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AN EMPIRICAL DISEQUILIBRIUM MODEL OF LABOR, CONSUMPTION, AND INVESTMENT*

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A macroeconomic disequilibrium model of the U.S. economy is constructed with three markets—one each for labor, consumption goods, and investment goods. Demand and supply in each market are obtained from underlying microeconomic theory, with adjustment costs and possible intermarket spillovers from quantity rationing taken into account. Indicators of excess demand for each market aid in estimation. No evidence is found for Walrasian market equilibrium.

1. INTRODUCTION

The assumption of Walrasian market equilibrium has been prominent in much of recent macroeconomics, most notably, in the new classical and real business cycle research programs. Although the assumption that markets are continuously cleared by prices aids in the formulation of rigorous theoretical macroeconomic models, it is still in doubt as to whether such equilibrium models can be reconciled with the short-run behavior of the economy (e.g., see Boschen and Grossman 1982 and McCallum 1986). Within the context of a disequilibrium model, which allows for the *possibility* that prices may not move quickly enough to clear markets, one can often construct a direct econometric test of the hypothesis of Walrasian market equilibrium. This paper conducts such a test, using data from the United States, in a disequilibrium model that contains three explicit markets—one each for labor, consumption goods, and investment goods.

Besides providing evidence on the question of market equilibration, this paper is also an attempt to advance the structure of empirical disequilibrium models. The formal, multimarket disequilibrium models described by Barro and Grossman (1971), Malinvaud (1977), Muellbauer and Portes (1978), and econometrically specified by Gourieroux, Laffont and Monfort (1980) and Ito (1980), have been useful for theoretical discussions of macroeconomic behavior. For example, the variety of available market rationing regimes has fostered the recognition of different *types* of unemployment; these, in turn, have suggested alternative policy prescriptions. While the theory of multimarket disequilibrium models has been well developed, the empirical implementation of these models has lagged behind, slowed by difficulties in estimation. Computational intractability has also led to substantive structural differences between the first, simple multimarket disequilib-

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rium models actually estimated (e.g., Kooiman and Kloek 1985; Sneessens 1983; Artus, Laroque, and Michel 1984) and the theoretical work on disequilibrium models listed above. The empirical models have a more traditional Keynesian structure than models explicitly grounded in non-marketclearing microeconomics. In some sense, previous empirical multimarket applications of the disequilibrium model have simply superimposed some features of disequilibrium analysis on a traditional Keynesian formulation. Although this may be a legitimate research strategy,[2] I will estimate instead a disequilibrium model more closely related to those discussed in the theoretical literature.

The microeconomic behavior of households and firms, which governs demand and supply in each market, is presented in the next section and takes into account both the intermarket spillover effects of rationing and the intertemporal effects of costly adjustment and expectations. Section 3 describes the interaction of agents in each of the three markets; it also specifies non-stochastic indicators of excess demand for each market. The information on excess demand permits estimation of the structurally complex, dynamic, multimarket disequilibrium model. Section 4 discusses the estimation procedure, a test for the special case of equilibrium, and the empirical results.

2. THE BEHAVIOR OF AGENTS

Households and firms trade on multiple markets in the face of possible quantity rationing. Households supply labor and demand consumer goods. Firms demand labor, supply consumer goods, and also operate on a third market by both demanding and supplying investment goods. A rigorous microeconomic derivation of these demands and supplies in the presence of quantity constraints and adjustment costs will not be attempted here; however, static Walrasian offers are derived and then augmented with linear spillovers for quantity rationing and lagged variables for dynamic adjustment.

2.1. *Household Behavior.* The equations of previous macroeconometric disequilibrium models have relatively simple, traditional specifications with little consideration of price and wage effects on household behavior. In contrast, I consider a household labor-consumption decision that is closer to that presented in theoretical multimarket disequilibrium models and the general discussions of household behavior under quantity rations (e.g., Deaton and Muellbauer 1984; and Killingsworth 1983). The model differs, however, from much of the theoretical literature by assuming that consumer demand is always satisfied. Since there are two product markets, a plausible distinction can be made between household demand for consumer goods, which is not rationed, and firm demand for capital goods, which may be rationed. This difference in market structure arises because the consumer goods market is characterized by "pervasive inventories," large,

[2] It may be that merely modifying Keynesian macroeconometric models to account for various rationing regimes is an improvement, leading for example to greater structural stability. More fundamental changes however are suggested by theory.

available quantities of finished goods inventories that completely buffer fluctuations in demand, so the household is never rationed in the goods market.[3]

Consider a static version of the household optimization problem. In the absence of quantity constraints, the household maximizes utility over consumption and labor supplied, subject only to the budget constraint, that is,

$$\max U(C, L)$$

subject to

$$P_C C = WL + \mu$$

where P_C is the price of consumer goods, W is the (nominal) wage, and μ is non-labor income.[4] The resulting Walrasian or notional consumption demand and labor supply (denoted by subscript ω) are

$$C^d_\omega(P_C, W, \mu) \qquad \text{and} \qquad L^s_\omega(P_C, W, \mu).$$

When the household faces a binding quantity constraint on the labor market, $\bar{L}$, which it believes to be exogenous, household behavior is determined by

$$\max U(C, L)$$

subject to $$P_C C = WL + \mu \qquad \text{and} \qquad L \leq \bar{L}.$$

This yields demand and supply

$$C^d = C^d_e(P_C, W, \mu; \bar{L}) \qquad \text{and} \qquad L^s = \bar{L}.$$

The subscript e denotes constrained maximization, and C^d_e is the "effective demand" for consumption.

For econometric work, it is convenient to restate effective demand in another form. Note that when the labor constraint is not binding and employment equals notional labor supply, effective commodity demand should equal Walrasian commodity demand; namely,

$$C^d_e(P_C, W, \mu; L^s_\omega(P_C, W, \mu)) = C^d_\omega(P_C, W, \mu).$$

Taking a Taylor expansion around this unrationed point, we have the local approximation

$$\begin{aligned} C^d_e(P_C, W, \mu; \bar{L}) &\approx C^d_e(P_C, W, \mu; L^s_\omega(P_C, W, \mu)) + s_C(\bar{L} - L^s_\omega(P_C, W, \mu)) \\ &\approx C^d_\omega(P_C, W, \mu) + s_C(\bar{L} - L^s_\omega(P_C, W, \mu)) \end{aligned}$$

[3] Benassy (1984) also argues that consumers are not rationed in the goods market: "First we would like to avoid the apparition of demand rationing of the goods market, as this feature is usually not observed in capitalist market economies" (p. 263). He rationalizes this by assuming one-sided (downward) price rigidity, rather than pervasive inventories.

[4] All variables refer to period t, though the time subscript will be dropped for ease of notation.

where $$s_C \equiv \frac{\partial C_e}{\partial \bar{L}}(P_C, W, \mu; L_\omega^s(P_C, W, \mu)).$$

Thus, the effect of a labor supply ration on Walrasian commodity demand is, to first-order approximation, proportional to the difference between the labor ration and notional labor supply.[5] The spillover coefficients, s_C and others below, will be treated as constants, which can be rationalized by assuming the economy is in the neighborhood of equilibrium (see Gourieroux, Laffont and Monfort 1980). The aggregate quantity traded in the labor market will be determined by a minimum condition, $L = \min(L^d, L^s)$, so at the aggregate level, the household constrained level, $\bar{L}$, can be replaced by the quantity of labor transacted, L. That is,

$$C^d = C_\omega^d(P_C, W, \mu) + s_C(L - L^s).$$

I assume that the consumer is never rationed in the goods market, so there is no distinction between effective and notional labor supply. Labor supply is given by

$$L^s = L_\omega^s(P_C, W, \mu).$$

When the household faces a dynamic optimization problem, its current labor-consumption choice is also based on past consumption decisions and on expectations about the future path of wages and consumption of prices.[6] A household with a convex utility surface, for example, would anticipate future variables in an attempt to smooth consumption. The effects of costly adjustment, consumer habit, and expectations for Walrasian demands and supplies can be modeled by the inclusion of lagged dependent variables and expected future prices (see Deaton and Muellbauer 1984 for discussion). Assuming a univariate price generating process, expectations can be proxied for by a distributed lag on past price values. To further simplify the analysis, we consider dynamic labor supply and consumption demand of the form

$$C^d = C_\omega^d(\Sigma P_C, \Sigma W, \mu, C_{-1}^d) + s_C(L - L^s) \tag{1}$$

$$L^s = L_\omega^s(\Sigma P_C, \Sigma W, \mu, L_{-1}^s) \tag{2}$$

where $\Sigma\, x$ represents a distributed lag on the variable x and the subscript -1 represents a one-period lag. Thus, dynamic consideration is given to the Walrasian elements and, implicitly, to previous quantity constraints through the lagged dependent variables.

2.2. *Firm Behavior.* The optimal production decision is separated into the determination of factor demands and the choice of output levels. To solve the first

[5] The form of the spillover term, and hence effective demand, depends crucially upon the rationing scheme and agents' perceptions about that scheme. Even assuming deterministic quantity rations faced by agents, there are several possible specifications (see footnote 8 below).

[6] First attempts at exploring the consequences of explicitly incorporating expectations into theoretical quantity rationing models have been made by Hildenbrand and Hildenbrand (1978), Benassy (1982), and Cuddington, Johansson and Löfgren (1984, chapter 3).

problem, assume that firms produce a single output with a technology summarized by the production function:

$$Y = F(L, KS, E)$$

where Y is the flow of output, and L, KS, and E are the flow inputs of labor services, capital services, and energy, respectively, during period t. We assume that the individual firm takes as given both prices and possible quantity constraints in input and output markets. The real producer wage is $WP \equiv W/P_Y$, where W is the nominal wage and P_Y is the price of output. Let $RP \equiv R/P_Y$ be the real user cost of capital, that is, the nominal cost of capital divided by the price of output. Finally, let EP be the real producer price of energy, the market for which is not modeled.

Marginal conditions for profit maximization by the firm equates real factor prices with their respective marginal products:

$$WP = F_L(L^*, KS^*, E^*)$$

$$RP = F_{KS}(L^*, KS^*, E^*)$$

$$EP = F_E(L^*, KS^*, E^*)$$

where L^*, KS^*, and E^* are the jointly determined desired flows of labor, capital services, and energy flows. These can be solved for static Walrasian demands for labor, capital services, and energy:

$$L^d_\omega = L^d_\omega(WP, RP, EP) \tag{3}$$

$$KS^d_\omega = KS^d_\omega(WP, RP, EP) \tag{4}$$

$$E^d_\omega = E^d_\omega(WP, RP, EP). \tag{5}$$

I assume that because of transactions costs there are negligible rental markets and secondary markets for capital, so each firm must obtain required capital services from its own stock of capital. To the extent that the firm desires to keep a steady rate of capacity utilization, fluctuations in the flow demand for capital services, KS^d_ω, are translated into fluctuations in the desired stock of capital and fluctuations in the flow demand for newly-produced capital goods. The latter, which is gross investment demand, is given by

$$I^d_\omega = I^*(WP, RP, EP, K_{-1}) \tag{6}$$

where K_{-1} is the existing capital stock.

Firms also make a simultaneous choice of output given input prices. Optimal output under profit maximization can be determined by substituting factor demands into the production function:

$$\begin{aligned} Y^s_\omega &= F(L^d_\omega, KS^d_\omega, E^d_\omega) \\ &= Y^s_\omega(WP, RP, EP) \end{aligned}$$

which depends only on real input prices. To determine the composition of this output, I assume that each industry is concerned with real factor prices in terms of its own output price; that is, firms specialize in the short-run by producing either consumption goods or investment goods.[7] If the price of consumer goods is P_C, the relevant wage rate for the consumer goods industry profit maximization is $WPC \equiv W/P_C$. As a function of prices, the supply of consumer goods can be written,

$$C^s_\omega = C^s_\omega(WPC, RPC, EPC) \tag{7}$$

where the arguments are the nominal wage, cost of capital, and price of energy, each deflated by the price of consumer goods. Similarly, the supply of investment goods is

$$I^s_\omega = I^s_\omega(WPI, RPI, EPI) \tag{8}$$

where each factor input price is divided by the price of investment goods P_I.

So far we have obtained static forms of Walrasian demands (L^d_ω, I^d_ω) and supplies (C^s_ω, I^s_ω) in equations (3), (6), (7), and (8). As described in the literature on dynamic factor demands (e.g., Sargent 1978; Meese 1980), if firms face costs of adjusting input and output levels, then the demands and supplies must be modified by the inclusion of lagged dependent variables and expected future prices. With a distributed lag proxy for expectations, the final Walrasian demands and supplies of the firm are

$$L^d_\omega = L^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, L^d_{-1}) \tag{9}$$

$$I^d_\omega = I^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, K_{-1}, I^d_{-1}) \tag{10}$$

$$C^s_\omega = C^s_\omega(\Sigma WPC, \Sigma RPC, \Sigma EPC, C^s_{-1}) \tag{11}$$

$$I^s_\omega = I^s_\omega(\Sigma WPI, \Sigma RPI, \Sigma EPI, I^s_{-1}). \tag{12}$$

To obtain effective offers, the direct quantity spillovers from other markets must be added to these Walrasian offers, and, in general, a quantity constraint on any demand or supply of a firm will influence its demands and supplies in other markets. For example, assuming linear spillovers,[8] effective labor demand is

$$L^d = L^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, L^d_{-1}) + s_1(I - I^s) + s_2(C - C^s) \tag{13}$$

with spillover coefficients s_1 and s_2. These spillovers represent the impact of possible rationing of the supply of output in the investment goods and consumption

[7] It is possible to construct an alternative model with firms that can produce both investment and consumption goods. The price of investment goods relative to consumption goods will then determine the relative flow supply of the goods. (See Engle and Foley 1975.) Such a formulation is similar to the model with product specialization, though the price terms are slightly different and there are more potential spillovers.

[8] There are three major formulations of linear spillovers described in the literature. The one used here can be attributed to Portes (1977) and Benassy (1975) and has also been used by Green and Laffont (1981). For a description of the other variants, see Ito (1980) and Lee (1986).

goods industries. Labor demand should be lower, given wages, prices, and previous demand, if firms cannot sell all of the goods they would like ($I < I^s$ or $C < C^s$ and positive s_1 and s_2). Another potential spillover, of the form $s_0(I - I^d)$, could be included to represent the effect of restrained investment demand on labor demand (a positive or negative spillover depending on factor substitutability). However, in order to simplify the analysis, I assume *a priori* that the effects on the firm of rationed investment demand are negligible, and this spillover is ignored.[9]

The other demands and supplies of the firm will also be affected by rationing. Effective investment demand will reflect quantity constraints on labor demand ($L < L^d$) and, as for the case of effective labor demand, rations on output supply in each sector:

$$I^d = I^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, I^d_{-1}) + s_3(L - L^d) + s_4(I - I^s) + s_5(C - C^s). \tag{14}$$

The constrained output spillover coefficients, s_4 and s_5, will be positive, while the sign of the coefficient on rationing of the other factor, s_3, depends on input substitutability.

Assuming that firms have specialized in either the production of consumer goods or investment goods, only input quantity constraints are relevant for the supply decision; as above, the effect of a ration on investment goods demand is ignored. Thus, effective investment and consumer goods supplies are the Walrasian offers modified by a single spillover from labor demand:

$$I^s = I^s_\omega(\Sigma WPI, \Sigma RPI, \Sigma EPI, I^s_{-1}) + s_6(L - L^d) \tag{15}$$

$$C^s = C^s_\omega(\Sigma WPC, \Sigma RPC, \Sigma EPC, C^s_{-1}) + s_7(L - L^d). \tag{16}$$

3. MARKET STRUCTURE

Given the demands and supplies that agents express in the presence of rationing, the interaction of these agents and the reconciliation of their effective offers must still be described for the labor market, the capital goods market, and the consumer goods market. Each market contains demand and supply equations, a condition that expresses the rationed transacted quantity, and a deterministic equation that indicates market excess demand. As will be described in Section 4, the market tension or excess demand information is crucial for a tractable estimation procedure.

3.1. *Labor Market.* The four equations for the labor sector in this model are

$$L^d = L^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, L^d_{-1}) + s_1(I - I^s) + s_2(C - C^s) + u_1 \tag{17}$$

$$L^s = L^s_\omega(\Sigma WNET, PROP, TRAN, L^s_{-1}) + u_2 \tag{18}$$

[9] The assumption that investment demand rations have only second-order effects could be rationalized by variations in capacity utilization, which would cushion the spillover. That is, firms are largely unrationed with regard to capital services (as opposed to capital goods), but they are not at the minimum of the cost curve.

(19) $$L = \min\,(L^d, L^s)$$

(20) $$L^d - L^s = \delta_L(Z_L - Z_L^E).$$

Equations (17) and (18) are the effective labor demand and labor supply functions derived earlier with the addition of stochastic errors u_1 and u_2. For estimation, the Walrasian labor supply function combines the nominal wage and consumption price into *WNET*, which is the wage net of taxes deflated by the price of consumption, and two types of consumer nonlabor income are recognized: *PROP*, real property income, and *TRAN*, real transfer income.

Equation (19) describes the rationing mechanism that determines the actual quantity transacted in the market. An equilibrium model of the labor market replaces the min condition with $L = L^d = L^s$; however, if the wage does not adjust quickly enough during the period, either labor demand or labor supply will be rationed, and the level of employment L is determined as the minimum of supply and demand. Wages, and other market prices, are not considered fixed or exogenous but simply slow to adjust. Although price determination is not explicitly specified, prices are treated as econometrically endogenous to the system by instrumental variables estimation.

Equation (20) is an exact indicator equation that incorporates information on the extent of labor market excess demand. Z_L is a statistic that measures or indicates such excess demand, and Z_L^E is its equilibrium value when labor demand equals labor supply. Assuming $\delta_L \geq 0$ (i.e., Z_L is, if anything, an indicator of excess demand not excess supply), when $Z_L \geq Z_L^E$, the market is in excess demand, so $L^d \geq L^s$ and $L = L^s$. The opposite is true during excess supply. Thus, the indicator equation provides an exact partition of the sample and a quantitative measure of excess demand, effectively identifying the unobservable side of the market.[10] The exact indicator equation specializes to the usual deterministic price adjustment equation (see Fair and Jaffee 1972) if the indicator is the change in the wage rate with a zero equilibrium level. In a disequilibrium model, where markets are imperfect, it is likely that there are other more direct and more informative indicators of excess demand than price movements.

The indicator of labor market tension, Z_L, should be a series correlated with excess demand, not necessarily causal, and it will be treated as an endogenous variable in estimation. Possible indicators of labor market excess demand include unemployment, help wanted advertising, quits, layoffs, and changes in the wage rate. The information contained in such series has been explored in Rudebusch (1987); here, a weighted average of the first two is used. The resulting indicator, $Z_L - Z_L^E$, graphed in Figure 1 as a solid line is the first principal component of deviations from trend of help wanted advertising and deviations from trend of the inverse of unemployment. The market equilibrium level, similar to a natural rate, is

[10] See Rudebusch (1986) for further discussion. In addition, the econometric consequences of assuming a *non-stochastic* excess demand indicator equation were examined in Rudebusch (1987), where for a particular single market model, the non-stochastic indicator was found to provide a close approximation to the stochastic indicator. For more general results, Goldfeld and Quandt (1981) provide a favorable Monte-Carlo study.

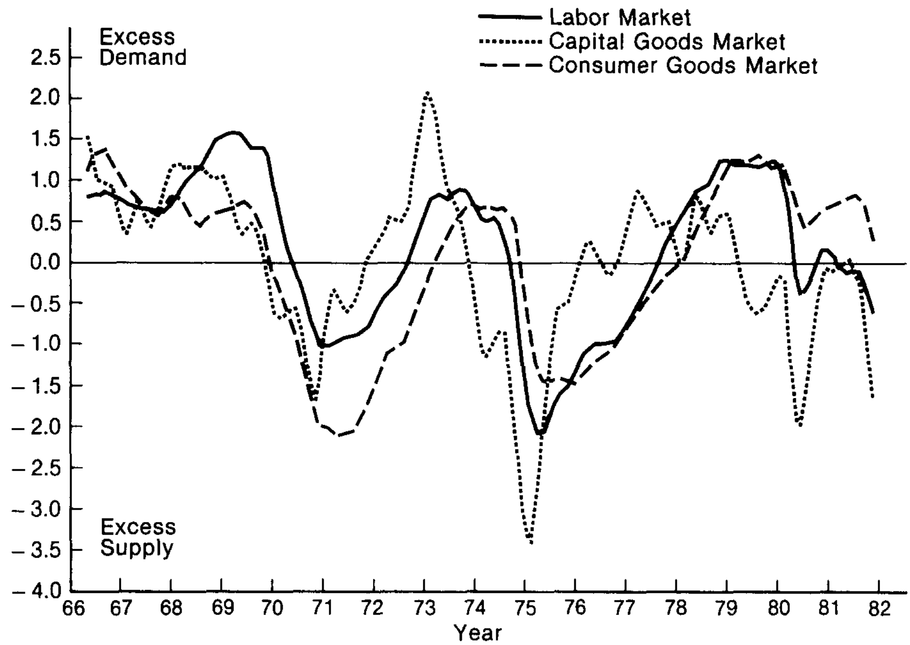

FIGURE 1

EXCESS DEMAND INDICATORS

proxied for by the long-run trend component, on the assumption that if the market is characterized by disequilibrium, it is composed of periods of both excess supply and excess demand.[11] For unemployment, where some general notions of an equilibrium rate are available (e.g., Gordon 1977), the quadratic trend matches these very closely.[12] The sample separation that results from using a trend equilibrium level is also consistent with qualitative descriptions of the labor market.

3.2. *Capital Goods Market.* The acquisition of newly produced capital goods is not usually treated within a market framework. Particularly since the rise to dominance of the neoclassical theory of investment (circa Hall and Jorgenson 1967), almost all of the econometric literature has centered on the *demand* for investment, which is considered "the" investment function. In such models, the level of real investment is determined solely from the demand for an optimal capital stock, which is a function of output, prices, and financial variables. However, standard economic theory suggests that the price and quantity of a good are jointly

[11] As in the special case of the price adjustment indicator equation, disequilibrium is not *assumed* since δ_{l} may be zero (see Section 4 below). However, market rationing, if it exists, is assumed to occur according to the regimes shown in Figure 1. (Although the results are robust to small variations in the trend.) Thus, markets that are characterized by predominantly excess demand or excess supply cannot be distinguished. See Quandt and Rosen (1985) for a test of the chronic excess supply hypothesis in the labor market.

[12] Results were similar when equilibrium rates were defined as linear or cubic trends or as a 30-quarter moving average.

determined by demand and supply; thus, both demand and supply variables, such as factor input prices, should be considered in the determination of the quantity of investment. The price of capital goods may not clear the market, so possible rationing and disequilibrium must be taken into account. Two previous disequilibrium models of the investment goods market are Nishimizu, Quandt, and Rosen (1981) and Artus and Muet (1984). Also, see Engle and Foley (1975) and Abel (1980) for further discussion of the supply of investment goods.

Our disequilibrium investment model will follow the exact excess demand specification described above; namely,[13]

$$I^d = I^d_\omega(\Sigma RP, \Sigma WP, \Sigma EP, I^d_{-1}) + s_3(L - L^d) + s_4(I - I^s) + s_5(C - C^s) + u_3 \tag{21}$$

$$I^s = I^s_\omega(\Sigma WPI, \Sigma RPI, \Sigma EPI, I^s_{-1}) + s_6(L - L^d) + u_4 \tag{22}$$

$$I = \min(I^d, I^s) \tag{23}$$

$$I^d - I^s = \delta_I(Z_I - Z_I^E) \tag{24}$$

where u_3 and u_4 are stochastic errors. The indicator Z_I measures excess investment demand and is constructed as the first principal component of several individual series. An obvious series to use is the level of unfilled orders for capital goods deflated by their price. This is consistent with a strand of the investment literature that regresses investment commitments (appropriations, orders, or contracts, not realized expenditures) on the determinants of investment (e.g., Ando, Modigliani, Rasche and Turnovsky 1974). A quadratic trend representing an underlying equilibrium frictional level of unfilled orders is subtracted.

To supplement unfilled orders, data on inventories and capacity utilization of the capital goods producing firms, sensitive indicators of supply conditions, are also used. Low capacity utilization has long been associated with insufficient product demand relative to supply (Schultze 1963; Perry 1973; and Ruist and Söderström 1975); thus, we use deviations in capacity utilization from an equilibrium level (the mean) as indicative of excess demand. The inventories held by the manufacturers of capital goods play a role that complements unfilled orders in reflecting unforeseen changes in demand and supply. Each period's inventories are deflated by sales, and (the inverse of) percentage deviations from trend are used.

Finally, taking the first principal component of unfilled orders, capacity utilization, and inventory-sales deviations gives the indicator of tension or disequilibrium in the investment goods market, $Z_I - Z_I^E$, graphed in Figure 1 as a dotted line.

3.3. *The Consumer Goods Market.* For the labor and investment sectors, the market rule governing interaction was simple: the short side of the market

[13] The traditional demand-determined formulation involves long distributed lags on the determinants of investment that are rationalized by assuming adjustment costs internal to the firm and a delayed delivery response for capital goods. Here, lagged investment terms only reflect costs of adjustment *internal* to the firm, for such costs are properly taken into account by the firm in formulating notional demands and supplies. These lagged elements do not reflect delivery lags in the acquisition process *external* to the firm that indicate imperfections in the market.

dominates and determines quantity. In the consumer goods market, we use an aggregate rationing scheme that accounts for the large buffer stock of inventories. The major role of inventories is to cushion the effects of unforeseen fluctuations in demands or supplies; however, while inventories do provide some elasticity to quantity constraints, the general conclusions from earlier disequilibrium models remain. This is clear from theoretical models that incorporate inventories (Malinvaud 1977; Muellbauer and Portes 1978; Honkapohja and Ito 1980; and Green and Laffont 1981). Instead of an aggregate min condition, I invoke a more Keynesian assumption that demand is satisfied via unanticipated inventory fluctuations. Demand is never rationed, and the observable transacted quantity of sales C is equal to the demand for consumer goods C^d. Sales are not, however, always equal to the supply of consumer goods C^s, which is the amount of goods that firms *desire* to sell in the marketplace at given prices. In the case of a storable good, this desired supply is equal to production (Q_C) minus the *intended* or *desired* inventory accumulation, namely, $C^s = Q_C - \Delta H_C^i$. Suppliers may be rationed in the sense that their realized supply (sales) does not match their notional or intended supply.

To see this more clearly, conceptually divide all changes in consumer good inventories into intended changes and unintended changes, $\Delta H_C = \Delta H_C^i + \Delta H_C^u$, and apply this division within the accounting identity that all production is either sold or added to inventory,

$$Q_C - (\Delta H_C^i + \Delta H_C^u) = C.$$

Given the equality of sales with demand and the definition of supply given before, we obtain directly

$$C^s - C^d = \Delta H_C^u.$$

Excess supply is exactly unintended inventory accumulation.

The consumer goods market with pervasive inventories is illustrated in Figure 2. The heavy line is the set of potential sales and price pairs. (This line can be compared with the wedge-shaped quantity-price set in the traditional min-condition model.) Demand is always observable; supply is never directly observable except at equilibrium (pt. E). Points above E are oversupply with unexpectedly low demand, $\Delta H_C^u > 0$; points below E are undersupply with unexpectedly high demand, $\Delta H_C^u < 0$. Note that this is in accordance with the traditional Keynesian empirical consumption function where sales is identified exactly with consumption demand, though here a consumption supply curve can also be estimated given a constructed series of unintended inventory accumulation.

Our model of the consumer goods market then takes the form:

$$C^d = C_\omega^d(\Sigma PCNET, PROP, TRAN, C_{-1}^d) + s_C(L - L^s) + u_5 \tag{25}$$

$$C^s = C_\omega^s(\Sigma WPC, \Sigma RPC, \Sigma EPC, C_{-1}^s) + s_7(L - L^d) + u_6 \tag{26}$$

$$C = C^d \tag{27}$$

$$C^s - C^d = \delta_C XCON \tag{28}$$

where u_5 and u_6 are stochastic errors and $XCON$ is the estimate of excess supply. For consumer demand, $PCNET$ is the price of consumption in real wage terms, and $PROP$ and $TRAN$ are real household property and transfer income.

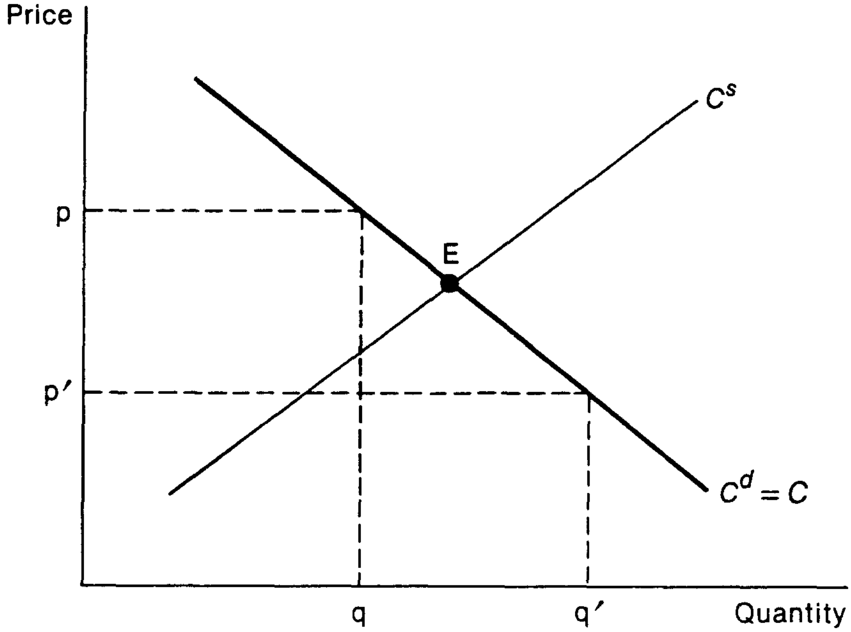

FIGURE 2

THE CONSUMER GOODS MARKET

Implicit in our discussion is the common notion that firms choose an optimal target for inventories and that there are costs associated with deviations from this target. On the aggregate level, we will make the simplifying assumption that the desired level of inventories is a constant or slowly time-varying proportion of sales. This provides a time series on desired inventory levels, which can be compared to actual inventories to obtain undesired inventory holdings. We consider inventories held by both consumer goods manufacturers and retailers deflated by the proper measure of sales. Unintended inventory accumulation will be an adequate indicator of supply and demand imbalances; however, if firms realize that inventories are rising and do not foresee any increases in sales, they will cut back on production. This is "discouraged production," reflected by reduced capacity utilization, in the sense that firms would like to sell more given prices and wages but cannot and hence do not produce. Thus, the final indicator of excess consumer goods demand ($Z_C - Z_C^E = -XCON$) is the first principal component of the excess capacity series and the unintended inventory series and is graphed in Figure 1 as a dashed line.

4. ESTIMATION AND RESULTS

This section describes how the three-market disequilibrium model can be estimated through the use of excess demand information. The results of estimation of the disequilibrium model are discussed and compared with parameter estimates of the associated equilibrium model, and an econometric test of market equilibrium is performed.

4.1. *Estimation Equations.* For estimation, the structural market equations presented earlier (equations (17) through (28)) must be transformed to eliminate the unobservable demands and supplies. This can be done by using the exact excess demand indicators. Let us first define partitioned excess demand variables for the two markets with min conditions:

$$XDLAB = \begin{cases} (Z_L - Z_L^E) & \text{if } Z_L - Z_L^E > 0 \quad \text{(excess demand)} \\ 0 & \text{otherwise} \end{cases}$$

$$XSLAB = \begin{cases} -(Z_L - Z_L^E) & \text{if } Z_L - Z_L^E < 0 \quad \text{(excess supply)} \\ 0 & \text{otherwise} \end{cases}$$

$$XDINV = \begin{cases} (Z_I - Z_I^E) & \text{if } Z_I - Z_I^E > 0 \quad \text{(excess demand)} \\ 0 & \text{otherwise} \end{cases}$$

$$XSINV = \begin{cases} -(Z_I - Z_I^E) & \text{if } Z_I - Z_I^E < 0 \quad \text{(excess supply)} \\ 0 & \text{otherwise} \end{cases}$$

and an unpartitioned excess supply variable for the consumption goods market:

$$XCON = -(Z_C - Z_C^E).$$

These variables represent the combination of the indicator equation and the rationing rule for each market. In particular, note the definitional relationships,

$$L^d - L = \delta_L XDLAB$$

$$L^s - L = \delta_L XSLAB$$

$$I^d - I = \delta_I XDINV$$

$$I^s - I = \delta_I XSINV$$

$$C^d - C = 0$$

$$C^s - C = \delta_C XCON$$

where L, I, and C are the transacted quantities of labor, investment, and consumption. If we substitute into these equations the supply and demand functions derived in Section 2, we obtain (suppressing the arguments of the Walrasian offers)

(D1) $$L = L_\omega^d(\cdot) + s_1(I - I^s) + s_2(C - C^s) - \delta_L XDLAB + u_1$$

(D2) $$L = L_\omega^s(\cdot) - \delta_L XSLAB + u_2$$

(D3) $$I = I_\omega^d(\cdot) + s_3(L - L^d) + s_4(I - I^s) + s_5(C - C^s) - \delta_I XDINV + u_3$$

(D4) $$I = I^s_\omega(\,\cdot\,) + s_6(L - L^d) - \delta_I XSINV + u_4$$

(D5) $$C = C^d_\omega(\,\cdot\,) + s_C(L - L^s) + u_5$$

(D6) $$C = C^s_\omega(\,\cdot\,) + s_7(L - L^d) - \delta_C XCON + u_6.$$

With the partitioned excess demand variables, we have reduced the four structural equations for each market to two estimation equations. For example, in equation (D1), the transacted quantity of labor equals labor demand (Walrasian plus intermarket rationing spillovers) minus any excess demand during periods of excess demand. Similarly, labor equals labor supply minus any excess supply during periods of excess supply. Pervasive inventories in the consumer goods market are reflected in estimation equations (D5), where demand always equals the quantity, and (D6) where *XCON* is correlated with excess supply and reflects both positive and negative deviations from equilibrium.

The spillover terms can also be expressed using the partitioned indicators, and the final disequilibrium estimation equations are

(D1) $$L = L^d_\omega(\,\cdot\,) - s_1\delta_I XSINV - s_2\delta_C XCON - \delta_L XDLAB + u_1$$

(D2) $$L = L^s_\omega(\,\cdot\,) - \delta_L XSLAB + u_2$$

(D3) $$I = I^d_\omega(\,\cdot\,) - s_3\delta_L XDLAB - s_4\delta_I XSINV - s_5\delta_C XCON - \delta_I XDINV + u_3$$

(D4) $$I = I^s_\omega(\,\cdot\,) - s_6\delta_L XDLAB - \delta_I XSINV + u_4$$

(D5) $$C = C^d_\omega(\,\cdot\,) - s_C\delta_L XSLAB + u_5$$

(D6) $$C = C^s_\omega(\,\cdot\,) - s_7\delta_L XDLAB - \delta_C XCON + u_6.$$

The only remaining unobservables in these equations are the lagged demands and supplies in the Walrasian offers, which can be represented by the transacted quantity plus any positive excess demand or supply (that is, $L^d_{-1} = L_{-1} + \delta_L XDLAB_{-1}$). Thus, all latent variables in this disequilibrium system are identified, and equations (D1) through (D6) can easily be estimated by standard statistical computer packages.

For comparison, we also estimate an equilibrium version of the structural model presented. The estimation equations of an equilibrium model, where demand equals supply in each market, are

(E1) $$L = L^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, L^d_{-1}) + u_1$$

(E2) $$L = L^d_\omega(\Sigma WNET, PROP, TRAN, L^s_{-1}) + u_2$$

(E3) $$I = I^d_\omega(\Sigma WP, \Sigma RP, \Sigma EP, K_{-1}, I^d_{-1}) + u_3$$

(E4) $$I = I^s_\omega(\Sigma WPI, \Sigma RPI, \Sigma EPI, I^s_{-1}) + u_4$$

(E5) $$C = C^d_\omega(\Sigma PCNET, PROP, TRAN, C^d_{-1}) + u_5$$

(E6) $$C = C^s_\omega(\Sigma WPC, \Sigma RPC, \Sigma EPC, C^s_{-1}) + u_6.$$

Here we have explicitly written in the arguments of the Walrasian demands and supplies (which are, of course, identical for the disequilibrium and equilibrium models). It is important to note that the equilibrium model is a special case of the disequilibrium model. The disequilibrium system, equations (D1) through (D6), reduces to the equilibrium system, (E1) through (E6), when δ_L, δ_C, and δ_I equal zero. Thus, the significance of the excess demand indicator coefficients provides a nested econometric test of the hypothesis of market equilibrium (see Rudebusch 1986). This procedure is analogous to testing the significance of the price adjustment coefficient in a standard disequilibrium model augmented by a price adjustment equation.

4.2. *Results*. The sample data are quarterly observations drawn from the United States from 1967-QI to 1981-Q4. All variables are in logarithms and are described in the Appendix. Nonlinear three stage least squares was used to estimate equations (D1) through (D6) allowing for a full non-zero six by six variance-covariance matrix. The variables considered endogenous to the system are consumption, investment, and labor, and their nominal prices, and the market excess demand indicators.[14] Estimates of the disequilibrium model are given Table 1 with asymptotic t-statistics in parentheses. For each market there is a demand equation, given first, and a supply equation. Durbin-Watson statistics (dw_d, dw_s) for each demand and supply equation are given,[15] and the sum of squared fitted residuals weighted by the covariances ($E'HH'E$), the distance function minimized in estimation, is given for the two models.

There are two equations representing the behavior of the household: labor supply (D2) and consumption demand (D3). The effect of transfer income has the proper sign on labor supply; the effect of property income has the proper sign on consumption demand. The wage and price responses are plausible though not very strong. The four equations representing the behavior of the firm (labor demand (D1), consumption supply (D4), investment demand (D5), and investment supply (D6)) are composed primarily of relative price terms with unrestricted coefficients, which is the most flexible representation of the Walrasian price effects (and strengthens our later rejection of equilibrium). Coefficient restrictions or smoothness priors would avoid the time profile of alternating signs for the price responses and might aid in structural interpretation but not in accounting for the Walrasian elements.

Most of the estimated spillover terms were found to be insignificant. Table 1 provides the estimated coefficients of the disequilibrium model limited to two highly

[14] All other variables, which are exogenous, and lagged values of quantities and prices were used as instruments for the endogenous variables. A small, empirically insignificant, open economy correction was applied by subtracting net exports for each industry from the quantity variable (see Rudebusch 1987).

[15] The Durbin-Watson statistics given are biased by the presence of lagged dependent variables. Durbin's h-statistic cannot be applied to the disequilibrium model since the lagged dependent variable is constructed.

TABLE 1:
THREE-MARKET DISEQUILIBRIUM MODEL PARAMETER ESTIMATES

$$L_t = -.225 - \underset{(6.05)}{.013{*}XCON_t} + \underset{(24.1)}{.864{*}L^d_{t-1}} - \underset{(7.94)}{.027{*}XDLAB_t} - \underset{(1.82)}{.885{*}WP_t} + \underset{(.361)}{.161{*}WP_{t-1}}$$

$$+ \underset{(.109)}{.175{*}WP_{t-2}} + \underset{(.677)}{.679{*}WP_{t-3}} - \underset{(.503)}{.025{*}RP_t} + \underset{(.535)}{.041{*}RP_{t-1}} - \underset{(.617)}{.039{*}RP_{t-2}}$$

$$+ \underset{(1.04)}{.039{*}RP_{t-3}} - \underset{(.080)}{.005{*}EP_t} - \underset{(.340)}{.060{*}EP_{t-1}} + \underset{(.149)}{.033{*}EP_{t-2}} + \underset{(.374)}{.039{*}EP_{t-3}}$$

$$L_t = -1.08 + \underset{(1.52)}{.018{*}PROP_t} - \underset{(3.11)}{.046{*}TRAN_t} + \underset{(19.7)}{.950{*}L^s_{t-1}} - \underset{(7.94)}{.027{*}XSLAB_t}$$

$$- \underset{(.160)}{.021{*}WNET_t} + \underset{(.707)}{.112{*}WNET_{t-1}} + \underset{(.563)}{.141{*}WNET_{t-2}} + \underset{(.079)}{.014{*}WNET_{t-3}}$$

$dw_d = 1.54 \qquad dw_s = 1.55$

$$C_t = -.845 + \underset{(1.01)}{.022{*}PROP_t} - \underset{(.604)}{.014{*}TRAN_t} + \underset{(14.5)}{.876{*}C^d_{t-1}} - \underset{(1.47)}{.294{*}PCNET_t}$$

$$+ \underset{(.096)}{.024{*}PCNET_{t-1}} + \underset{(.670)}{.258{*}PCNET_{t-2}} - \underset{(.979)}{.266{*}PCNET_{t-3}}$$

$$C_t = -.137 + \underset{(12.0)}{.977{*}C^s_{t-1}} - \underset{(3.87)}{.012{*}XCON_t} + \underset{(1.21)}{.405{*}WPC_t} - \underset{(1.87)}{.696{*}WPC_{t-1}} + \underset{(.591)}{.772{*}WPC_{t-2}}$$

$$- \underset{(.519)}{.434{*}WPC_{t-3}} + \underset{(1.35)}{.051{*}RPC_t} - \underset{(.676)}{.047{*}RPC_{t-1}} + \underset{(1.22)}{.069{*}RPC_{t-2}} - \underset{(1.58)}{.071{*}RPC_{t-3}}$$

$$+ \underset{(1.40)}{0.67{*}EPC_t} - \underset{(1.37)}{.200{*}EPC_{t-1}} + \underset{(.822)}{.163{*}EPC_{t-2}} - \underset{(.274)}{.027{*}EPC_{t-3}}$$

$dw_d = 1.57 \qquad dw_s = 2.27$

$$I_t = .500 + \underset{(1.38)}{.477{*}K_{-1}} - \underset{(3.24)}{.029{*}XCON_t} + \underset{(19.3)}{.919{*}I^d_{t-1}} - \underset{(3.11)}{.063{*}XDINV_t} - \underset{(1.00)}{1.33{*}WP_t}$$

$$- \underset{(.976)}{1.08{*}WP_{t-1}} + \underset{(1.20)}{4.45{*}WP_{t-2}} - \underset{(1.08)}{.257{*}WP_{t-3}} + \underset{(1.88)}{.220{*}RP_t} - \underset{(1.89)}{.339{*}RP_{t-1}}$$

$$+ \underset{(.990)}{.182{*}RP_{t-2}} + \underset{(.097)}{.012{*}RP_{t-3}} + \underset{(1.22)}{.189{*}EP_t} - \underset{(1.47)}{.679{*}EP_{t-1}} + \underset{(1.17)}{.677{*}EP_{t-2}} - \underset{(.878)}{.241{*}EP_{t-3}}$$

$$I_t = -2.06 + \underset{(10.5)}{.934{*}I^s_{t-1}} - \underset{(3.11)}{.063{*}XSINV_t} + \underset{(1.37)}{.693{*}WPI_t} + \underset{(.268)}{.190{*}WPI_{t-1}} - \underset{(.656)}{.826{*}WPI_{t-2}}$$

$$+ \underset{(.333)}{.258{*}WPI_{t-3}} + \underset{(2.23)}{.178{*}RPI_t} - \underset{(1.70)}{.189{*}RPI_{t-1}} + \underset{(.746)}{.084{*}RPI_{t-2}} + \underset{(.734)}{.060{*}RPI_{t-3}}$$

$$+ \underset{(.789)}{.094{*}EPI_t} - \underset{(.810)}{.249{*}EPI_{t-1}} + \underset{(.492)}{.180{*}EPI_{t-2}} + \underset{(.103)}{.018{*}EPI_{t-3}}$$

$dw_d = 2.72 \qquad dw_s = 2.19$

$E'HH'E = 77.5 \qquad (E'HH'E)$[1] $= 79.7$

[1] Estimated with fixed variance-covariance matrix obtained from 2SLS estimates.

significant spillovers, rationing of firms in the consumer goods market (a sales constraint, *XCON*) affects both labor demand and investment demand. It is surprising that the spillover from the excess supply of labor (*XSLAB*) was not a significant influence on consumption demand. Such a spillover is a major part of Clower's (1965) rationalization of the Keynesian consumption function, and it provided much of the original impetus for research in disequilibrium models. It may be that using a linear spillover with a constant coefficient is not a rich enough specification to model such spillover effects.

The most interesting result from this model is the information provided on the question of whether the labor and product markets clear within the quarter. As described above, the equilibrium model is nested as a special case of the disequilibrium model when the excess demand indicator coefficients are equal to zero. The excess demand and excess supply terms account for the deviation between the observed quantity and the agent's offer. From Table 1, the indicator coefficients and t-statistics are

$$\underset{(7.94)}{\delta_L = 0.027} \quad \underset{(3.11)}{\delta_I = 0.063} \quad \underset{(3.87)}{\delta_C = 0.012}$$

The significance of these coefficients allows us to reject the hypothesis of short-run market equilibrium. A more comprehensive test can be formed from the weighted sum of the residuals ($E'HH'E$), which is inversely related to the likelihood function. A test based on the likelihood-ratio statistic can be formed from the difference in the $E'HH'E$ values for the restricted (equilibrium) and unrestricted (disequilibrium) models. This test is asymptotically distributed one-half chi-squared with three degrees of freedom (see Gallant and Jorgenson 1979 and note the non-negativity restriction on the parameter set). Thus, from Tables 1 and 2 the test statistic can be constructed

$$(E'HH'E)^*_{\text{res.}} - (E'HH'E)^*_{\text{unres.}} = 174.1 - 79.7 = 94.4$$

The starred values of $E'HH'E$ are used since the variance-covariance matrix must be held constant. The 5 percent significance level of $1/2\chi^2(3)$ is 3.91, and the 1 percent level is 5.65. Clearly, we can reject the joint hypothesis of three markets in equilibrium.

The general lack of contemporaneous price effects on quantity in both Tables 1 and 2 is further evidence against equilibrium. In order for a market to clear (by a Walrasian mechanism) within the period, the price must be flexible and either demand or supply must be sufficiently responsive to the *current* price. If demand and supply are completely unresponsive to current price changes, there is no Walrasian mechanism to equilibrate the market. It is sometimes asserted that a contemporaneous price-quantity relationship is unnecessary for equilibrium models, and instead attention is given to the summed response of demand or supply to the whole vector of lagged previous prices. For instance, Symons and Layard (1984) estimate such labor demand functions with negligible contemporaneous price effects but a significant and correctly signed averaged response to several quarters of lagged prices; they interpret this as supporting a labor market in equilibrium. Such price responses, however, merely imply that there is a *long-run* equilibrating

TABLE 2:
THREE-MARKET EQUILIBRIUM MODEL PARAMETER ESTIMATES

$$L_t = .010 + \underset{(15.15)}{.908}{*}L^d_{t-1} - \underset{(1.18)}{.753}{*}WP_t - \underset{(1.02)}{.642}{*}WP_{t-1} + \underset{(1.28)}{2.53}{*}WP_{t-2} - \underset{(.871)}{1.05}{*}WP_{t-3}$$

$$\underset{(.231)}{.016}{*}RP_t - \underset{(.065)}{.007}{*}RP_{t-1} - \underset{(.719)}{.068}{*}RP_{t-2} + \underset{(.379)}{.022}{*}RP_{t-3} - \underset{(.610)}{.056}{*}EP_t$$

$$+ \underset{(.335)}{.087}{*}EP_{t-1} - \underset{(.520)}{.166}{*}EP_{t-2} - \underset{(.953)}{.141}{*}EP_{t-3}$$

$$L_t = -1.66 + \underset{(2.19)}{.042}{*}PROP_t - \underset{(3.00)}{.076}{*}TRAN_t + \underset{(16.0)}{.849}{*}L^s_{t-1} - \underset{(.062)}{.013}{*}WNET_t - \underset{(.370)}{.093}{*}WNET_{t-1}$$

$$+ \underset{(.636)}{.251}{*}WNET_{t-2} - \underset{(.997)}{.284}{*}WNET_{t-3}$$

$dw_d = 2.20 \qquad dw_s = 1.16$

$$C_t = -.793 + \underset{(1.57)}{.031}{*}PROP_t - \underset{(.277)}{.006}{*}TRAN_t + \underset{(15.1)}{.832}{*}C^d_{t-1} - \underset{(1.27)}{.245}{*}PCNET_t - \underset{(.052)}{.013}{*}PCNET_{t-1}$$

$$+ \underset{(.644)}{.245}{*}PCNET_{t-2} - \underset{(1.13)}{.293}{*}PCNET_{t-3}$$

$$C_t = -.751 + \underset{(11.0)}{.781}{*}C^s_{t-1} + \underset{(.126)}{.065}{*}WPC_t - \underset{(1.29)}{.722}{*}WPC_{t-1} + \underset{(.975)}{1.75}{*}WPC_{t-2} - \underset{(.658)}{.0757}WPC_{t-3}$$

$$+ \underset{(1.14)}{.068}{*}RPC_t - \underset{(1.27)}{.122}{*}RPC_{t-1} + \underset{(.657)}{.056}{*}RPC_{t-2} + \underset{(.044)}{.002}{*}RPC_{t-3} + \underset{(.470)}{.036}{*}EPC_t$$

$$- \underset{(.684)}{.158}{*}EPC_{t-1} + \underset{(.583)}{.176}{*}EPC_{t-2} - \underset{(.242)}{.035}{*}EPC_{t-3}$$

$dw_d = 1.46 \qquad dw_s = 2.04$

$$I_t = -.411 - \underset{(.440)}{.056}{*}K_{-1} + \underset{(25.3)}{.995}{*}I^d_{t-1} - \underset{(.612)}{.572}{*}WP_t - \underset{(2.37)}{.239}{*}WP_{t-1} - \underset{(2.56)}{7.58}{*}WP_{t-2}$$

$$+ \underset{(2.47)}{4.57}{*}WP_{t-3} + \underset{(2.16)}{.243}{*}RP_t - \underset{(2.00)}{.333}{*}RP_{t-1} - \underset{(.157)}{.023}{*}RP_{t-2} + \underset{(.372)}{.035}{*}RP_{t-3}$$

$$- \underset{(.183)}{.026}{*}EP_t - \underset{(.491)}{.197}{*}EP_{t-1} + \underset{(.328)}{.160}{*}EP_{t-2} + \underset{(.234)}{.052}{*}EP_{t-3}$$

$$I_t = -1.20 + \underset{(19.7)}{.996}{*}I^s_{t-1} + \underset{(1.23)}{.542}{*}WPI_t - \underset{(1.36)}{.812}{*}WPI_{t-1} + \underset{(1.31)}{1.24}{*}WPI_{t-2} - \underset{(1.37)}{.735}{*}WPI_{t-3}$$

$$+ \underset{(1.10)}{.104}{*}RPI_t - \underset{(.454)}{.057}{*}RPI_{t-1} - \underset{(1.39)}{.162}{*}RPI_{t-2} + \underset{(.734)}{.063}{*}RPI_{t-3} - \underset{(1.22)}{.153}{*}EPI_t$$

$$+ \underset{(1.21)}{.375}{*}EPI_{t-1} - \underset{(1.58)}{.569}{*}EPI_{t-2} + \underset{(1.90)}{.332}{*}EPI_{t-3}$$

$dw_d = 2.74 \qquad dw_s = 2.18$

$E'HH'E = 94.5 \qquad (E'HH'E)$[1] $= 174.1$

[1] Estimated with fixed variance-covariance matrix obtained from 2SLS estimates.

mechanism at work, which is entirely consistent with short-run disequilibrium and provides no evidence that prices can equilibrate the market during the period.

5. CONCLUSION

Relying on non-stochastic excess demand information, we have been able to estimate a structurally complex, dynamic, three-market disequilibrium model with a clear distinction between Walrasian and effective demand. Our main empirical conclusion, from the significance of the excess demand indicators, is the rejection of the hypothesis of quarterly Walrasian equilibrium in each market. The insignificance of contemporaneous prices also has supported this conclusion.

Another, more general modeling conclusion, however, can be also drawn from our estimation of a multimarket disequilibrium model rich in economic structure. The practical feasibility of a disequilibrium methodology for macroeconomic modeling has been questioned by some (for example, Kooiman and Kloek 1985, p. 345). Previous empirical multimarket disequilibrium models have been criticized as too simple in structure and too difficult to implement. Here we have demonstrated the tractability of estimation of multimarket disequilibrium models in the presence of market tension and rationing information. Further research is suggested, both in refining the structural model and the measures of excess demand.

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APPENDIX
DEFINITION OF VARIABLES

The data are taken from the MPS databank and the Citibank Economic Data Base, and all variables are seasonally adjusted.

Series–Description

- *C*– Log of personal consumption expenditures.
- *EP*– $\text{Log}(P_E/P_Y)$.
- *EPC*– $\text{Log}(P_E/P_C)$.
- *EPI*– $\text{Log}(P_E/P_I)$.
- *I*– Log of business fixed investment.
- *K*– Log of capital stock, end of period.
- *L*– Log of hours of employees in the nonfarm business sector.
- P_C– Implicit price of consumption.
- P_E– Producer price index for fuels and power.
- P_Y– Implicit price of output.
- *PCNET*– $\text{Log}(P_C/W(1 - \theta))$.
- *PROP*– Log of real consumer property income.
- *R*– Nominal rent per unit of capital services.
- *RP*– $\text{Log}(R/P_Y)$.

RPC– $\text{Log}(R/P_C)$.
RPI– $\text{Log}(R/P_I)$.
θ– Effective average rate of personal income taxation.
TRAN– Log of real consumer transfer income.
W– Nominal employee compensation in the nonfarm business sector.
WNET– $\text{Log}((1 - \theta)W/P_C)$.
WP– $\text{Log}(W/P_Y)$.
WPC– $\text{Log}(W/P_C)$.
WPI– $\text{Log}(W/P_I)$.
Y– Log of output of employees in the nonfarm business sector.

Indicators

The excess demand indicators are the first principal components of these series:

Labor Market
Percentage deviation from trend of the unemployment rate.
Percentage deviation from trend of the index of help wanted advertising.
Capital Goods Market
Percentage deviation from trend of real unfilled orders in the capital goods industry.
Percentage deviation from mean of capital goods capacity utilization, constructed from business equipment industrial production index with linear peak-to-peak capacity.
Consumer goods market
Percentage deviation from trend of consumer goods manufacturing inventory-sales ratio.
Percentage deviation from trend of retail inventory-sales ratio.
Percentage deviation of consumer goods capacity utilization, constructed from consumer goods industrial production index with linear peak-to-peak capacity.

REFERENCES

ABEL, A., "Empirical Investment Equations: An Integrative Framework," in K. Brunner and A. Meltzer, eds., *On the State of Macroeconomics*, Vol. 12 of a supplementary series to *Journal of Monetary Economics* (1980), 39–91.

ANDO, A., F. MODIGLIANI, R. RASCHE AND S. TURNOVSKY, "On the Role of Expectations of Price and Technological Change in an Investment Function," *International Economic Review* 15 (1974), 384–401.

ARTUS, P., G. LAROQUE AND G. MICHEL, "Estimation of a Quarterly Econometric Model with Quantity Rationing," *Econometrica* 52 (1984), 1387–1414.

——— AND P. A. MUET, "Investment, Output and Labor Constraints, and Financial Constraints: The Estimation of a Model with Several Regimes," *Recherches Economiques de Louvain* 50 (1984) 25–44.

BARRO, R. J. AND H. GROSSMAN, "A General Disequilibrium Model of Income and Employment," *American Economic Review* 61 (1971), 82–93.

BENASSY, J. P., "Neo-Keynesian Disequilibrium Theory in a Monetary Economy," *Review of Economics and Statistics* 44 (1975), 503–524.

———, "Developments in Non-Walrasian Economics and the Microeconomic Foundations of Macroeconomics," in W. Hildenbrand, ed., *Advances in Economic Theory* (Cambridge: Cambridge University Press, 1982).

———, "Tariffs and Pareto Optimality in International Trade: The Case of Unemployment," *European Economic Review* 26 (1984), 261–276.

BOSCHEN, J. F. AND H. GROSSMAN, "Tests of Equilibrium Macroeconomics Using Contemporaneous Monetary Data," *Journal of Monetary Economics* 10 (1982), 309–333.

CLOWER, R. W., "The Keynesian Counter-Revolution: A Theoretical Appraisal," in F. M. Hahn and F. P. R. Brechling, eds., *The Theory of Interest Rates* (London: Macmillan, 1965).

CUDDINGTON, J., P. JOHANSSON AND K. LÖFGREN, *Disequilibrium Macroeconomics in Open Economies* (Oxford: Blackwell, 1985).

DEATON, A. AND J. MUELLBAUER, *Economics and Consumer Behavior* (Cambridge: Cambridge University Press, 1984).

ENGLE, R. AND D. FOLEY, "An Asset Price Model of Aggregate Investment," *International Economic Review* 16 (1975), 625–647.

FAIR, R. AND D. JAFFEE, "Methods of Estimation for Markets in Disequilibrium," *Econometrica* 40 (1972), 497–517.

GALLANT, A. R. AND D. JORGENSON, "Statistical Inference for a System of Simultaneous, Non-Linear, Implicit Equations in the Context of Instrumental Variable Estimation," *Journal of Econometrics* 11 (1979), 275–302.

GOLDFELD, S. AND R. QUANDT, "Single Market Disequilibrium Models: Estimation and Testing," *Economic Studies Quarterly* 32 (1981), 12–28.

GORDON, R. J., "Structural Unemployment and the Productivity of Women," in K. K. Brunner and A. Meltzer, eds., *Stabilization of Domestic and International Economy*, Vol. 5 of a supplementary series to *Journal of Monetary Economics* (1977), 181–226.

GOURIEROUX, C., J.-J. LAFFONT AND A. MONFORT, "Disequilibrium Econometrics in Simultaneous Equation Systems," *Econometrica* 48 (1980), 75–96.

GREEN, J. AND J.-J. LAFFONT, "Disequilibrium Dynamics with Inventories and Anticipatory Price-Setting," *European Economic Review* 16 (1981), 199–221.

HALL, R. AND D. JORGENSON, "Tax Policy and Investment Behavior," *American Economic Review* 57 (1967), 391–414.

HILDENBRAND, K. AND W. HILDENBRAND, "On Keynesian Equilibria with Unemployment and Quantity Rationing," *Journal of Economic Theory* 18 (1978), 255–277.

HONKAPOHJA, S. AND T. ITO, "Inventory Dynamics in a Simple Disequilibrium Macroeconomic Model," *Scandinavian Journal of Economics* 82 (1980), 184–198.

ITO, T., "Methods of Estimation for Multi-Market Disequilibrium Models," *Econometrica* 48 (1980), 97–126.

KILLINGSWORTH, M. R., *Labor Supply* (Cambridge: Cambridge University Press, 1983).

KOOIMAN, P. AND T. KLOEK, "An Empirical Two Market Disequilibrium Model for Dutch Manufacturing," *European Economic Review* 29 (1985), 323–354.

LEE, L.-F., "The Specification of Multi-Market Disequilibrium Econometric Models," *Journal of Econometrics* 32 (1986), 297–332.

MALINVAUD, E., *The Theory of Unemployment Reconsidered* (Oxford: Blackwell, 1977).

MCCALLUM, B., "On 'Real' and 'Sticky-Price' Theories of the Business Cycle," *Journal of Money, Credit, and Banking* 18 (1986), 397–414.

MEESE, R., "Dynamic Factor Demand Schedules for Labor and Capital Under Rational Expectations," *Journal of Econometrics* 14 (1980), 141–158.

MUELLBAUER, J., AND R. PORTES, "Macroeconomic Models with Quantity Rationing," *Economic Journal* 88 (1978), 788–821.

NISHIMIZU, M., R. E. QUANDT AND H. S. ROSEN, "The Demand and Supply of Investment Goods: Does the Market Clear?" *Journal of Macroeconomics* 4 (1982), 1–21.

PERRY, G. L., "Capacity in Manufacturing," *Brookings Papers on Economic Activity* (1973), 701–742.

PORTES, R., "Effective Demand and Spillovers in Empirical Two-Market Disequilibrium Models," Discussion Paper No. 595, Harvard Institute of Economic Research, 1977.

QUANDT, R. E. AND H. S. ROSEN, "Is There Chronic Excess Supply of Labor?," *Economics Letters* 19 (1985), 193–197.

RUDEBUSCH, G. D., "Testing for Labor Market Equilibrium with an Exact Excess Demand Disequilibrium Model," *The Review of Economics and Statistics*, 68 (1986), 468–476.

———, *The Estimation of Macroeconomic Disequilibrium Models with Regime Classification Information* (New York: Springer-Verlag, 1987).

RUIST, E. AND H. T. SÖDERSTRÖM, "Measuring Capacity Utilization and Excess Demand," *European Economic Review* 6 (1975), 369–386.

SARGENT, T., "Estimation of Dynamic Labor Demand Schedules Under Rational Expectations," *Journal of Political Economy* 86 (1978), 1009–1044.

SCHULTZE, C. L., "Uses of Capacity Measures for Short-Run Economic Analysis," *American Economic Review* 53 (1963), 293–308.

SNEESSENS, H., "A Macroeconomic Rationing Model of the Belgium Economy," *European Economic Review* 20 (1983), 193–215.

SYMONS, J. AND R. LAYARD, "Neoclassical Demand for Labor Functions for Six Major Economies," *Economic Journal* 94 (1984), 788–799.