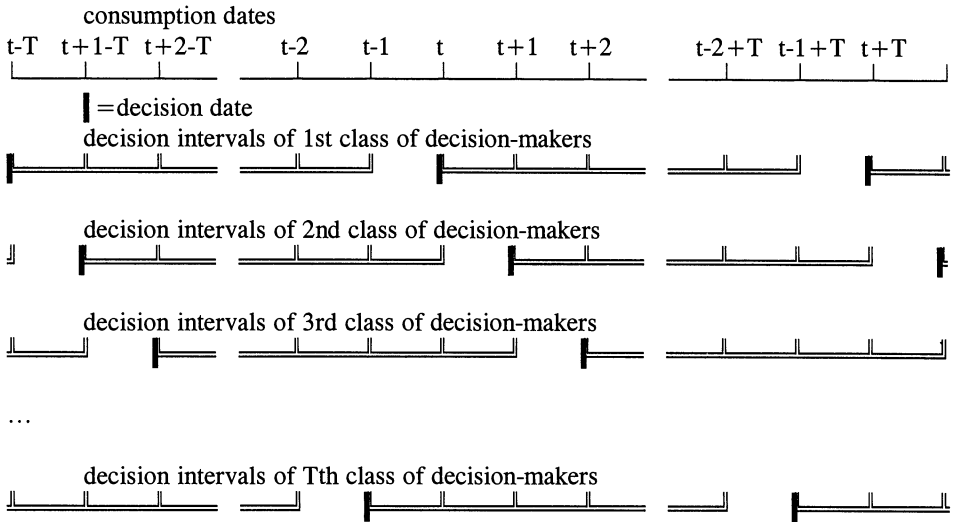


Figure 1. Decision structure in the overlapping generations SDI model with decision interval of T and so T classes of individuals.

chreoneity disappears and is replaced by a monthly decision-making representative-agent.

An overlapping-generations-style economy is specified in which each individual has a finite life of L periods. So each individual makes L/T decisions in her lifetime. The number of investors that are alive at any point in time is also L . Each period one individual dies and is replaced by a newborn.⁵ The starting wealth for newborn individuals grows deterministically at a rate g per period ensuring a stationary distribution for aggregate consumption growth.⁶

The key feature of the consumer's problem is that consumption and portfolio rebalancing decisions are made simultaneously every T periods. Consumption within a decision interval is determined at the start of the interval while portfolio rebalancing only occurs at the start of an interval. In particular, individuals consume out of the riskless asset within each decision interval.

More formally, the power utility individual born at t solves the following problem:

$$\max \left\{ E_t \left[\sum_{q=0}^{L-1} \beta^q \frac{1}{1-\gamma} [c(t+q)]^{1-\gamma} \right] \right\} \quad (1)$$

⁵ Individuals are indexed by $i = 0, 1, 2, \dots, T-1$ (an individual's decision-making class) and by $\ell = 0, 1, 2, \dots, (L/T)-1$ (an individual's generational class). An individual of type (i, ℓ) is born at $wL + \ell T + i$ for each w an integer, and then makes decisions at (L/T) points in time, each T apart: $wL + \ell T + i, wL + (\ell+1)T + i, \dots, wL + \ell T + L - T + i$. At any point in time there is one individual of each type alive.

⁶ While the starting wealth of the newborn can be denoted by $[W(0)g^t]$, consumption growth rates do not depend on the assumed value of $W(0)$.

with respect to

$$\{c(t + q)\}_{q=0}^{L-1}, \quad \text{and} \quad \{\alpha(t + jT)\}_{j=0}^{(L/T)-1} \quad (2)$$

and subject to

$$c(t + jT + \hat{q}) \in \mathcal{F}(t + jT),$$

$$\hat{q} = 0, 1, \dots, T - 1 \quad \text{and} \quad j = 0, 1, \dots, (L/T) - 1,$$

$$\alpha(t + jT) \in \mathcal{F}(t + jT), \quad j = 0, 1, \dots, (L/T) - 1, \quad (3)$$

$$W(t + [j + 1]T) = [W(t + jT) - \hat{c}(t + jT)] \\ \cdot [\alpha(t + jT)(R^z(t + jT, \quad t + [j + 1]T) - R^T) + R^T], \quad (4)$$

and

$$\hat{c}(t + jT) = \sum_{\hat{q}=0}^{T-1} R^{-\hat{q}} c(t + jT + \hat{q}) \quad \text{for} \quad j = 0, 1, 2, \dots, (L/T) - 1, \quad (5)$$

where $\gamma > 0, \neq 1$ is the relative risk aversion (RRA) coefficient, $\beta > 0$ is the rate of time preference, the riskless rate R is constant, the risky asset return R^z is i.i.d., $\mathcal{F}(t)$ is the filtration generated by $\{R^z(t - 1, t), R^z(t - 2, t - 1), \dots\}$ and starting wealth $W(t)$ is $[W(0)g^t]$. Equation (2) describes the individual's choice variables. The individual consumes in every period of her life but only rebalances her portfolio when she makes a decision. This explains why equation (2) has L consumption numbers ($c(t + q)$ for $q = 0, 1, \dots, L - 1$) but only (L/T) portfolio weights ($\alpha(t + jT)$ for $j = 0, 1, \dots, L/T - 1$).

With respect to restriction (3), $\mathcal{F}(t + jT)$ is the information available at the time of the individual's $(j + 1)$ th decision and $c(t + jT)$, $c(t + jT + 1)$, $\dots$ and $c(t + jT + T - 1)$ are the individual's consumptions for the T months following her $(j + 1)$ th decision. Consequently, this restriction says that consumption within a decision interval is only measurable with respect to information available at the interval's start, which formalizes the notion that consumption within a decision interval is decided at the interval's start. Restriction (4) is the wealth evolution equation, while restriction (5) formalizes the idea that individuals consume out of the riskless asset within a decision interval: $\hat{c}(t + jT)$ is set aside at the time of the $(j + 1)$ th decision for consumption until the next decision, and this amount accumulates at the riskless rate R .

The solution to this problem applies standard results for the constant opportunity set problem with constant RRA utility (see Ingersoll (1987)). Details are presented in the appendix.

B. An Overlapping Generations Representative Agent (RA) Model

Consider an economy in which only one of the T decision-making classes described above exists. Aggregate consumption in this economy equals the consumption of the chosen class in the SDI economy. This new economy is an overlapping generations RA economy in which all agents make decisions at the same time every T periods. When $T = 1$, the RA and SDI economies are the same.

II. The Calibration Exercise

The next section describes the data used to calibrate returns, while the subsequent section presents details of how the various economies are simulated.

A. Data Used to Calibrate Returns

The sample moments used to calibrate the binomial process for the risky asset are calculated for the monthly real return on a value weighted New York Stock Exchange (NYSE) index derived from the Center for Research in Security Prices (CRSP) index files. The real riskless rate is estimated using the mean of the month- t return on the shortest term U.S. treasury bill having not less than one month to maturity; this series is obtained from CRSP. For comparison purposes, sample moments for growth in aggregate consumption are also reported. The monthly aggregate consumption series is obtained by deflating monthly nondurable consumption and monthly services consumption by their respective price deflators and by population and then taking the sum. The implicit price deflator for this derived nondurable and services consumption series is also used to deflate the nominal asset returns. Data from 1/59 to 12/91 are then used to calculate moments for NYSE real return and growth in aggregate consumption at monthly, quarterly, and annual frequencies. Results are contained in Table I.

B. Simulation Details

The risky asset's return evolves according to a binomial process with each state equally likely. To match the mean and variance of the NYSE value-weighted index return reported in Table I, the monthly risky asset return takes values of 1.0492 and 0.9615 in the two states. The average real U.S. Treasury bill rate (reported in Table I), which was 1.0011 over the sample period, is used as the riskless rate. The assumed value for the growth of the newborn's initial wealth is 1.002 per month, and a rate of time preference of 1 is used. Five simulations each with 10,000 usable observations are used to calculate the moments for each economy.⁷ The SDI and RA models are both calibrated for RRAs of 5 and 10, and decision intervals of 1, 3, 6, and 12.

⁷ Several simulations are repeated to check the reliability of the results. The estimated moments are virtually identical whenever a simulation is repeated.

Table I

Sample Moments for U.S. Consumption and Asset Return Data

This table lists sample moments for the following U.S. data series over the period 1/59 to 12/91: $R^z(t_1, t_2)$ denotes the real discretely compounded return on a value weighted index of New York Stock Exchange (NYSE) stocks from the end of month t_1 until the end of month t_2 ; $\bar{c}_F(t + 1)$ denotes aggregate per capita real consumption of nondurables and services from month $t + 1$ to month $t + F$; and $R(t)$ is the month- t return on the shortest term U.S. treasury bill having not less than one month to maturity. N is the number of observations.

Sample Moment	<i>F</i>		
	1	3	12
<i>N</i>	395	393	384
$\text{av}[R^z(t, t + F)]$	1.005343	1.01552	1.06512
$\text{std}[R^z(t, t + F)]$	0.04385	0.07812	0.1610
$\text{av}[\bar{c}_F(t)/\bar{c}_F(t - F)]$	1.001628	1.004870	1.02026
$\text{std}[\bar{c}_F(t)/\bar{c}_F(t - F)]$	0.004078	0.004854	0.01237
$\rho[R^z(t, t + F), \bar{c}_F(t + 1)/\bar{c}_F(t + 1 - F)]$	0.1289	0.1605	-0.0315
$\text{av}[R(t)]$	1.001087		

It is worth noting that the calibration exercise specifies an exogenous return process and then solves for consumption. Thus, the calibration framework is in the spirit of Constantinides (1990) and can be contrasted with the alternate approach of specifying the endowment process exogenously and solving for the market-clearing prices (see, for example, Mehra and Prescott (1985)). However, the approach described above can be put in a general equilibrium framework by saying that there are two linear technologies, one riskless and the other risky, both in perfectly elastic supply.

A final issue is the calculation of moments in the overlapping generations RA model. Suppose that the agents in this model make decisions every T periods at $t + 1, t + 1 + T, t + 1 + 2T, \dots$ and let $\bar{c}_F(t + 1)$ be the sum of aggregate consumption from time $(t + 1)$ to time $(t + F)$ where F is an integer multiple of T . The unconditional moments for $\bar{c}_F(t + 1)/\bar{c}_F(t + 1 - F)$ differ from those for $\bar{c}_F(t + 1 + \zeta)/\bar{c}_F(t + 1 + \zeta - F)$ for any $\zeta = 1, \dots, T - 1$. Table II reports moments of $\bar{c}_F(t + 1)/\bar{c}_F(t + 1 - F)$ for F , an integer multiple of T . Matching the consumption interval to the decision interval in this manner is consistent with the econometrician knowing when decisions are made and only using consumption numbers over intervals that coincide with the decision intervals of the agents.

III. Calibration Results

The major issue addressed by the calibrations is the impact of unsynchronized and less frequent decision-making on aggregate consumption growth volatility and its correlation with equity return. For a given data frequency, this joint impact can be assessed by examining the behavior of these moments for the SDI model of Section I.A as the decision interval T is increased. Table

Table II
Moments for Aggregate Consumption Growth in Overlapping
Generations SDI and RA Economies

In both economies, power utility individuals who live for 240 months make consumption and portfolio composition decisions every T months. In the SDI economy, decision-making is not synchronized across individuals, while in the RA economy all individuals make decisions at the same time. Newborn's initial wealth endowment grows at 0.2 percent per month in both economies. In the SDI economy, the oldest individual who would otherwise be making a decision dies each month and is replaced by a newborn. In the RA economy, an individual dies and is replaced by a newborn every T months at the time of each decision. For both economies, the riskfree rate and parameters of the binomial process for the risky asset are chosen to match the sample moments for the U.S. economy over the period 1/59–12/91 (see Table I). Results are based on 5 simulations of 10,000 observations. γ is the RRA coefficient, and a rate of time preference of 1 is used. $1/F$ is the data frequency. $R^z(t, t + F)$ is risky asset return from t to $(t + F)$. For both economies, moments are calculated for $\bar{c}_F(t + 1)$ which is the sum of aggregate consumption from time $(t + 1)$ to time $(t + F)$. So in the RA economy, decisions are made at $(t + 1)$, $(t + 1 + T)$, $\dots$. Let $\sigma_c(\gamma, T, F)$ denote $\sigma[\bar{c}_F(t + 1)/\bar{c}_F(t + 1 - F)]$ and $\rho_{cz}(\gamma, T, F)$ denote $\rho[R^z(t, t + F), \{\bar{c}_F(t + 1)/\bar{c}_F(t + 1 - F)\}]$.

Parameters			Moments			
			RA Economy		SDI Economy	
γ	T	F	$\sigma_c(\gamma, T, F)$	$\rho_{cz}(\gamma, T, F)$	$\sigma_c(\gamma, T, F)$	$\rho_{cz}(\gamma, T, F)$
5	1	1	0.0195	0.998	0.0195	0.998
		3	0.0281	0.789	0.0281	0.789
		12	0.0559	0.655	0.0559	0.655
	3	1	****	****	0.0112	0.573
		3	0.0337	0.333	0.0258	0.486
		12	0.0578	0.554	0.0566	0.570
	6	1	****	****	0.0079	0.403
		3	****	****	0.0210	0.284
		12	0.0585	0.357	0.0535	0.431
	12	1	****	****	0.0056	0.286
		3	****	****	0.0161	0.196
		12	0.0708	0.053	0.0514	0.272
10	1	1	0.0097	0.998	0.0097	0.998
		3	0.0141	0.789	0.0141	0.789
		12	0.0280	0.653	0.0280	0.653
	3	1	****	****	0.0056	0.574
		3	0.0170	0.335	0.0129	0.489
		12	0.0289	0.554	0.0283	0.567
	6	1	****	****	0.0039	0.405
		3	****	****	0.0105	0.292
		12	0.0294	0.379	0.0269	0.439
	12	1	****	****	0.0028	0.285
		3	****	****	0.0081	0.199
		12	0.0348	0.082	0.0258	0.285

II contains moments for both the overlapping generations SDI and RA economies described in Section I. The moments for the RA economy can be used to decompose the joint effects of unsynchronized and less frequent decision-making into the separate effects of each and to measure the impact of temporal aggregation.⁸

While both consumption and portfolio rebalancing decisions are made less frequently in the SDI economy described above, an appendix available from the author contains results for overlapping generations staggered decision-making economies in which only one of the consumption and portfolio rebalancing decisions is made infrequently. When only the consumption decision is made infrequently, the moments are similar to those obtained for the SDI economy in which both decisions are made infrequently. On the other hand, when only portfolio rebalancing is performed infrequently, the moments are similar to those obtained when both decisions are made every month. These (unreported) results indicate that the less frequent consumption decision-making and not the less frequent portfolio rebalancing is driving the volatility and correlation reductions (relative to the $T = 1$ case) discussed below for the SDI economy.

A. Volatility of Aggregate Consumption Growth

Table II contains aggregate consumption growth volatility (labeled σ_c) for the overlapping generations SDI economy described in Section I.A. As the decision interval is increased for a given value of the RRA coefficient, the standard deviation of monthly aggregate consumption growth is decreasing. As expected, a negative relation exists between the RRA coefficient (γ) and the variability of aggregate monthly consumption growth. For two specifications ($\{\gamma = 10, T = 6\}$, $\{\gamma = 10, T = 12\}$), the standard deviation from the SDI model is less than the sample estimate for the U.S. economy in Table II. This result suggests that infrequent and unsynchronized decision-making by agents may be at least a partial cause of the lack of volatility of monthly aggregate consumption growth.

The results in Table II show that the impact of less frequent and unsynchronized decision-making on annual consumption growth moments is very different from its impact on monthly moments. Increasing the decision interval from one month to one year has almost no impact on the volatility of annual consumption growth.

This inability to reduce annual aggregate consumption growth volatility is likely due to decision intervals greater than a year not being considered. The evidence supporting this contention is contained in Figure 2, which reports consumption growth standard deviations for the SDI model ($RRA = 5$) as the data interval F is varied from 1 to 12 months by monthly increments. Relative to the $T = 1$ case, less frequent decision-making causes volatility reductions

⁸ These moments are virtually identical to those obtained using an infinitely-lived representative agent with the same RRA coefficient. The implication is that the assumed lifespan for agents in the overlapping generations model is not an important determinant of the reported results.

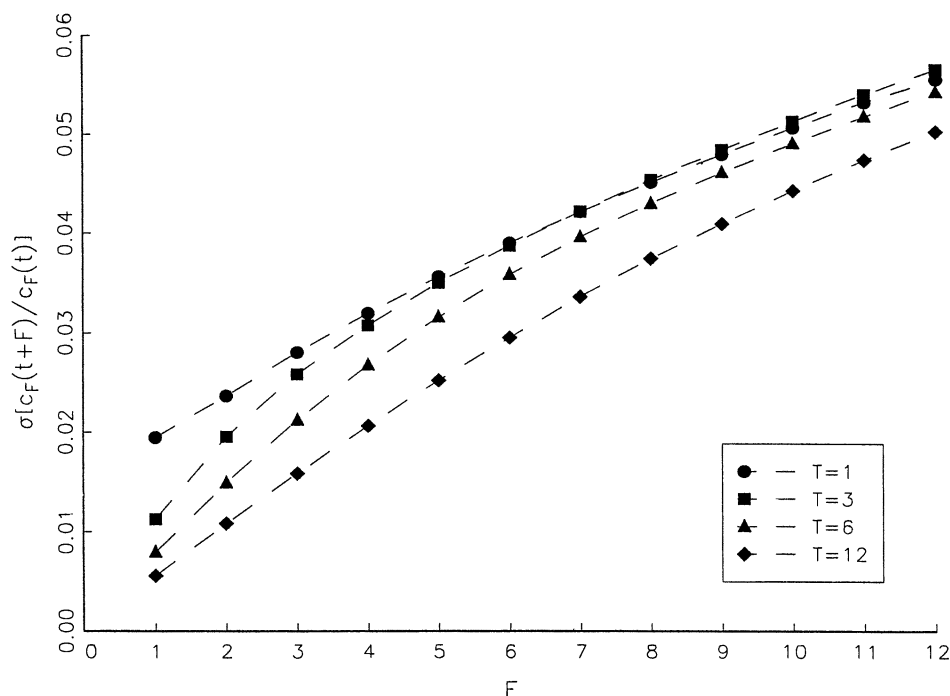


Figure 2. Volatility of aggregate consumption growth in an overlapping generations SDI model. Effect of varying the data interval (F) and decision interval (T) in the model described in Section I.A, in which an agent makes her nondurable consumption and portfolio rebalancing decisions simultaneously every T months. $(1/T)$ th of the population makes a decision in any month. Agents have power utility with RRA of 5 and live for 240 months. Each month one individual dies and is replaced by a newborn. The endowment for the newborn grows at a deterministic rate of 0.2 percent per month.

for F less than the decision interval with the reduction largest for $F = 1$ and smallest for F equal to the decision interval. The reason is positive autocorrelation in monthly aggregate consumption growth which is induced by the unsynchronized decision-making and which persists out to longer lags as the decision interval is increased.⁹ The results for $T = 3$ and $F \geq 8$ indicate that

⁹ In the data, monthly aggregate consumption growth has significantly negative first order autocorrelation and significantly positive autocorrelation at only the third and seventh lags. However, incorporating durability into the consumption good is likely to alleviate the positive autocorrelation implied by the SDI model (see Heaton (1993) for an example of durability having this affect). Further, measurement error in the aggregate consumption numbers is likely to generate negative first order autocorrelation in consumption growth and reduce the positive autocorrelation at longer lags (see Wilcox (1992) and Bell and Wilcox (1993) for discussions of the form of the measurement error in U.S. consumption figures and its impact on the time-series properties of consumption growth). A closer examination of the consumption growth autocorrelations implied by the SDI model (incorporating durability and measurement error) is an interesting direction for future research, but is beyond the scope of the current paper.

for F sufficiently large relative to the decision interval, consumption growth volatility exceeds that for the $T = 1$ case.

Thus, Figure 2 indicates that the relative frequency of the data (relative to the decision frequency) is the crucial determinant of less frequent decision-making's impact on aggregate consumption growth volatility. This conclusion, together with Table II, suggests that unless a decision interval longer than a year is considered reasonable, the SDI model is unable to deliver substantial reductions in annual aggregate consumption growth volatility relative to the $T = 1$ case.

Table II also allows the joint effect of less frequent and unsynchronized decision-making on volatility at a given data frequency to be decomposed into the separate effects of each. The decomposition first compares the volatility for the RA economy with a given T to the volatility when $T = 1$. The difference between the two can be treated as the effect of less frequent decision-making. The volatility of annual (quarterly) consumption growth increases by roughly 25 percent (20 percent) when agents make annual (quarterly) rather than monthly decisions. Thus, less frequent decision-making alone increases the volatility of low frequency consumption growth.

The intuition for this result is as follows. Focusing on annual consumption growth, a shorter decision interval allows consumption in the later part of the previous year to be more closely related to consumption in the early part of the current year. When decisions are made annually, none of last year's consumption depends on that year's risky asset return, while all of this year's consumption is affected. Note that this intuition for the volatility increase does not rely on the worsened opportunity set that results from less frequent decision-making.¹⁰

Comparing the RA moments for a given T with the SDI moments for the same T gives the effect of nonsynchronicity. While annual decision-making alone increases the volatility of aggregate annual consumption growth by around 25 percent, an examination of Table II shows that introducing nonsynchronicity reduces the volatility back to a level which is slightly less than for the $T = 1$ case. Since nonsynchronicity implies that people make decisions throughout the year rather than all in the same month, its introduction causes this year's aggregate consumption to become more like last year's, and the annual growth rate's volatility to be reduced. This reasoning explains why nonsynchronicity offsets the impact of less frequent decision-making on the volatility of low frequency aggregate consumption growth.

The decrease in annual consumption growth volatility for the RA economy going from $T = 12$ to $T = 1$ (discussed above) can also be thought of as a measure of the impact of temporal aggregation on the volatility of annual consumption growth.¹¹ However, assuming that decisions are made monthly

¹⁰ This intuition is thus consistent with unreported results mentioned earlier, which indicate that less frequent portfolio rebalancing alone has a negligible affect on consumption volatility.

¹¹ This finding can be distinguished from Grossman, Melino, and Shiller (1987) who consider an individual making decisions continuously and find that the volatility of temporally aggregated

and not annually does not cause annual volatility to decline by enough to mirror the volatility in the data. For a RRA coefficient of 10, reducing the decision interval from a year to a month reduces the standard deviation of annual consumption growth reported in Table II from 0.0348 to 0.0280, which is still more than double the empirical volatility. For monthly and quarterly consumption volatilities, the story is the same, with the empirical volatility being less than half that implied by the $T = 1$ model. These results suggest that temporal aggregation in a RA setting cannot explain the magnitude of the equity premium for reasonable RRA values.¹²

B. Correlation of Aggregate Consumption Growth with Risky Asset Return

Turning to the correlation results in Table II for the SDI economy, the contemporaneous correlation of aggregate consumption growth and risky asset return (labeled ρ_{cz}) is declining in the decision interval at all three frequencies. For a given decision interval, the correlation at each of the frequencies is similar across RRA values. For a decision interval of a year, the correlation is always less than 0.30 for annual and monthly frequencies and less than 0.20 for quarterly. Thus, infrequent and unsynchronized decision-making can at least partially explain the low contemporaneous correlation with equity returns found in the data. Turning to the correlation numbers for the RA economy (also in Table II), large reductions in the low frequency correlations occur going from $T = 1$ to $T = 12$. This result indicates that infrequent trading alone reduces the correlation between aggregate consumption growth and contemporaneous risky asset return.¹³

Figure 3 reports correlations for the SDI model ($RRA = 5$) at data intervals from 1 to 12 months in increments of a month. For each data frequency ($1/F$), the correlation is monotonically declining in the decision interval, a result that is consistent with the Table II results. However, the finer grid for the data frequency allows one to focus on the relation between correlation and data frequency for any given decision interval. For $T = 1$ (the representative-agent case), there is a negative relation between correlation and data interval (F) which is monotonic. For $T > 1$, there is a *U-shaped* relation with correlation highest for the shortest and longest data intervals; further, the data interval with the lowest correlation is increasing in T . Thus, it seems that the introduction of less frequent and unsynchronized decision-making changes the

consumption increases at a slower rate than the time interval over which consumption is aggregated. Their result fixes the decision interval and varies the data interval, while the volatility decrease documented in Table II for the RA economy holds the data interval fixed and decreases the decision interval. To see their result in Table II, vary the data interval (F) for the $T = 1$ case: consumption growth volatility increases at a rate much less than one for one as the data interval is increased.

¹² However, the RA model in this article does not allow agents to make decisions continuously.

¹³ The correlation for the RA economy is not 1 when the data interval equals the decision interval because risky asset return is being matched with contemporaneous rather than future consumption growth. This timing reflects the way returns and consumption are matched empirically.

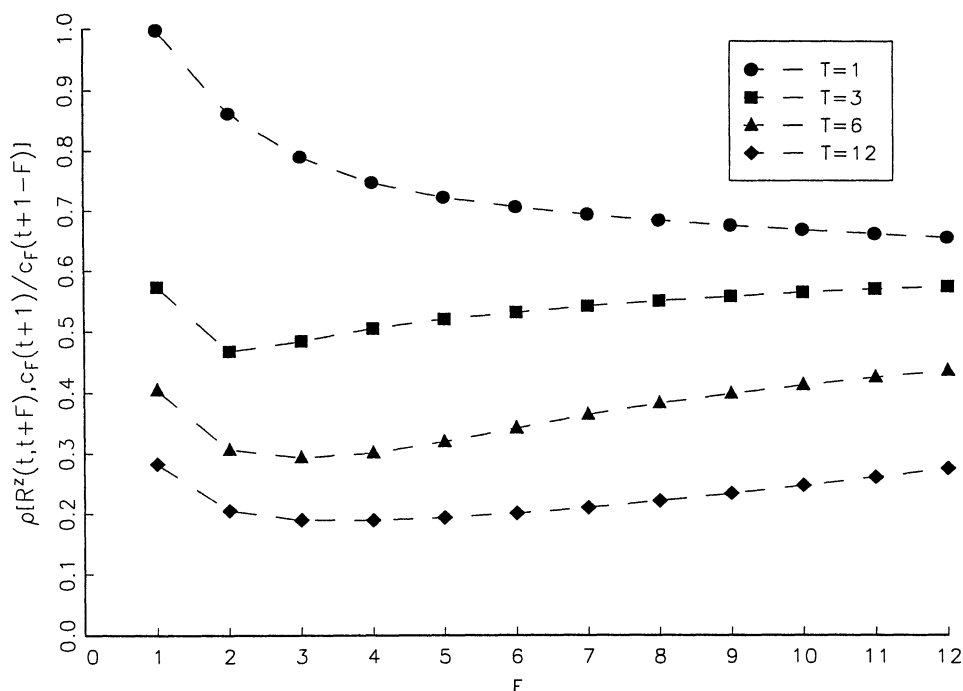


Figure 3. Contemporaneous correlation of aggregate consumption growth and risky asset return in an overlapping generations SDI model. Effect of varying the data interval (F) and decision interval (T) in the model described in Section I.A in which an agent makes her nondurable consumption and portfolio rebalancing decisions simultaneously every T months. $(1/T)$ th of the population makes a decision in any month. Agents have power utility with RRA of 5 and live for 240 months. Each month one individual dies and is replaced by a newborn. The endowment for the newborn grows at a deterministic rate of 0.2 percent per month.

nature of the relation between aggregate consumption growth and asset returns relative to the $T = 1$ case.

IV. The Utility Cost of Less Frequent Decisions

Table III reports the utility cost associated with less frequent decision-making for an infinitely lived, power utility individual with a rate of time preference of 1. The risky and riskless asset return processes are the same as for the calibration work discussed above. By making consumption and portfolio rebalancing decisions every T months, the individual enjoys a certain level of utility that depends on her wealth. If she made decisions every period, she could attain this level of utility with a reduced level of wealth. The reported cost is the fractional reduction in her wealth that would allow her to attain the same level of utility by making decisions every period. For all values of the RRA coefficient and any decision interval up to a year, this fractional cost is

Table III

Cost to an Infinitely-Lived Individual with RRA Coefficient γ of Making Consumption and Portfolio Rebalancing Decisions Every T Months

The riskfree rate and parameters of the binomial process for the risky asset are chosen to match the sample moments for the U.S. economy over the period 1/59–12/91 (see Table I). A rate of time preference of 1 is used.

By making decisions every T months, the individual enjoys a certain level of utility at the time of making a decision which depends on her wealth. If she made decisions every period, she could attain this level of utility with a reduced level of wealth. The reported cost is the percentage reduction in her wealth, which would allow her to attain the same level of utility by making decisions every period.

γ	$T =$			
	1	3	6	12
3	0.00%	0.17%	0.42%	0.92%
5	0.00%	0.13%	0.32%	0.70%
8	0.00%	0.10%	0.25%	0.53%
10	0.00%	0.09%	0.21%	0.46%

less than 1 percent. If the decision interval is restricted to be less than six months, then the fractional utility cost is always less than 0.5 percent.¹⁴

The apparently low utility cost associated with infrequent decision-making supports the plausibility of the argument that costly information processing, transacting, and optimizing could cause individuals to make decisions less frequently. These results complement work by Cochrane (1989), Caballero (1992), and Marshall (1993), whose evidence indicates that the utility cost of near-rational behavior is small. Also, Constantinides (1986) finds that proportional transaction costs in the asset market require a negligible return premium to leave utility unaffected. Proportional transaction costs alone imply a state-dependent decision rule. This section's results suggest that Constantinides' conclusion continues to hold when the decision interval is not allowed to be state-dependent but is instead assumed constant.

V. Concluding Remarks

Casual observation of human behavior suggests people decide infrequently how much to spend on consumption, but are constantly deciding which products are to be consumed with the allocated money. The decision on how much to allocate to consumption depends largely on current wealth and can be a time-consuming activity; people try to behave optimally. Within a decision interval, product choices depend on relative prices, product innovation, and whim, and are made subject to the total within-interval consumption con-

¹⁴ Utility cost as a function of RRA is of the opposite sign to that found by Caballero (1992). He obtains a positive relation because wealth shocks in his model are invariant to RRA, while the portfolio decision in this model implies that portfolio return volatility is decreasing in RRA.

straint; wealth shocks within the interval are largely irrelevant. The staggered decision-making (SDI) model considered in this article captures the essence of this behavior.

When the model is calibrated to U.S. data, the following results emerge. Infrequent decision-making can help explain the low volatility of aggregate consumption growth measured at high frequencies. The volatility reduction is particularly impressive if decision-making is not only infrequent but also unsynchronized across classes of agents. However, unsynchronized and infrequent decision-making has little effect on the volatility of aggregate consumption growth measured at lower frequencies. Annual consumption growth is much higher in the SDI model than in the data. Infrequent decision-making also helps to explain the low contemporaneous correlation between aggregate consumption growth and equity return. The correlation reduction does not depend on nonsynchronicity in decision-making; in fact, it is slightly more impressive when agents make synchronized decisions.

Reider (1994) examines what happens when consumption services from a Grossman-Laroque durable good are only a fraction of measured consumption and the remainder is nondurables. If the nondurables consumption is being adjusted continuously, the ability of a durable good transaction cost to deliver an equity premium with respect to measured consumption is severely reduced. One of the main themes of this article is that less frequent and unsynchronized consumption *nondurables* decision-making by individuals may be an important reason for the smoothness of aggregate consumption (particularly at high frequencies) and its lack of correlation with risky asset returns. Thus, the article complements the work of Grossman and Laroque and indicates that Reider's results do not hold if nondurable consumption decisions are made infrequently.

The model also complements Caballero's (1992) investigation of the behavior of aggregate nondurables consumption in the presence of near-rational behavior by agents. He assumes that individuals use a state-dependent adjustment rule with respect to nondurables consumption, while I consider a model in which individuals make decisions at fixed intervals. Both models are able to explain aspects of the U.S. data that are puzzling within the frictionless market, representative agent paradigm.

Further work is needed to empirically discriminate between these two models, and such efforts would seem worthwhile. In contrast to representative-agent models with decision-making every period, models with consumption decision-making frictions are able to deliver the low contemporaneous correlation between aggregate consumption and asset returns found in the data. Important recent work by Campbell and Cochrane (1994) considers a representative-agent model in which utility exhibits slowly moving habit. They are able to explain the equity premium and many other features of the data including return predictability. However, the one feature left unexplained is the low correlation of aggregate consumption with stock returns.

Another theme of this article is that nonsynchronicity of decision-making has distinct effects from those of less frequent decision-making. Thus, the time

series properties of consumption depend on both decision frequency and degree of synchronization across agents. For example, given a decision interval of a year, aggregate consumption is likely to behave very differently depending on whether one-twelfth of the population make a decision each month, or 90 percent make their decision in January. In particular, the nature of the seasonality in aggregate consumption would be affected.

An interesting feature of the SDI model presented in this paper is its potential to be tested using aggregate consumption data. The decision structure allows the marginal rate of substitution of the class determining prices each period to be expressed as a function of parameters, current and past aggregate consumption, interest rates, and an initial condition. There are some difficult econometric issues involved in estimating this type of model, but some preliminary work is contained in Lynch (1994).

Finally, the SDI model seems well suited for trying to explain monthly stock return behavior, particularly the documented autocorrelation behavior. Such an exploration would involve calibrating an economy where prices are determined endogenously. Performing this calibration is work in progress.

Appendix: Solution for the Overlapping Generations SDI Economy

As mentioned above, the individual's problem in the SDI economy of Section I.A has a closed-form solution. The solution for the individual born at t is given by:

$$E_{t+jT}[y^T(t + [j + 1]T)]^{-\gamma}(R^z(t + jT, t + [j + 1]T) - R^T) = 0, \\ \text{for } j = 0, 1, \dots, L/T - 1; \quad (6)$$

where:

$$y^T(t + [j + 1]T) = \alpha(t + jT)(R^z(t + jT, t + [j + 1]T) - R^T) + R^T;$$

and

$$W(t + jT) = W(t) \prod_{k=1}^j (1 - \alpha_{k-1}^T) y^T(t + kT)$$

$$\hat{c}(t + jT) = \alpha_j^T W(t + jT)$$

$$c(t + jT + \hat{q}) = \hat{c}(t + jT) K_{\hat{q}}$$

$$K_{\hat{q}} = K_0(\beta R)^{\hat{q}/\gamma}, \quad \text{for } \hat{q} = 0, 1, \dots, T - 1 \quad \text{and } j = 0, 1, \dots, L/T - 1; \quad (7)$$

where:

$$\Omega^T = (\beta E_t[[y^T(t + T)]^{1-\gamma}])^{-1/\gamma};$$

$$K_0^{-1} = \frac{1 - (\beta^{1/\gamma} R^{(1/\gamma)-1})^T}{1 - (\beta^{1/\gamma} R^{(1/\gamma)-1})}; \quad \text{and,} \quad a_j^T = \frac{1 - (\Omega^T)^{-1}}{1 - (\Omega^T)^{-((L/T)-j)}}.$$

REFERENCES

- Bell, William R., and David W. Wilcox, 1993, The effect of sampling error on the time series behavior of consumption data, *Journal of Econometrics* 55, 235–265.
- Breeden, Douglas T., 1979, An intertemporal asset pricing model with stochastic consumption and investment opportunities, *Journal of Financial Economics* 7, 265–296.
- Breeden, Douglas T., Michael R. Gibbons, and Robert H. Litzenberger, 1989, Empirical tests of the consumption-oriented CAPM, *Journal of Finance* 44, 231–262.
- Caballero, Ricardo J., 1992, Near-rationality, heterogeneity and aggregate consumption, NBER Working paper No. 4035.
- Caballero, Ricardo J., 1993, Durable goods: An explanation for their slow adjustment, *Journal of Political Economy* 101, 351–384.
- Campbell, John Y., and John H. Cochrane, 1994, By force of habit: A consumption-based explanation of aggregate stock market behavior, Working paper, University of Chicago.
- Christiano, Lawrence J., Martin Eichenbaum, and David Marshall, 1991, The permanent income hypothesis revisited, *Econometrica* 59, 397–423.
- Cochrane, John H., 1989, The sensitivity of tests of the intertemporal allocation of consumption to near-rational alternatives, *American Economic Review* 79, 319–337.
- Cochrane, John H., and Lars P. Hansen, 1992, Asset pricing explorations for macroeconomics, *NBER Macroeconomics Annual 1992* (MIT Press, Cambridge, Mass.).
- Constantinides, George M., 1986, Capital market equilibrium with transaction costs, *Journal of Political Economy* 94, 842–862.
- Constantinides, George M., 1990, Habit formation: A resolution of the equity premium puzzle, *Journal of Political Economy* 98, 519–543.
- Davis, Mark H. A., and Andrew R. Norman, 1990, Portfolio selection with transaction costs, *Mathematics of Operations Research* 15, 676–713.
- Duffie, Darrell, and Tong-sheng Sun, 1990, Transaction costs and portfolio choice in a discrete-continuous-time setting, *Journal of Economic Dynamics and Control* 14, 35–51.
- Ermini, Luigi, 1989a, Excessive sensitivity of consumption and postponed revision of the optimum plans, *Journal of Macroeconomics* 11, 409–422.
- Ermini, Luigi, 1989b, Some new evidence on the timing of consumption decisions and on their generating process, *Review of Economics and Statistics* 71, 643–650.
- Ferson, Wayne E., and Campbell R. Harvey, 1992, Seasonality and consumption-based asset pricing, *Journal of Finance* 47, 511–552.
- Grossman, Sanford J., and Guy Laroque, 1990, Asset pricing and optimal portfolio choice in the presence of illiquid durable consumption goods, *Econometrica* 58, 25–51.
- Grossman, Sanford J., Angelo Melino, and Robert J. Shiller, 1987, Estimating the continuous-time consumption-based asset-pricing model, *Journal of Business and Economic Statistics* 5, 315–327.
- Grossman, Sanford J., and Robert J. Shiller, 1982, Consumption correlatedness and risk management in economies with non-traded assets and heterogeneous information, *Journal of Financial Economics* 10, 195–210.
- Grossman, Sanford J., and Lawrence Weiss, 1983, A transaction based model of the monetary transmission mechanism, *American Economic Review* 73, 871–880.
- Hansen, Lars Peter, and Kenneth J. Singleton, 1982, Generalized instrumental variables estimation of nonlinear rational expectations models, *Econometrica* 50, 1269–1285.

- Hansen, Lars Peter, and Kenneth J. Singleton, 1983, Stochastic consumption, risk aversion, and the temporal behavior of asset returns, *Journal of Political Economy* 91, 249–265.
- He, Hua, and David M. Modest, 1995, Market frictions and consumption-based asset pricing, *Journal of Political Economy* 103, 94–117.
- Heaton, John, 1993, The interaction of time-nonseparable preferences and time aggregation, *Econometrica* 61, 353–385.
- Heaton, John, and Deborah J. Lucas, 1992, The effects of incomplete insurance markets and trading costs in a consumption-based asset pricing model, *Journal of Economic Dynamics and Control* 16, 601–620.
- Heaton, John, and Deborah J. Lucas, 1994, Evaluating the effects of incomplete markets on risk sharing and asset pricing, Working paper, MIT.
- Ingersoll, Jonathan E. Jr., 1987, *Theory of Financial Decision Making* (Rowman and Littlefield Publishers, Inc., Lanham, Md.).
- Longstaff, Francis A., 1989, Temporal aggregation and the continuous-time capital asset pricing model, *Journal of Finance* 44, 871–887.
- Lucas, Deborah J., 1994, Asset pricing with undiversifiable income risk and short sales constraints: Deepening the equity premium puzzle, *Journal of Monetary Economics* 34, 325–341.
- Luttmer, Erzo G. J., 1992, Asset pricing in economies with frictions, Working paper, University of Chicago.
- Lynch, Anthony W., 1994, Unsynchronized and infrequent decision-making by individuals: Some empirical evidence, Working paper, New York University.
- Mankiw, N. Gregory, 1986, The equity premium puzzle and the concentration of aggregate shocks, *Journal of Financial Economics* 17, 211–219.
- Marshall, David, 1993, Asset return volatility with extremely small costs of consumption adjustment, Working paper, Northwestern University.
- Mehra, Rajnish, and Edward C. Prescott, 1985, The equity premium: A puzzle, *Journal of Monetary Economics* 15, 145–161.
- Merton, Robert C., 1973, An intertemporal capital asset pricing model, *Econometrica* 41, 867–887.
- Reider, Robert L., 1994, Can transaction costs on durables explain high estimates of risk aversion, Working paper, University of Pennsylvania.
- Rotemberg, Julio J., 1984, A monetary equilibrium model with transaction costs, *Journal of Political Economy* 92, 40–58.
- Telmer, Chris I., 1993, Asset pricing puzzles and incomplete markets, *Journal of Finance* 48, 1803–1832.
- Wilcox, David W., 1992, The construction of U.S. consumption data: Some facts and their implications for empirical work, *American Economic Review* 82, 922–941.