1984

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ISSN 0228-4235
ISBN 0-7714-0573-1

CENTRE FOR THE STUDY OF INTERNATIONAL ECONOMIC RELATIONS

WORKING PAPER NO. 8433C

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August 1984 (revised)

† We are grateful to G. van der Laan and Bernd Koch for helpful comments. The Social Sciences and Humanities Research Council of Canada has provided for financial support.

This paper presents both an existence proof and numerical computations of equilibria in which endogenous transactions (or search) costs are determined in response to government legislated fixed relative prices. Price controls may apply to all commodities or only a subset of commodities. Real resources are involved with the equilibrating process as buyers attempt to locate sellers (or vice versa) at fixed prices. The larger the excess demand (or supply) in any market, the costlier it becomes to locate a transactor on the other side of the market. This formulation of real resource costs involved in equilibrating markets under price controls is related to Krueger's [6] well-known formulation of equilibrium under quantity controls where resources used in rent-seeking activities are part of the equilibrating process.

Our aim is eventual empirical application of this equilibrium concept directed towards an evaluation of the welfare costs of distortions induced by economy-wide wage and price controls. Most existing empirical literature on these controls focus on their macroeconomic impacts on inflation, unemployment, and other macro variables. This contrasts with the main attack on these controls from Friedman and others which is usually on resource allocation grounds.

Rather than model an economy with a given transactions technology, we allow transactions (search) costs to be endogenously determined. The parable is that in an economy with price controls, the larger the divergence between controlled and market-clearing prices, the costlier it becomes for sellers and buyers to locate each other. The differentials that these costs generate between effective buying and selling prices (including search costs) are endogenously determined so as to clear markets, and also provide the major part of the social costs of price controls. These equilibria are also equivalent to a formulation in which proportional rationing accompanies the constrained side of any market. Previous literature on the theory of distortions has not provided a general equilibrium formulation for investigating the resource allocation effects of government-controlled prices. This is what we attempt here.

Our work contrasts with the literature on fixed price equilibria generated by Drèze [2] and Benassy [1] which uses a quite different quantity rationing formulation as an equilibrating mechanism for resource allocation when prices are institutionally rigid. Developments within this literature have been mainly concerned with the formal characterization of these fixed price equilibria (including existence) and their relationship to Keynesian macroeconomics (e.g., Grandmont and Laroque [3]) rather than with an evaluation of the welfare effects of price controls. In our analysis prices are fixed by government fiat, as is the case of a system of economy-wide wage and price controls, instead of simply being sticky. Some of the recent computationally oriented models of fixed price equilibria such as Imam and Whalley [4], Kehoe and Serra-Puche [5], Nguyen [7], Reif [8], and van der Laan [12] have also been moving in this direction.

The plan of the paper is as follows: section 1 sets out the basic framework of an exchange economy with fixed prices and endogenously-determined transactions costs. Section 2 outlines an existence proof of an equilibrium with endogenously-determined transactions costs and market demands under exogenously-fixed relative prices. The mapping used in the existence proof also allows for any variant of the well-known fixed-point algorithms to be used to compute such an equilibrium. Section 3 provides some simple numerical examples using such computational procedures. Section 4 concludes the paper with some remarks on potential applications and further extensions of the model.

1. THE BASIC FRAMEWORK

We consider a pure exchange economy with m agents ($i = 1,\ldots,m$) and n goods ($j = 1,\ldots,n$). All prices are exogenously fixed by government decrees at <u>positive</u> non-market clearing levels $\mathbf{p} = (p_1,\ldots,p_n) > \mathbf{0}$. For simplicity we assume that each agent i has a <u>positive</u> vector of initial endowments $\mathbf{w}^i = (w_1{}^i,\ldots,w_n{}^i) > 0$. For each good j there are endogenously-determined search costs which produce buying prices (gross of search costs) $p_j{}^b \geq p_j$ and selling prices (net of search costs) $p_j{}^s \leq p_j$. In equilibrium these prices will 'clear' markets. Only one side of each market can be rationed since either excess demands or excess supplies, but not both, can occur simultaneously in any market under price controls. Thus either $p_j{}^b = p_j$ or $p_j{}^s = p_j$ or both conditions hold for each j. We denote the vector of prices received by the seller by $\mathbf{p}^s$ and the vector of prices paid by buyers as $\mathbf{p}^b$. Any differences from the controlled prices $\mathbf{p}$ are accounted for solely by the search costs involved.

In this model, equilibrium rationing involves real resource costs devoted to transacting, which increases as transacting becomes more costly. A parable for such equilibria is that real resources are expended as buyers or sellers on the constrained side of each market locate agents with whom they can transact, with the constrained side of the market bearing the costs involved. These search costs represent endogenously-determined transactions costs, in contrast to the fixed transactions technology approach often employed in the literature on general equilibrium in the presence of transactions costs. We could have complicated our model by explicitly representing the search technology as one of repeated trials, each involving an attempt to find an agent with whom one can transact at the fixed prices. With a fixed resource cost per trial, the number of trials would be endogenously determined yielding an equivalent but more complex version of the same formulation used here. The resource costs of transacting are an important ingredient of the model, since they become a major component of the welfare costs associated with price controls[1]

Two different formulations of our model are possible: one where endogenous transactions costs are associated with making <u>net</u> trades (demands less endowments) and one where costs accrue from making <u>gross</u> trades. The gross trade case is analytically and computationally simpler, the net trade case is slightly more complex.

In the case where transactions costs are associated with gross trades, the demand side of the economy is characterized by a set of continuous nonnegative market demand functions of these market buying and selling prices $x_j = x_j(p^b, p^s)$ for $j = 1,\ldots,n$. The x_j are homogeneous of degree zero with respect to (p^b, p^s) and satisfy a version of Walras law stated as

$$\Sigma_j\, p_j^b\, x_j \;=\; \Sigma_j\, p_j^s\, w_j \tag{1}$$

where aggregate initial endowments w_j $(j = 1,\ldots,n)$ equal the sum of individual initial endowments

$$w_j \;=\; \Sigma_i\, w_j^i. \tag{2}$$

Search (transactions) costs are assumed to be borne exclusively by the constrained side of any market, and involve a real resource cost denoted in units of that commodity. The search costs involved in selling a unit of commodity j at the price p_j are $(p_j - p_j^s) / p_j$ and search costs for buyers purchasing at the price p_j are $(p_j^b - p_j) / p_j$. This formulation models search costs as $(p_j - p_j^s)$ per dollars of sales at prices p_j and $(p_j^b - p_j)$ per dollars of purchases at prices p_j.

Since search costs in any market are measured in terms of the commodity traded, we can write market demand functions different from those in the more traditional Arrow-Debreu pure exchange general equilibrium model by including search costs on the demand and supply sides of each market. These are written as

$$z_j \;=\; (p_j^b/p_j)\, x_j - (p_j^s/p_j)\, w_j \tag{3}$$

$(j = 1,\ldots,n)$ where $(p_j^b/p_j)\, x_j$ denote the total demands (including buyers' search costs) for final demands x_j given buying and controlled prices p_j^b, p_j and $(p_j^s/p_j)\, w_j$ denote the net supplies (after sellers' search costs) given selling and controlled prices p_j^s, p_j.

We can rewrite Walras law (1) as

$$\Sigma_j \, p_j \, x_j \; = \; \Sigma_j \, p_j \, w_j \; - \; T \tag{4}$$

where

$$T \; = \; \Sigma_j \, (p_j^b - p_j) \, x_j \; + \; \Sigma_j \, (p_j - p_j^s) \, w_j$$

denotes the total transactions costs. Walras law then implies that $\Sigma_j \, p_j \, z_j = 0$. If there are no transactions costs (i.e., $p_j^b = p_j^s = p_j$ for all $j = 1,\ldots,n$) then Walras law (4) degenerates to the more usual form

$$\Sigma_j \; p_j \, x_j \; = \; \Sigma_j \, p_j \, w_j. \tag{5}$$

With this framework stated, an equilibrium can be defined as vectors of buying and selling prices $(\mathbf{p}^{b*},\mathbf{p}^{s*})$ and market demands $\mathbf{x}^* = \mathbf{x}^* \, (\mathbf{p}^{b*},\mathbf{p}^{s*})$ such that for $j = 1,\ldots,n$

$$z_j \; = \; (p_j^{b*}/p_j) \, x_j^* - (p_j^{s*}/p_j) \, w_j \; = \; 0, \tag{6}$$

$$\text{either } p_j^{b*} = p_j, \; 0 \le p_j^{s*} \le p_j \;\; \text{or} \;\; p_j^{s*} = p_j, \; p_j \le p_j^{b*}. \tag{7}$$

Condition (6) clears all markets in the sense that the market demand for any good j, including any transactions costs on the demand side, is equal to the supply of that good after sellers' transactions costs. A strict equality rather than the more usual demand-supply inequality characterizes equilibrium since strict positivity of controlled (and hence buying) prices is assumed. Condition (7) requires that only one side of any market bears transactions costs. In no markets do both buyers and sellers of the same good bear transactions costs at the same time. This one-side-of-market condition makes this concept of equilibrium a nontrivial extension of the traditional Arrow-Debreu theory of competitive equilibrium.

In the case where transactions costs are associated with making net trades the budget constraint for any agent i is written as

$$\Sigma_j\, p_j^{\,b} \max(x_j^{\,i}-w_j^{\,i},0) \;=\; \Sigma_j\, p_j^{\,s} \max(w_j^{\,i}-x_j^{\,i},0). \qquad (8)$$

Market demands x_j equal the sum of individual demands $\Sigma_i\, x_j^{\,i}$ and Walras law in this case is written as in (4)

$$\Sigma_j\, p_j\, x_j \;=\; \Sigma_j\, p_j\, w_j \;-\; T \qquad (9)$$

but now

$$T \;=\; \Sigma_i\, \Sigma_j\, (p_j^{\,b} - p_j) \max(x_j^{\,i}-w_j^{\,i},0) \;+\; \Sigma_i\, \Sigma_j\, (p_j - p_j^{\,s}) \max(w_j^{\,i}-x_j^{\,i},0).$$

Equilibrium is defined by vectors of buying and selling prices $(\mathbf{p}^{b*},\mathbf{p}^{s*})$ and market demands $\mathbf{x}^* = \mathbf{x}^*(\mathbf{p}^{b*},\mathbf{p}^{s*})$ such that for j = 1,...,n

$$z_j \;=\; x_j^{*} - w_j - \zeta_j \;=\; 0, \qquad (10)$$

$$\text{either } p_j^{\,b*} = p_j,\; 0 \le p_j^{\,s*} \le p_j \;\text{ or }\; p_j^{\,s*} = p_j,\; p_j \le p_j^{\,b*}. \qquad (11)$$

where the additional terms

$$\zeta_j \;=\; \Sigma_i\, \{(p_j^{\,b*} - p_j)/p_j\} \max(x_j^{\,i*}-w_j^{\,i},0) \;+\; \Sigma_i\, \{(p_j - p_j^{\,s*})/p_j\} \min(w_j^{\,i}-x_j^{\,i*},0)$$

(j = 1,...,n) in the demand supply equalities in this case reflect the endogenously-determined transactions costs denominated in units of the commodity traded. These terms are more complicated than in the case of transactions costs associated with gross trades.

2. EXISTENCE AND COMPUTATION OF EQUILIBRIA

In this section we provide an existence proof for equilibrium under fixed prices and endogenous transactions costs. The mapping constructed can also be used in a computational procedure to find such an equilibrium.

We consider a standard (n-1)-dimensional unit simplex S, and normalize the positive vector **p** of fixed prices so that **p** belongs to the interior of S. We define vectors of buying and selling prices $(\mathbf{p}^b, \mathbf{p}^s)$ in terms of elements **s** of S as follows:

$$p_j^b = \max(p_j, s_j) \geq p_j, \tag{12}$$

$$p_j^s = \min(p_j, s_j) \leq p_j, \tag{13}$$

(j = 1,...,n). This construction allows us to redefine the commodity demand functions in either the gross trade or net trade case as

$$x_j = x_j(\mathbf{p}^b, \mathbf{p}^s) = x_j(\mathbf{s}) \tag{14}$$

(j = 1,...,n) and the market excess demand functions [either (3) or (10)] as

$$z_j = z_j(\mathbf{s}) \tag{15}$$

(j = 1,...,n). Since $(\mathbf{p}^b, \mathbf{p}^s)$ are continuous functions of **s**, so are commodity demands $\mathbf{x} = (x_1,...,x_n)$ and excess demands $\mathbf{z} = (z_1,...,z_n)$. We next consider a variant of Gale-Nikaido mapping $G : S \rightarrow S$

$$G_j(\mathbf{s}) = \{s_j + \max(z_j(\mathbf{s}),0)\} / (1 + \Delta) \tag{16}$$

(j = 1,...,n) where

$$\Delta = \Sigma_j \max(z_j(\mathbf{s}),0). \tag{17}$$

G is clearly a continuous mapping of the standard unit simplex S into itself. Brouwer's fixed-point theorem then applies: there exists a fixed point s^* in S such that $s^* = G(s^*)$.

Let (p^{b*}, p^{s*}) and (x^*, z^*) be determined by the fixed point s^* according to Eqs. (12)-(15). It remains to show that (p^{b*}, p^{s*}) and (x^*, z^*) satisfy equilibrium conditions (6,7) [or (10,11)].

- The one-side-of-market condition (7) [or (11)] is clearly satisfied through the constructions (12,13).
- To check the market-clearing condition (6) [or (10)] we rewrite (16) as follows:

$$\Delta s_j^* = \max(z_j^*, 0) \tag{18}$$

(j = 1,...,n). Suppose $z_j^* > 0$ for at least one j. This implies $\Delta > 0$ and $s_j^* > 0$ which in turn implies $p_j^{b*} > 0$ and $p_j^{s*} > 0$. If $z_k^* < 0$ for at least one $k \neq j$, then the positivity of Δ [from (18)] implies that $s_k^* = 0$. This in turn implies that $p_k^{s*} = 0$. From (6) [or (10)], however, $p_k^{s*} = 0$ contradicts the negativity of z_k^*. Thus if $z_j^* > 0$ then $z_k^* \geq 0$ for all $k \neq j$. Walras law (4) [or (9)] implies that $\Sigma_j\, p_j\, z_j^* = 0$. The strict positivity of p_j therefore implies that z_j^* must equal to zero for all j. This implies that market clearing condition (6) [or (10)] must hold, and that an equilibrium exists in either the gross or net trade.

This same mapping G of the standard unit simplex S into itself can also be used to compute the equilibrium values of buying and selling prices, and market demands, given any set of fixed prices in either the gross or net trade case. Any one of the available fixed-point algorithms, such as Scarf [9] or the subsequent refinement due to van der Laan and Talman [10,11] can be adopted for this purpose. Extending this difficulty in approach to incorporate production seems to be relatively straightforward. Although Imam and Whalley [4] have recently noted that for a model in which price ceilings or floors are maintained by some government intervention schemes it is possible to construct an activity which will always make positive profits given the ceilings or floors, this issues does not arise with the present formulation due to the endogeneity of buying and selling prices.

2. A SIMPLE NUMERICAL EXAMPLE

To illustrate our approach we have computed a series of simple numerical examples of equilibria in the presence of government controlled prices where endogenous transactions costs are associated with gross rather than net trades. This case is simpler to code the computer program and serves to illustrate our approach, although transactions costs will be larger when associated with gross rather than net trades. The functions and parameter values used are arbitrarily chosen; in an application to practical policy situations they would clearly need to be more carefully specified.

We consider a pure exchange economy with 5 commodities and 6 consumers. Individual initial endowments are given by

Commodity			**Consumer**			
	1	2	3	4	5	6
1	20	5	10	10	5	44
2	5	10	10	10	2	21
3	10	10	30	5	3	6
4	5	10	10	3	5	30
5	4	10	4	1	20	1

We assume Cobb-Douglas preference functions for each consumer with the following preference parameters

Commodity	Consumer					
	1	2	3	4	5	6
1	0.143	0.200	0.428	0.143	0.143	0.143
2	0.143	0.200	0.143	0.428	0.143	0.143
3	0.428	0.200	0.143	0.143	0.143	0.143
4	0.143	0.200	0.143	0.143	0.143	0.428
5	0.143	0.200	0.143	0.143	0.428	0.143

A competitive equilibrium price vector for this economy in the absence of price controls is given by the normalized price vector (0.1332, 0.1812, 0.1752, 0.2242, 0.2862). If the controlled price vector (0.10, 0.18, 0.15, 0.25, 0.32) is considered, the equilibrium buying and selling prices are

Commodity	Buying Prices	Selling Prices	Fixed Prices
1	0.34	0.10	0.10
2	0.18	0.14	0.18
3	0.15	0.13	0.15
4	0.25	0.17	0.25
5	0.32	0.22	0.32

Market excess demands are all less than 0.002 in absolute value for a grid size of 100,000 in computation. Execution costs are small. Welfare losses from price controls in terms of Hicksian equivalent variations (EV) and compensating variations (CV) are 38.8% and 45.8% of national income[2], respectively.

In further examples we have considered sequences of cases in which the controlled prices asymptotically approach the competitive equilibrium prices. We have used CES preferences with the same Cobb-Douglas share parameters above and the following elasticities of substitution

	Consumer					
	1	2	3	4	5	6
Case 1	0.100	0.200	0.250	0.400	0.500	0.800
Case 2	0.325	0.400	0.4375	0.550	0.625	0.850
Case 3	0.550	0.600	0.625	0.700	0.750	0.900
Case 4	0.775	0.800	0.8125	0.850	0.875	0.950

We have computed the economy-wide welfare losses from price controls in terms of the arithmetic sum of EV's across individual consumers which, not surprisingly, monotonically falls as the controlled prices approach the competitive equilibrium prices (see Figure 1). We allow for this by initially fixing the controlled prices at the barycenter of the unit simplex, computing the welfare loss, and then allowing the controlled prices to approximate the competitive equilibrium prices by taking them to be alternative distances along the line segment connecting the barycenter and the competitive equilibrium prices. In each case, the welfare losses of fixing prices at the barycenter of the unit simplex are

	EV as % of National Income	**Euclidean Distance From Competitive Price Vector to the Barycenter**
Case 1	72.2	0.325
Case 2	67.1	0.234
Case 3	59.6	0.179
Case 4	51.2	0.141
Cobb-Douglas	42.3	0.116

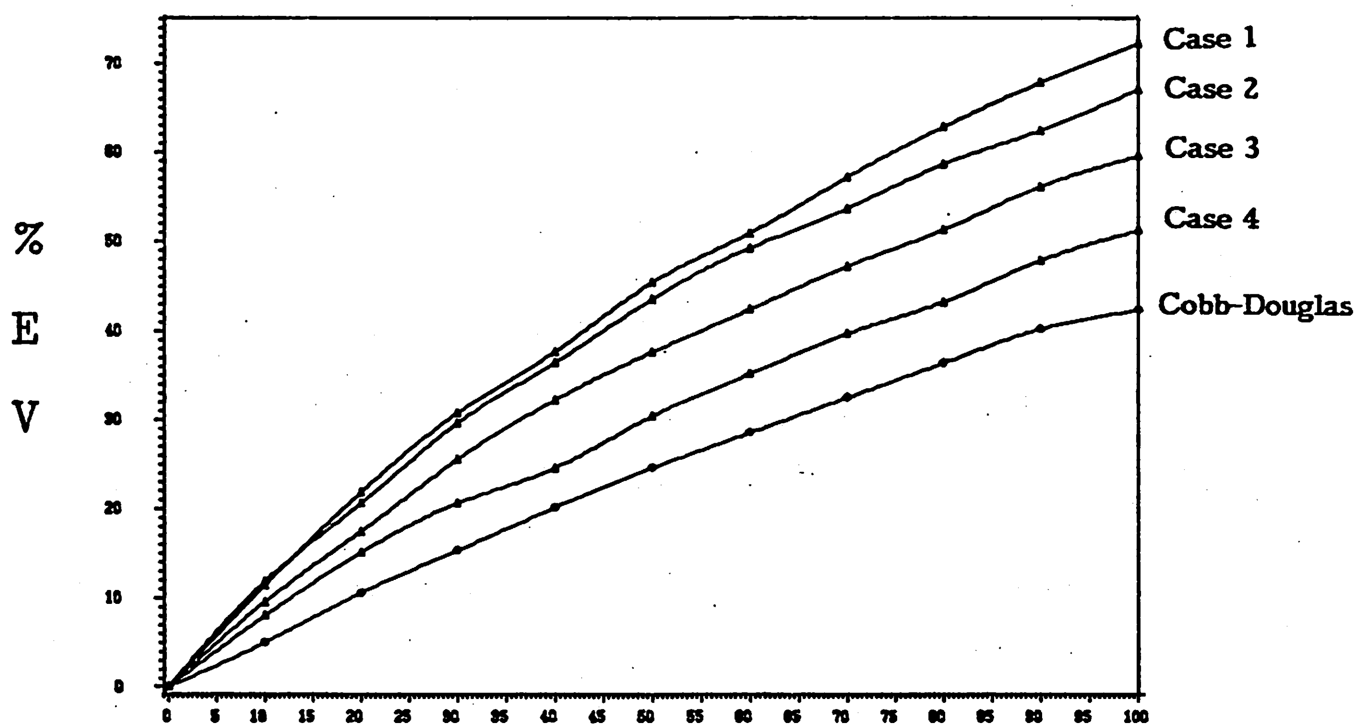
These large welfare costs reflect the endogenously-determined resource costs of the search activity involved although as we have noted above, the assumption of gross rather than net trades involved in transactions costs produces larger welfare cost estimates. While these calculations are not realistic representations of actual economies, the calculations are suggestive that welfare costs associated with fixed price equilibria may be much larger than the commonly measured costs of ad valorem tax and other distortions. These simple numerical examples thus demonstrate the applicability of the approach and its potential value for future policy evaluation work.

4. CONCLUSION

In this paper we have presented an equilibrium model for an exchange economy with fixed prices and endogenously-determined search or transactions costs. Given the fixed prices, endogenously-determined equilibrium buying and selling prices (which include transactions costs) result. These costs occur on either the demand or supply side of each market, but not both. We see an eventual application of this approach to an evaluation of welfare costs of economy-wide wage and price controls, and to sector-specific price controls such as energy. In the final section we present some simple numerical examples which illustrate the approach.

FIGURE 1

WELFARE LOSSES



COMPETITIVE EQUILIBRIUM (0%) TO BARYCENTER (100%)

NOTES

1. An alternative version of our model (not presented here) centers on a costless government agency which reallocates untraded commodities in a lump sum fashion once equilibrium is achieved. This income transfer model which involves endogenously-determined rationing proportions but no real resource costs in transacting at fixed prices, is discussed in [7].

2. National income is defined as the value of aggregate endowments at competitive equilibrium prices.

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