ENERGY, OUTPUT, AND EMPLOYMENT IN THE SHORT RUN

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ABSTRACT

This paper presents an analysis of a three-market, fix-price, open economy with quantity adjustments, as a contribution to the growing literature which examines the consequences of production and exchange occurring at non-market-clearing prices. In particular, it examines the various possible spillover effects in markets for output and labour from a market for energy as the second variable factor input, with energy imports and an energy excise. Explicit treatment of energy results in eight possible non-market-clearing regimes. The different responses of the economy to changing prices or changing exogenous variables are analysed for each regime. Possible government policies in response to adverse supply shocks are discussed.

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1. Introduction

Recent rises in the prices asked for their oil by the Organization of Petroleum Exporting Countries (OPEC) suppliers have been accompanied by shortages and rationing, and the prices to consumers of petroleum products have risen, for non-OPEC oil as well. (In Australia the Federal government has imposed a levy on locally produced crude oil, adjusted every six months to bring the price to consumers up to "world parity," as represented by the price of Arabian light crude. In the U.S., a phased decontrol of domestic oil prices is allowing U.S. prices to rise to the world level.) This paper asks how an economy might respond to such a shift in the supply schedule of oil, by examining the behaviour of an open, short-run model economy with three possibly non-clearing markets: for output and for the variable input factors of labour and energy. Possible policy actions and the response of the economy to changing prices or to changing exogenous variables (the size of the work-force, the supply of energy, the proportion of foreign energy purchases, and the exogenous demand for output) are examined and found to vary with the particular non-market-clearing regime of the moment.

Section 2 discusses disequilibrium adjustments in energy markets and previous work on the theory of non-market-clearing exchange, with the concept of "effective" demand and supply schedules (Clower [1965]). Section 3 introduces the model and the behaviour of firms and households. Section 4 introduces the eight disequilibrium regimes. Sections 5 and 6 examine in detail the regimes of "classical unemployment" and "Keynesian unemployment" (Malinvaud [1977]). Section 7 introduces a simple representation of the disequilibrium regimes by plotting the states of the economy in terms of the real wage and the real energy flow price, in an extension of the work of Barro and Grossman [1971, 1976]. Section 8 uses the model to analyse how shifts in the exogenous variables might affect output and employment in the short run, and to discuss possible government policies in response.

2. Disequilibrium and Exchange

Traditional theory has held that prices adjust quickly to excess supplies or demands, resulting in the rapid disappearance of any disequilibrium. Recent studies (Leijonhufvud [1968] and Malinvaud [1977]) have questioned the adequacy of this theory in describing the short-run behaviour of modern market economies, and there is a growing body of literature on the consequences of relaxing the assumption of rapid price adjustment.

Okun [1975] classifies markets into two groups: first, traditional "auction" markets for such goods as agricultural produce, raw materials, and most assets, in which prices quickly adjust to equate demand and supply; and, second, "customer" markets for services (such as labour) and goods (especially manufactured goods), in which prices do not react quickly to excess demand or supply. This "stickiness" may be because of the existence of long-run contracts: excess demand may mean higher prices in any new contracts made, with perhaps a rise in the number of new contracts—at any rate, the prices in existing contracts will remain unchanged. Or the "stickiness" may be due to two sources of supply: one price-controlled, the other an Okun auction market.

Under Okun's classification, markets in which *stocks* of energy resources are traded are usually auction markets, and the assumption of short-run market clearing holds.

However, there is a case that markets for resource *flows,* in which the resources are bought as input factors to production, behave more as Okun customer markets: until recently, less than 10% of the world oil trade was exchanged in the volatile spot market, almost all of the trade having been under long-run contract. Domestically, "old" oil has been sold at a fixed price, with a small (but growing) volume of "new" oil sold at the world price. In the absence of rapid price adjustment, rationing has been seen.

The model described below includes three markets (for output, labour, and energy flow) modelled as Okun customer markets, with the assumption that quantity adjustment in each in response to disequilibrium is much more rapid than price adjustment: the actual quantity demanded or supplied at any time is assumed equal to the target quantity demanded or supplied, a function of the vector of going prices. (Solow and Stiglitz [1968] describe a model in which quantity and price adjustments occur at comparable speeds.) We do not consider price adjustment, but treat prices as given: the speed of adjustment of prices in response to excess demand or supply can be thought of as being imperceptible in the period under analysis. (The analysis resembles that of the "fix-price" method of Hicks' [1965].)

Only recently have studies appeared which relax the assumption of market-clearing exchange, that the amount supplied or demanded ex ante by each economic actor at the going price in each market equals ex post the actual amount traded. Inter alia, Clower [1965] and Barro and Grossman [1971, 1976] have built models in which exchange can occur at "false," or non-market-clearing prices. This relaxation means, first, that quantities traded cannot be determined simply by reference to market-clearing conditions (rather, the actual trading process must be examined), and, second, that actors will in general be constrained in any market by conditions they experience in other markets: their demand (and supply) functions will no longer be unconstrained, *notional* schedules, but will be constrained, *effective* schedules (Clower [1965]), and quantities will be rationed.

There is no reason to expect that the effective schedules of any actor constrained in different markets will be mutually consistent: in an economy with rationing, ex ante supplies and demands are tentative, and it is no longer optimal for the actor to determine all his schedules at a stroke. Following Benassy [1975], we let the effective demand (supply) schedule of an actor in a market be the demand (supply) he will choose by maximizing his utility or profit subject to his budget constraint and to the quantity constraints he perceives in the *other* markets: he does not take into account any constraints he might experience in the market considered.

In aggregating individual schedules, we need to build a model in which there is consistency among individual actions. Malinvaud [1977] argues that there are three general properties necessary for the existence of quasi-equilibrium, in which for the given real prices quantities have no further tendency to move. First, trades balance: for each good the sum of purchases equals the sum of sales. Second, there is no involuntary exchange: no actor is forced to buy more than he demands or to sell more than he is willing to supply. Given the second property, an actor will be in one of four mutually exclusive states in a market: he will be a constrained (unconstrained) buyer if his demand exceeds (equals) his purchases; he will be a constrained (unconstrained) seller if his supply exceeds (equals) his sales.

Third, there cannot exist both a constrained buyer and a constrained seller in the same market, for, were this the case, each would be able to make an advantageous trade. That is, there is one and only one market for each commodity, and all actors have free access to this market.

Given these three properties, the target amount traded in any market will be determined by the "short" side of the market (that is, it will equal the lesser of the amounts supplied and demanded), and actors on the "long" side of the market will be constrained in their transactions, implying some means of rationing. The market for any commodity is then in one of three states: it can be balanced (with clearing and no rationing), or a sellers' market (with constrained buyers), or a buyers' market (with constrained sellers). We assume that the pattern of rationing does not affect the aggregate levels of the effective demands and supplies in the economy. (With this assumption and those of fixed supply of labour and of energy flow, we sidestep the conclusions of Hildenbrand and Hildenbrand [1978] that there is no sound foundation for the non-market-clearing comparative statics propositions derived by Malinvaud [1977].)

3. The Model

The model includes three commodities: labour services, a homogeneous output of production, and an energy flow. There are two types of decision makers: firms and households. Labour services and flow of energy are the two variable inputs in the production process, which produces the homogeneous output. Other inputs are fixed in the short-run period under consideration, and have no alternative use and zero user cost. It is assumed that firms, households, and energy suppliers are price-takers.

The representative firm (a typical unit whose behaviour is identical with the industry's: in using it we abstract away from any distributional changes) is assumed to maximize profits, which can be considered as the return to the non-variable inputs. The firm demands labour services and energy flow, and supplies homogeneous output. All current output is produced by the same technology, and can be considered to assume its specific identity according to the buyer: firms buy investment goods, households buy consumables, the government buys government-demanded goods and services, and foreigners buy exports.

Households receive the total wage bill and the total profits, and a proportion of the sales of energy flow net of an energy excise (the rest accrues to foreign suppliers, who may choose to purchase domestic output as exports). Households are taxed, and with their remaining disposable income will either demand consumables or accumulate savings. We ignore monetary factors, assuming that the interest rate is kept constant and that the household consumption function does not depend on cash balances or the interest rate.

We examine how the economy reacts to changes in the supply of energy as an input factor of production. In doing so, we abstract away from the decisions of the energy suppliers, and assume that the (net) supply of energy flow, $\bar{E}^S$, is exogenously determined and completely inelastic. (Marks [1979] models $\bar{E}^S$ as endogenous, with energy flow supply depending on the expectations of the owners of energy stocks, but his economy is closed and treats the two input factors completely symmetrically, with no energy excise.)

The analysis below will be concerned, at a general level, with the determination of the quantities of the goods traded, given their relative prices. (We do not address the important question of how these prices are determined, but take them as exogenously given.) We examine the determination of effective supplies and demands and analyse their implications for the determination of ouput, employment, and energy use under non-market-clearing conditions.

Because consumables and investment goods are produced by the same technology, they are perfectly substitutable on the supply side, which effectively fixes their relative price. Thus, the basic model involves three independent exchange ratios: P, the nominal price of output, W, the nominal wage rate, and V, the nominal energy price, and hence two real prices: w, the real wage rate, and v, the real energy flow price, where

$$w \equiv W/P, \qquad (1)$$
$$v \equiv V/P.$$

A basic assumption in the model is that the economy can be specified completely at any instant in terms of its real prices, w and v. From these can be deduced all other endogenous variables, including the quantities of output, labour services, and energy flow traded at any (w, v).

3.1 The firms

It is assumed that the object of firms is to maximize profits, the difference between sales revenues and payments to the two variable input factors, labour services and energy flow. Hence, in real terms, profit π is given by, ex ante,

$$\pi \equiv Y^S - w\,L^D - v\,E^D, \qquad (2)$$

where Y^S is the firm's supply of output goods, L^D its demand for labour services, E^D its demand for energy flow, and where w and v are prices taken by the firm. In a non-market-clearing regime the representative firm is assumed to maximize its ex ante profit, given the real wage and the real energy flow price and the production function, and subject to the constraints of labour supply, of supply of energy flow, and of output demand. This constrained maximization is examined in detail in the Appendix (equations (A1)).

The ex post profit is given by

$$\pi = Y - w\,L - v\,E, \qquad (3)$$

where the quantities are those actually traded. Only if market clearing occurs or if the firm is on the unconstrained, short side of all three markets will Y equal Y^S, L equal L^D, and E equal E^D.

The short-run production function, which relates the quantities of inputs of labour services and energy flows to the quantity of output, constrains the set of feasible choices. For the representative firm, the short-run production function is assumed to be

$$Y = F(L, E), \qquad (4)$$

where $F(.,.)$ exhibits positive and diminishing marginal products with respect to each input, as well as diminishing returns to scale, which occurs in the short run with the physical amount of capital stock held constant. It is also assumed that labour services and energy flow are technical complements in production: increasing the flow of one increases the marginal productivity of the other. Hence the signs of the partial derivatives of $F(.,.)$

are

$$F_L > 0,\ F_E > 0,\ F_{LL} < 0,\ F_{EE} < 0,\ F_{LE} > 0. \tag{5}$$

We assume that there is no inventory accumulation. (Blinder [1980] and Green and Laffont [1980] have discussed the implications of this for non-market-clearing analysis.) Further, we assume that costs of quantity adjustment are zero, which excludes the possibility of levels of output or inputs independent of prices or sales: firms set output to be equal to sales at all times and minimize the costs of the input factors given this level of output.

In a market-clearing model the representative firm maximizes the profit (equation (3)), subject only to the constraint of the production function (equation (4)). First-order conditions for this unconstrained maximization require that the marginal physical product of each input be set equal to its real price:

$$\begin{aligned} w &= F_L, \\ v &= F_E. \end{aligned} \tag{6}$$

Second-order conditions are that the production function be strictly concave in the neighbourhood of the optimal point in the space of (Y, L, E). Given diminishing returns to scale, this is equivalent to

$$D_1 \equiv F_{LL}\, F_{EE} - (F_{LE})^2 > 0. \tag{7}$$

Then the first-order conditions are necessary and sufficient for profit maximization.

Solution of the first-order conditions results in expressions for the notional demand for labour services, the notional demand for energy flow, and notional supply of output, all in terms of the real wage rate and the real energy price:

$$\begin{aligned} L &= L^D(w, v), \\ E &= E^D(w, v) \\ Y &= F(L^D, E^D) = Y^S(w, v). \end{aligned} \tag{8}$$

That is, the short-run notional supply of output is the output corresponding to the employment at which the marginal product of labour equals the real wage and to the energy use at which the marginal product of energy use equals the real price of energy flow.

Standard analysis yields the comparative statics behaviour (equations (A6)), in which L^D, E^D, and Y^S are found to be decreasing functions of both w and v. Thus, profit maximization subject to the assumed production function implies that notional labour demand, notional energy flow demand, and notional output supply are all inversely related both to the real wage and to the real energy price.

3.2 The households

The households receive all profits, all wages, and a fraction of all energy receipts, less other taxes T, which in total is the disposable income Y^{DI}:

$$Y^{DI} \equiv \pi + w\, \bar{L}^S + (1 - \alpha)(1 - \tau)\, v\, \bar{E}^S - T, \qquad 0 \le \alpha \le 1, 0 \le \tau < 1, \tag{9}$$

where α is the proportion of energy purchases made from foreign suppliers, and where τ is the rate of ad valorem excise on the sale of energy. Ex post, this becomes

$$Y^{DI} = Y - T - \{ \tau + \alpha(1 - \tau)\} \, v \, E, \tag{10}$$

that is, the disposable income of the households equals the value in real terms of the actual sales less a proportion of energy receipts less other taxes.

In modelling the household decision to save or to consume, we assume that the average propensity to save out of disposable income is the constant s, $0 < s < 1$. Households supply labour services, $\bar{L}^S$, assumed in this model to be completely inelastic.

3.3 Exogenous economic actors

The government can control the flow of government purchases of goods and services G, the rate τ of energy excise in real terms, and the flow of tax revenues T (net of transfers and energy excise) from the households. These three variables are assumed to be fixed. The model also includes the exogenous variables I, the flow of investment goods purchased, and X, the flow of exports purchased by foreign energy suppliers. We assume that the government, the investors, and the foreign importers have a preferred position: they are never constrained. The flow of energy available for purchase by firms as an input factor, $\bar{E}^S$, is taken to be completely inelastic and exogenously determined.

3.4 The aggregate demand for output, Y^D

The aggregate demand for output Y^D is the sum of the exogenous purchases and the household demand:

$$Y^D = G + I + X + (1 - s)\, Y^{DI}. \tag{11}$$

Ex post, from equation (10), this becomes

$$Y^D = G + I + X + (1 - s)\,(Y - T) - (1 - s)\,(\tau + \alpha(1 - \tau))\, v \, E, \tag{12}$$

where the actual output Y is determined by the short side of the output market:

$$Y = \min(Y^D, Y^S). \tag{13}$$

In general there are two cases: the output market is (i) a sellers' market, or (ii) a buyers' market.

(i) If $Y^D > Y^S$, then the buyers of output are constrained. From equations (12) and (13), aggregate demand for output can be written as

$$(Y^D)_i = Y^S + s\,(Y^A - Y^S) > Y^S, \tag{14}$$

where Y^A, the autonomous demand for output, is defined by

$$Y^A \equiv \bar{Y} - \beta v \, E, \tag{15}$$

where $\bar{Y}$, the exogenous demand for output, is defined by

$$\bar{Y} \equiv \{G + I + X - (1 - s)T\}/s, \tag{16}$$

and where β, the degree of leakage of aggregate demand for output to government and to foreign energy suppliers, is defined by

$$\beta \equiv \{\tau + \alpha(1-\tau)\}(1-s)/s. \tag{17}$$

(ii) If $Y^D < Y^S$, then the sellers of output are constrained. From equations (12) and (13), aggregate demand for output can be written as

$$(Y^D)_{ii} = Y^A < Y^S. \tag{18}$$

From equations (14) and (18) it is possible to plot Y^D against Y^S to obtain the non-market-clearing version of the Keynesian cross diagram. This is done in Figure 1.

In region (i) the aggregate demand behaves as in equilibrium, but in region (ii), because of the sales constraints on firms, it is independent of output, although with foreign energy purchases ($0 < \alpha \leq 1$) or with an energy excise ($0 < \tau < 1$) there will be some leakage of aggregate demand if energy revenues increase.

When there is no aggregate demand leakage (β=0), then the autonomous demand for output Y^A is completely exogenous and equal to $\bar{Y}$, but when there are some foreign purchases or when there is an energy excise, then Y^A is less than $\bar{Y}$. With positive β, a rise in the real price of energy will have two opposite effects on the autonomous and aggregate demands for output: the price increase will tend to increase the leakage of aggregate demand and hence to reduce autonomous and aggregate demands for output, but substitution away from energy as an input will tend to have an opposite effect on demand. The net effect will depend upon the total energy bill: if the own-price elasticity of energy use is greater than unity, aggregate demand will increase, if less than unity, decrease. (We shall see below that the price elasticity of energy use will vary with non-market-clearing regime.)

4. Types of Fix-Price Regimes

The nature of the fix-price regime will play an important rôle in the analysis of impacts of policy measures or of exogenous disturbances. It is thus important to classify the various types of regimes, to study their respective properties, and to ask which are more likely to occur.

In Section 2 we noted that each of the three markets will be in one of three states: balanced (or clearing), a sellers' market, or a buyers' market. Noting that the first state is a boundary between the other two, we find, ignoring the balanced state, that there are eight (2^3) possibilities for the state of the economy. These possibilities are summarized in Table 1, which describes the state

of the three markets, the symbols used in this paper, and the labels given to the combination of states of the two markets for output and labour by Malinvaud [1977], who considered only one variable input factor, labour services. As shown below, the existence of non-market-clearing trading in the energy market can change some policy recommendations.

The symbols introduced in Table 1 are derived from the representative firm's situation in the three markets: when the firm is unconstrained in all three markets the level of activity of the economy is determined by the diminishing returns to scale of the production technology. This is the regime SC, for "(output) supply constrained," of Table 1. Neither labour nor the flow of energy is fully employed, and yet firms sell all their output: Malinvaud labels this regime "classical unemployment." The output market is a

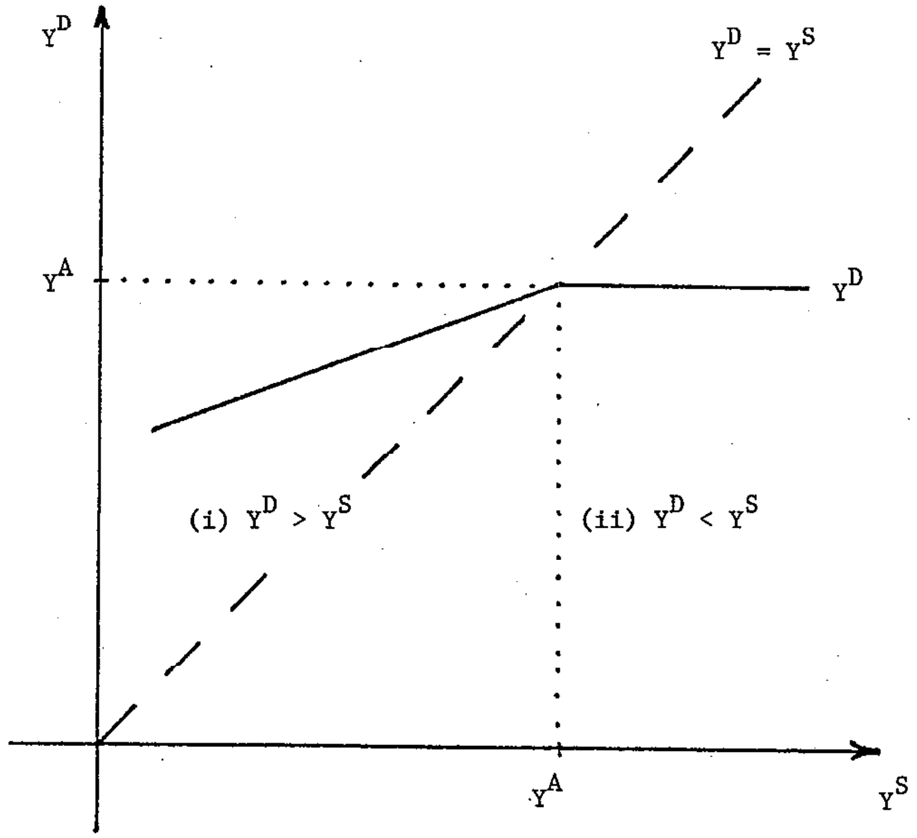


Figure 1: The disequilibrium Keynesian cross

Table 1: The eight possible disequilibrium regimes

Output market	Labour market	Energy flow market	Our symbol	Malinvaud's name
sellers' $Y = Y^S < Y^D$ (consumers rationed)	buyers' $L = L^D < L^S$ (workers rationed)	buyers' $E = E^D < E^S$ (suppliers rationed)	SC	classical unemployment
"	"	sellers' $E = E^S < E^D$ (firms rationed)	EC	
"	sellers' $L = L^S < L^D$ (firms rationed)	buyers'	LC	
"	"	sellers'	LEC	repressed inflation
buyers' $Y = Y^D < Y^S$ (firms rationed)	buyers'	buyers'	DC	Keynesian unemployment
"	"	sellers'	DEC	
"	sellers'	buyers'	DLC	
"	"	sellers'	DLEC	uninteresting

sellers' market and the input factor markets are buyers' markets.

When the firm is unconstrained in the output market but constrained in both input factor markets the level of activity of the economy is determined by the supplies of input factors, $\bar{L}^S$ and $\bar{E}^S$. This is the regime LEC, for "labour and energy constrained," of Table 1. In this regime demand exceeds supply in all markets and there is demand-pull inflationary pressure. With the short-run price rigidities there is what Malinvaud calls "repressed inflation." All three markets are sellers' markets.

When the firm is unconstrained in the input factor markets, but constrained in the market for output, the level of activity of the economy is determined by the level of autonomous demand for output, Y^A (we ignore the possibility of output stockpiling). This is the regime DC, for "(output) demand constrained," of Table 1. In this regime there is excess supply in all markets: there is unemployment of labour and energy flow, and firms do not produce more because of lack of autonomous demand for output. Malinvaud labels this regime "Keynesian unemployment." All three markets are buyers' markets.

Symmetry suggests a regime, DLEC, in which the firm is constrained in all three markets. But in this regime the level of activity of the economy is determined by at least two of the variables $\bar{L}^S$, $\bar{E}^S$, and Y^A, since a rise in aggregate demand for output can be met by a rise in production only if the supply of one or both of the input factors increases as well. In this model, with some leakage of aggregate demand, regime DLEC collapses to the point DLE of triple market clearing, in Figure 4, below.

The explicit modelling of a third market, that for energy flow, has introduced four additional regimes: (*a*) Regime EC occurs when the firm is unconstrained in the markets for output and labour, but is constrained in the market for energy flow, so that the levels of output and employment are completely inelastic with respect to the real price of energy flow. This regime is similar to that of classical unemployment, regime SC, but in that regime the firm is unconstrained in the energy market, and output and employment are more elastic with respect to the real wage than in regime EC, at least for Cobb-Douglas technology.

(*b*) Regime LC occurs when the firm is unconstrained in the markets for output and energy flow, but is constrained in the labour market. A fall in the real price of energy will result in rises in output sold and energy used. This regime is similar to that of repressed inflation, regime LEC, but in that regime the firm is constrained in the energy market as well as in the labour market, so that a change in the real price of energy will have no effect.

(*c*) Regime DEC occurs when the firm is unconstrained in the labour market, but is constrained in the markets for output and energy, so that there is no possibility of the substitution between labour and energy in response to a change in the real wage that occurs in the regime DC of Keynesian unemployment. Moreover, with leakage in aggregate demand through the energy excise and foreign energy purchases, a rise in the real energy price will lead to reductions in both output and employment: in regime DC such a rise would result in an *increase* of employment, at least for Cobb-Douglas technology.

(*d*) Regime DLC occurs when the firm is unconstrained in the market for energy flow, but is constrained in the output and labour markets. With foreign energy purchases or an energy excise, a rise in the real price of energy will result in a drop in the aggregate demand for output and hence in the levels of output exchanged and energy used in production.

The eight regimes can be derived from the first-order conditions (the Kuhn-Tucker conditions) for the constrained maximization of the profit of the representative firm. Analysis of the characteristics and comparative statics of the eight regimes is presented in the Appendix. We shall examine the two regimes SC and DC further below.

5. SC: The Regime of Classical Unemployment

This section analyzes the determination of output, employment, and energy use at values of w and v such that excess demand exists in the market for output, and excess supply exists in the markets for labour services and energy flow. In this regime the principle of voluntary exchange implies that output is supply-determined and that employment and energy use are both demand-determined. The firm is unconstrained in all three markets, and the level of activity of the economy is determined by the diminishing returns to scale of the production technology at any combination of real prices, w and v. We assert that

$$\begin{aligned} L &= L^D < \bar{L}^S \\ E &= E^D < \bar{E}^S \\ Y &= Y^S(w, v) < Y^D = Y^S + s\,(Y^A - Y^S), \end{aligned} \tag{19}$$

and we argue that quantities determined in this way are not inconsistent. Written as functions of w and v only, these functions are the same as the notional functions of standard equilibrium analysis, although the economy is no longer balanced, and no market clears.

Underlying the market-clearing profit maximization of Section 3.1 is the assumption that the representative firm can sell all the output it offers and can buy all the labour and energy it demands at the going real price vector (w, v). Since the representative firm is on the short side in all three markets, this assumption holds for the SC regime, and the functions of equation (8) are those of the SC regime:

$$\begin{aligned} L^D &= L^{SCD}(w, v) \\ E^D &= E^{SCD}(w, v) \\ Y^S &= Y^{SCS}(w, v), \end{aligned} \tag{20}$$

where the superscript SC indicates the SC regime. From equations (A6) we see that the output supply function and both input factor demand functions are decreasing functions of both the real wage and the real energy flow price.

Since in this regime the market for output is a sellers' market, there is unsatisfied aggregate effective demand and the regime can be classified as falling into case (i) of Section 3.4, with the ex post, actual, aggregate demand for output given by equation (14). We note that as the real prices decrease Y^{SCS} increases, and with it but less rapidly Y^D until the two are equal, and the output market clears, as seen in Figure 1 above.

Since the firm is on the short side in all three markets the principle of voluntary exchange means that the level of output is the output corresponding to the employment at which the marginal product of labour equals the real wage, and to the energy use at which the marginal product of energy use equals the real price of energy.

5.1 Comparative statics of the SC regime

Increased exogenous demand $\bar{Y}$ will not reduce the unemployment level or increase the use of energy, nor will it increase output, since the level of output is determined by the decreasing returns to scale of the production process. Increases in the energy bill, in the rate of energy excise, or in the proportion of foreign energy purchases will not affect the three quantities, unless sufficient to reduce aggregate demand below supply, leading to regime DC. However, a reduction in the real wage w or the real energy price v or both will lead to a reduction in unemployment and a rise in energy use as the level of output increases. Changes in the supply of labour $\bar{L}^S$ or the supply of energy flow $\bar{E}^S$ will have no effect on quantities traded in the SC regime, since both input factor markets are buyers' markets. A change in production technology will affect the level of activity of the economy.

6. DC: The Regime of Keynesian Unemployment

This is the regime of generalized excess supply, when the values of w and v are such that all three markets are buyers' markets. The principle of voluntary exchange implies that employment, energy use, and output are all demand-determined in this regime, given that firms adjust output to equal sales at all times, with no change in inventories. But this does not mean that the unconstrained, notional functions will determine the quantities traded, since quantities determined in this manner would be inconsistent. In particular, if firms are constrained to produce output less than $Y^{SCS}(w, v)$, their demands for input factors will not be given by the notional functions $L^{SCD}(w, v)$ and $E^{SCD}(w, v)$; while if there is excess supply in the market for output, we saw in Section 3.4 above that aggregate demand for output will not be given by equation (14).

The representative firm is on the constrained, long side in the market for output, and is on the unconstrained, short side of both of the input factor markets. From the Benassy assumption, the firm's supply function will be the unconstrained schedule of equation (20), $Y^{SCS}(w, v)$, and from equation (18) the effective demand for output is given by the autonomous demand: $Y^D = Y^A$, the level of output sold. Thus, the firm acts as a quantity taker with respect to its sales, as well as acting as a real wage and real energy price taker. In the SC regime of Section 5 the level of sales was a choice variable. Now, however, the level of sales is a demand-determined constraint. Formally, the representative firm has to choose its effective demands for labour services and energy use, represented by L^{DCD} and E^{DCD}, respectively, so as to maximize its profit, subject to the constraint on sales, $Y \le Y^A$, given by equation (18).

This problem is solved in the Appendix, to yield the effective demand schedules in terms of w, v, and Y^A of equations (A17):

$$\begin{aligned} L^D &= L^{DCD}(w/v, Y^A) \\ E^D &= E^{DCD}(w/v, Y^A), \end{aligned} \tag{21}$$

such that

$$Y^A = F(L^{DCD}, E^{DCD}), \tag{22}$$

and such that the quantities determined are consistent; the marginal product of labour exceeds the real wage and the marginal product of energy exceeds the real energy price.

One implication of the effective schedules L^{DCD} and E^{DCD} is that the effective demand for input factors can vary even with the real prices fixed: changes in the level of exogenous demand Y^A influence the effective demands independently of changes in w or v. If the constraint on sales were eased, the representative firm would respond, at the existing real price vector (w, v), by raising output, employment, and energy use. If possible, this process would continue until the marginal products fell sufficiently to equal their respective real prices, at which point the representative firm would be operating according to its notional supply of output and demands for input factors. Along the expansion path the ratio of the input factor marginal products equals the ratio of their respective prices:

$$(F_L)/(F_E) = w/v. \tag{23}$$

6.1 Comparative statics of the DC regime

Increased exogenous demand $\bar{Y}$ will lead to a rise in aggregate demand for output, from equation (15), and, since the market for output is a buyers' market, the level of production of the economy will increase to meet the increased demand, and there will be a rise in employment and energy use. A reduction in the energy bill, in the rate of energy excise, or in the proportion of foreign energy purchases will have a similar effect, as the leakage of aggregate demand decreases.

A change in the supply of labour $\bar{L}^S$ or in the supply of energy flow $\bar{E}^S$ will have no effect on the quantities traded in the DC regime, since both input factor markets are buyers' markets. A change in the ratio of real prices will affect the levels of employment and energy use by inducing substitution between labour and energy in the production process.

In this regime, with inelastic demand for energy, a rise in the real price of energy will have two opposite effects on employment: employment will tend to rise as substitution occurs from energy to the more attractive input of labour, and employment will tend to fall as autonomous demand falls due to increased leakage of aggregate demand. In the case of Cobb-Douglas technology it is easily shown that energy demand is inelastic in regime DC, so that autonomous demand (and hence sales) of output falls with a real energy price rise. But the employment effects of this are more than offset by substitution to labour, so that, with foreign energy purchases or an energy excise, employment will increase in response to a rise in v.

7. Effective Market-Clearing Loci

As noted in Section 4, there are eight possible regimes of non-market clearing, although, depending on the values of the exogenous variables, not all of them can be attained for different real wage w and real energy price v. These eight regimes were introduced in Section 4 and Table 1. We have examined two regimes in detail: SC and DC. Table 2 summarizes

Table 2: Quantities traded in the eight regimes.

Regime	Output, Y	Employment, L	Energy use, E
SC	$Y^{SCS}(w,v) < Y^{D}$	$L^{SCD}(w,v) < \bar{L}^{S}$	$E^{SCD}(w,v) < \bar{E}^{S}$
EC	$Y^{ECS}(w,\bar{E}^{S}) < Y^{D}$	$L^{ECD}(w,\bar{E}^{S}) < \bar{L}^{S}$	$\bar{E}^{S} < E^{SCD}$
LC	$Y^{LCS}(v,\bar{L}^{S}) < Y^{D}$	$\bar{L}^{S} < L^{SCD}$	$E^{LCD}(v,\bar{L}^{S}) < \bar{E}^{S}$
LEC	$Y^{LECS}(\bar{L}^{S},\bar{E}^{S}) < Y^{D}$	$\bar{L}^{S} < L^{ECD}$	$\bar{E}^{S} < E^{LCD}$
DC	$Y^{A}(vE) < Y^{SCS}$	$L^{DCD}(w/v,Y^{A}) < \bar{L}^{S}$	$E^{DCD}(w/v,Y^{A}) < \bar{E}^{S}$
DEC	$Y^{A} < Y^{ECS}$	$L^{DECD}(\bar{E}^{S},Y^{A}) < \bar{L}^{S}$	$\bar{E}^{S} < E^{DCD}$
DLC	$Y^{A} < Y^{LCS}$	$\bar{L}^{S} < L^{DCD}$	$E^{DLCD}(\bar{L}^{S},Y^{A}) < \bar{E}^{S}$
DLEC	$Y^{A} = Y^{LECS}$	$\bar{L}^{S} = L^{DECD}$	$\bar{E}^{S} = E^{DLCD}$

the effective supply schedules for output, the effective demand schedules for labour and energy flow, and the actual quantities traded, derived for all eight regimes in the Appendix. Table 3 shows the signs of the partial derivatives of

the quantities traded for the eight regimes. Note that in regime DC it is possible to reduce unemployment (that is, to increase L) by increasing the real price of energy flow v, at least with Cobb-Douglas technology. Also note that in regimes LC, LEC, DEC, DLC, and DLEC lowering the real wage w will not result in any increase of employment.

By plotting the effective market-clearing loci in the (v, w)-plane, we can associate each combination of real wage and real energy price with one of the eight regimes, depending on the relative magnitudes of the exogenous demand for output, $\bar{Y}$, the leakage of aggregate demand, $\beta v E$, and the full-employment output $F(\bar{L}^S, \bar{E}^S)$. This greatly assists our understanding of the comparative statics of the economy in cases of possible exogenous supply (or demand) changes.

Figure 2 has been plotted for the regimes in which

$$\bar{Y} < F(\bar{L}^S, \bar{E}^S). \tag{24}$$

The line O-DE-E is the locus of effective clearing in the energy flow market: for given aggregate demand, and inelastic supplies of labour and energy flow, the energy flow market clears for any pair of real wage and real energy price along the locus. The locus divides the positive quadrant of the (v, w)-plane into two areas: to the left, for lower values of real energy price v, there is excess demand in the energy flow market, that is, the firm finds itself on the long side as it demands energy as an input factor—it is constrained by the supply; to the right, at higher values of v, there is excess supply in the energy flow market, and the firm is on the unconstrained, short side. The line O-DL-L is the locus of effective clearing in the labour market. Below it, at lower values of real wage w, there is excess demand in the labour market and above it, at higher values of w, there is excess supply in the labour market (unemployment of labour). The line Y'-DE-DL-Y is the locus of effective clearing in the market for output. At values of (v, w) to its northeast, there is excess demand for output; to the southwest of the locus, there is excess supply of output.

At the point of intersection of the energy- and output-market-clearing loci, DE, there is clearing in these two markets, while the third, that for labour, is in a state of excess supply. At the point of intersection of the labour- and output-market-clearing loci, DL, there is clearing in these two markets, while the third, that for energy flow, is in a state of excess supply.

Excess supply of output is only possible if the supplies of input factors are sufficiently large and the aggregate demand for output sufficiently small that the demand can be satisfied by the supply of output. If the supplies of input factors are too small or the exogenous demand too large, then Figure 2 will no longer describe the situation. Figure 3 has been drawn for the regimes in which

$$\bar{Y} - \beta v^* \bar{E}^S > F(\bar{L}^S, \bar{E}^S), \tag{25}$$

where (v^*, w^*) is the point LE, at which

$$E^{SCD}(v^*, w^*) = \bar{E}^S, \tag{26}$$

Table 3: Signs of the partial derivatives of the quantities traded, wrt real wage w, real energy price v, energy supply $\bar{E}^S$, and autonomous output Y^A

Regime	Y_w	Y_v	$Y_{\bar{E}^S}$	L_w	L_v	L_{Y^A}	$L_{\bar{E}^S}$	E_w	E_v	E_{Y^A}
SC	−	−	0	−	−	0	0	−	−	0
EC	−	0	+	−	0	0	+	0	0	0
LC	0	−	0	0	0	0	0	0	−	0
LEC	0	0	+	0	0	0	0	0	0	0
DC	−	a	0	−	b	+	0	+	−	+
DEC	0	−	−	0	−	+	−	0	0	0
DLC	0	−	0	0	0	0	0	0	−	+
DLEC	0	0	0	0	0	0	0	0	0	0

where a is negative for Cobb-Douglas technology, otherwise ±

where b is positive for Cobb-Douglas technology, otherwise ±

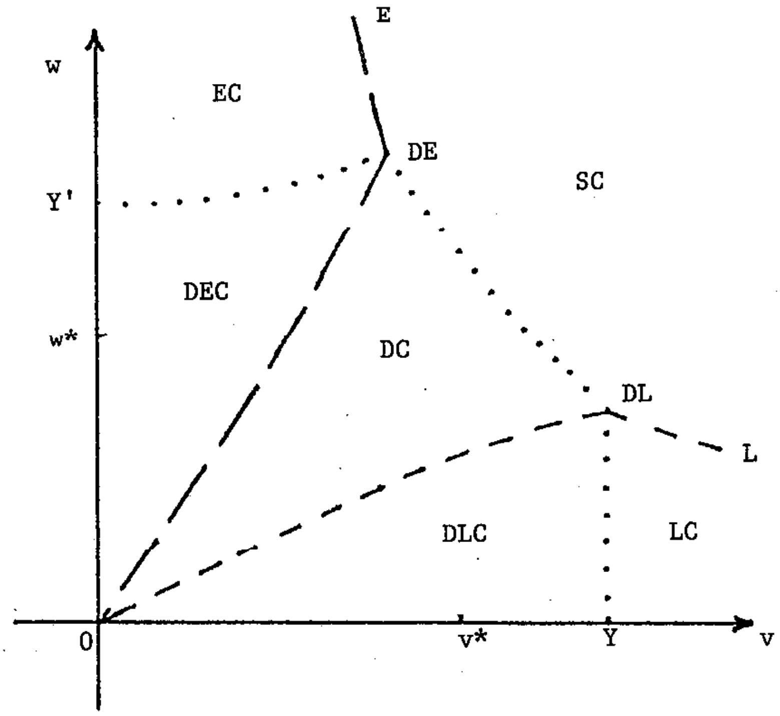


Figure 2: The effective market-clearing loci, $\bar{Y} < F(\bar{L}^S, \bar{E}^S)$

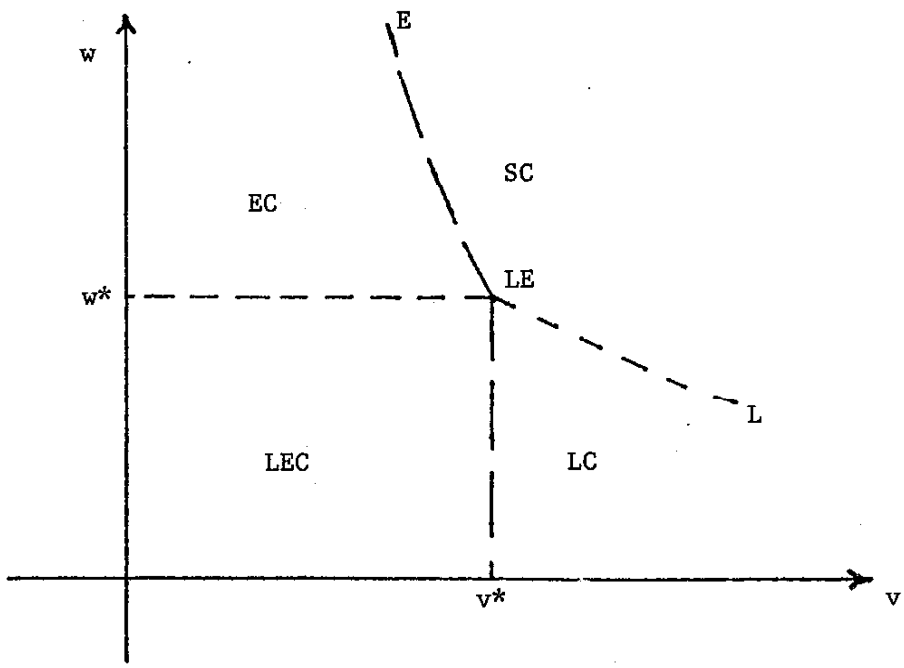


Figure 3: The effective market-clearing loci, $\bar{Y} - \beta v^* \bar{E}^S > F(\bar{L}^S, \bar{E}^S)$

$$L^{SCD}(v*, w*) = \bar{L}^S.$$

Again, there are loci of market clearing, but since there is excess demand for output even when input factors are fully employed, there can be no locus of clearing in the output market. The line E-LE-v* is the locus of effective clearing in the market for energy use: to the left there is excess demand, to the right, excess supply. The line w*-LE-L is the locus of effective clearing in the market for labour: below it there is full employment with excess demand for labour, above, unemployment. At the point of intersection of the labour- and energy-market-clearing loci, LE, there is clearing in these two markets, while the third, that for output, is in a state of excess demand.

When, perhaps because of government fiscal action, the exogenous demand for output is only "slightly" greater than full-employment output,

$$0 < \bar{Y} - F(\bar{L}^S, \bar{E}^S) < \not\beta v * \bar{E}^S, \tag{27}$$

all seven of the non-degenerate regimes appear, as shown in Figure 4.

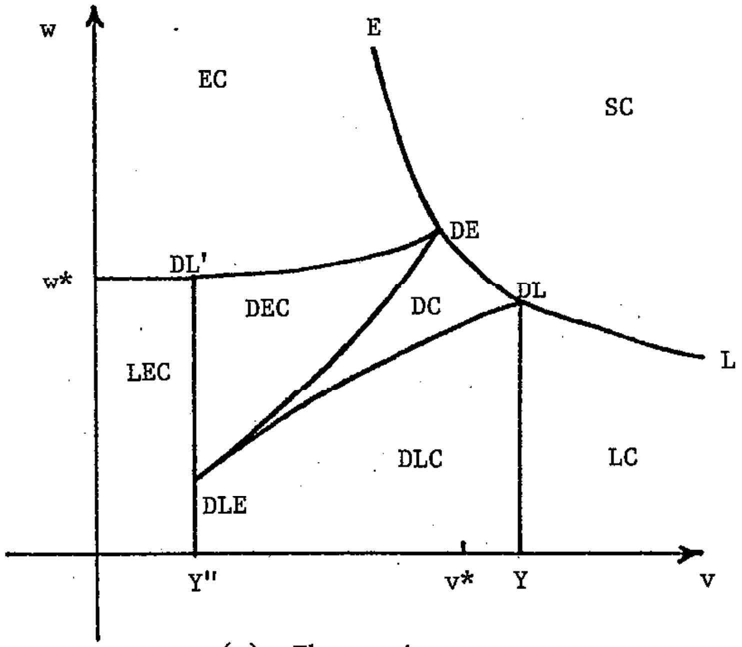
(The three effective market-clearing loci are shown separately in the smaller figures.) Inside the demand locus Y''-DLE-DL'-DE-DL-Y there is excess supply in the output market; outside, excess demand. Below the labour locus w*-DL'-DLE-DL-L there is full employment with excess demand for labour; above, unemployment with excess supply. To the left of the energy flow locus Y''-DLE-DE-E there is excess demand; to the right, excess supply. At the points DL and DL' the output and labour markets clear: at point DL there is excess supply of energy, at point DL', excess demand for energy. At the point DE the output and energy flow markets clear, with excess supply of labour. At the point DLE all markets clear.

The slopes of the effective market-clearing loci can easily be determined. With completely inelastic factor supplies the lines w *-LE and w *-DL' are horizontal as shown, and the lines DL-Y, LE-v *, and Y''-DLE-DL' are vertical as shown. If, in addition, the economy is closed with no foreign energy purchases and zero energy excise, then the lines Y'-DE and w *-DLE are horizontal and the lines O-DE and O-DL are straight. The other lines are in general curved, and have been drawn with the relative slopes corresponding to a Cobb-Douglas production function with diminishing returns to scale.

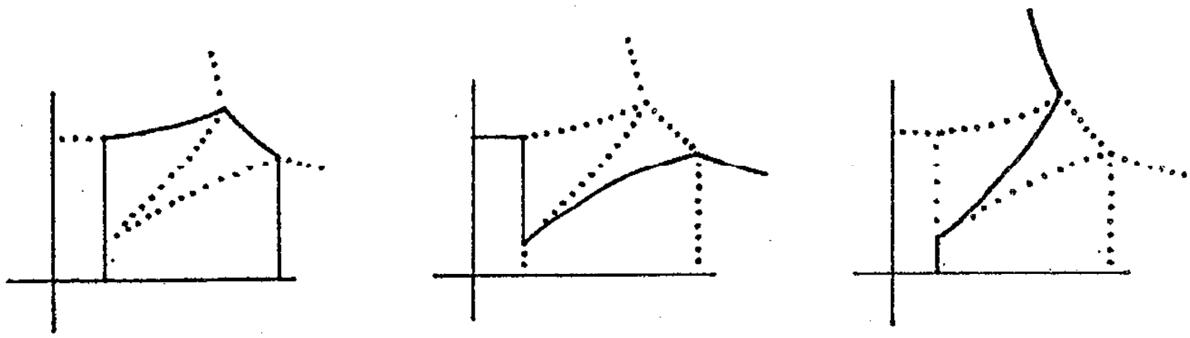
Note that because of the substitution possible between labour and energy, there exists no unique full-employment real wage, nor even a unique combination of real wage and real energy price at which all three markets clear.

7.1 Comparative statics of the effective market-clearing loci

A change in exogenous demand $\bar{Y}$ will not shift those sections of the energy- and labour-market-clearing loci associated with excess demand for output, since $\bar{Y}$ is not an argument of those effective schedules. In Figure 2 in response to a rise in $\bar{Y}$, the output-market-clearing locus Y'-DE-DL-Y will shift towards the origin, with lines O-DE and O-DL approaching each other until $\bar{Y} = F(\bar{L}^S, \bar{E}^S)$, at which time Figure 2 will have become Figure 4, with the triple-market-clearing point DLE at the origin. Further increase in $\bar{Y}$ will result in the shifting of line Y''-DLE-DL' to the right, as the point DLE moves up the ray $w = w * v/v *$ to the point $(v*, w*)$. At the same time the line DL-Y will shift to the left and the curved line DE-DL will become horizontal, until $\bar{Y} - \not\beta v * \bar{E}^S = F(\bar{L}^S, \bar{E}^S)$.



(a) The regimes



(b) Demand locus (c) Labor locus (d) Energy locus

Figure 4: The effective market-clearing loci, $0 < \bar{Y} - F(\bar{L}^S, \bar{E}^S) < \beta v^* \bar{E}^S$

Further increase in $\bar{Y}$ will result in Figure 3, which will be unchanging, since none of its effective schedules includes $\bar{Y}$ as an argument.

A fall in the proportion α of foreign energy purchases, a fall in the rate τ of energy excise, or a rise in the savings ratio s will reduce the degree β of aggregate demand leakage, with effects similar to those of a rise in exogenous demand $\bar{Y}$ discussed above. In addition, at the limit of no leakage of aggregate demand (β=0), the lines Y'-DE, O-DE, and O-DL in Figure 2 will be straight. However, as shown by Marks [1979], in this case Figure 4 will appear similar to Figure 3, with the regime of triple market clearing DLEC corresponding to regime LEC, and the point DLE corresponding to point LE.

A change in supply of energy flow $\bar{E}^S$ will not alter those loci to the right of the energy-market-clearing locus, since in that region there is an excess supply of energy and $\bar{E}^S$ is not an argument of the effective schedules. In Figure 2, a fall in $\bar{E}^S$ will be seen as a shift of the line DE-E to the right with point DE moving down the unshifting line DE-DL, line O-DE rotating clockwise, and line Y'-DE shifting down. If the fall in $\bar{E}^S$ continues, line O-DE will approach line O-DL until $\bar{Y}$ = F($\bar{L}^S$,$\bar{E}^S$), at which time Figure 2 will have become Figure 4. Further decrease of $\bar{E}^S$ will result in point DLE moving along the unshifting line DLE-DL, with further rotation of line DLE-DE, a downward shift of line w *-DL'-DE, and a shift to the right of line Y''-DLE-DL', until $\bar{Y} - \beta v * \bar{E}^S = F(\bar{L}^S, \bar{E}^S)$, at which time Figure 4 will have become Figure 3. Further decrease of $\bar{E}^S$ will result in point LE moving down the unshifting line LE-L, corresponding to falling w * and increasing v *. Line E-LE-v * will shift to the right and line w *-LE will shift down. A change in labour supply $\bar{L}^S$ can be analysed similarly.

When we look at any point in the (v, w)-plane, to examine its "regime history" as exogenous variables change, ceteris paribus, we see strong similarities. In response to a fall in exogenous demand $\bar{Y}$, a rise in the degree β of aggregate demand leakage, or a rise in energy supply $\bar{E}^S$, it is possible for a point initially near the point DE in Figure 2 to be successively in regimes EC, DEC, and DC, or to remain in any of these, once attained. In response to a rise in $\bar{Y}$, a fall in β, or a fall in $\bar{E}^S$, the reverse may happen, although for points initially in regime DC in response to a rise in $\bar{Y}$ or a fall in β the regime history may be more complex.

8. Energy in the Short Run

The model described in the previous sections provides a framework for answering questions of policy for a simple economy importing energy and only slowly adjusting towards market-clearing prices. We discuss possible initial states for such an economy and then consider how our model would respond to two types of adverse supply shock to the economy: (1) a fall in the supply of energy flow $\bar{E}^S$, corresponding in the case of oil to an embargo or to a cut-back in world oil production such as threatened during the Iranian revolution and the Iran-Iraq war, and (2) a rise in the real energy price v, corresponding in the case of oil to action by the OPEC cartel to raise the nominal price V followed by a less than proportional increase in the overall price level leading to a rise in v and to a slight reduction in the real wage w for a constant nominal wage W. We consider the appropriateness of possible responses on the part of the government, given the possible instruments available.

We assume that the economy is initially either (*a*) in the close vicinity of the full-employment real wage w^* and real energy price v^*, or (*b*) at the same real wage w^* but at a real energy price less than v^*. Assumption (*a*) models a nearly balanced economy, with all three markets close to clearing, given autonomous demand close to full-employment output. (An alternative sustainable state would be a quasi-equilibrium, with unbalanced markets, proportionally changing nominal prices, and constant real prices, but this is beyond the present analysis.) Assumption (*b*) models an economy with excess demand for energy: such a state would facilitate action on the part of energy suppliers to raise prices or to reduce supply. The actual initial regime will depend on the level of autonomous demand for output Y^A: if $Y^A < F(\bar{L}^S, \bar{E}^S)$, then in case (*a*) the initial regime will be regime DC, and in case (*b*), either regime DC or regime DEC; but if $Y^A \geq F(\bar{L}^S, \bar{E}^S)$, then in case (*a*) the initial regime will be one of those around point LE in Figure 4—EC, LEC, LC, or SC—and in case (*b*), either regime EC or regime LEC. We do not consider the labour-rationed regimes LC or LEC for the initial regime, since recent supply shocks have not been accompanied by excess demand for labour services. We consider the following initial regimes: DC of Keynesian unemployment, SC of classical unemployment, EC, and DEC. (If we take energy to be oil, then there is a case that many industrialized economies were close to being energy-rationed before the first OPEC price jump.)

(1) A fall in supply of energy flow $\bar{E}^S$ will result in a fall in w^* and a rise in v^*, as the energy-market-clearing locus moves to the right in Figures 2, 3, and 4. Starting initially in an SC or DC regime, an economy will experience no change in output, employment, or energy use until constrained in the energy market, whereupon the SC regime becomes an EC regime and the DC regime becomes a DEC regime. In regime EC, output, employment, and energy use will all fall as the energy supply drops further. In regime DEC, as energy use falls with the reduced energy supply the leakage of aggregate demand is also reduced, and output and employment *rise* slightly as the aggregate demand increases. It is possible that the aggregate demand will increase sufficiently that the output market is no longer a buyers' market, whereupon the DEC regime becomes an EC regime, which will persist.

We note that the levels of output, employment, and energy use are non-increasing, except in regime DEC, in which output and employment increase in response to a fall in energy supply. In this regime the output market is a buyers' market, with the representative firm on the constrained, long side. With no leakage of aggregate demand a fall in supply of either of the input factors would have no effect on the amount of output traded. However, with foreign energy purchases or an energy excise, a fall in energy supply (if there is no change in β) will lead to a rise in output as decreased leakage of demand occurs. At the same time the firm will substitute labour for energy in the production process. A rise in employment will result.

This analysis has been made with the assumption of unchanging real energy price v, real wage w, and degree β of leakage of aggregate demand. It is likely, however, that a sudden energy supply shortage would soon be translated into upwards pressure on the nominal price of energy and hence (to a lesser extent) on the overall price level, with a resultant rise in the real energy price and fall in the real wage. Moreover, if the energy shortage were initiated by foreign suppliers, the economy might soon attempt to reduce its dependence on foreign sources of supply, with a possible reduction in the proportion α of foreign energy purchases. But for simplicity we abstract away from medium-term structural reactions and from endogenous price effects, and hence from formal discussion of inflation.

(2) *A* rise in the real energy price v (and a slight fall in the real wage w) will move any economy to the southeast in the Figures. From Figures 2 and 4 we can see that two possible histories exist for an economy initially in regime EC and two more for an economy initially in regime DEC or regime DC. Starting initially in an EC regime, firms will reduce their demands for energy with no change in output, employment, or energy use until the previously unsatisfied demand for energy falls below the its supply, whereupon the economy enters the SC regime; further increases in the real energy price will reduce output, employment, and energy use; another possibility is that the increased leakage of aggregate demand results in its falling sufficiently to constrain firms in the output market while they are still constrained in the energy market: the economy will move from regime EC to regime DEC, in which increasing real energy price will lead to increased leakage of, and therefore a reduction in, aggregate demand, accompanied by falling output and employment but unchanging energy use; continued increases in the energy price will reduce the demand for energy below its supply and the economy will enter the DC regime with falling energy use. From equations (A19) and Table 3 we see that in the DC regime the responses of output and employment to further increases in the energy price are undetermined in general, but for Cobb-Douglas technology output will fall and employment will *increase,* with the own-price elasticity of energy use less than unity. If output falls sufficiently, the economy will move from regime DC to regime SC. But another possibility occurs if the demand for labour increases sufficiently to outstrip supply: the continued increases in the energy price might then result in regime DC becoming regime DLC with constant (full) employment, falling output, and falling energy use. If the supply of output falls sufficiently, then regime DLC will become regime LC, with full employment, falling output, and falling energy use; if the demand for labour falls below its supply, then the economy will move from regime LC to regime SC, which will persist. We note that the levels of output, employment, and energy use are non-increasing, except in regime DC, in which employment will increase in response to a rise in the real energy price, with Cobb-Douglas technology.

As with the analysis of the effects of a fall in energy supply above, this analysis is ceteris paribus. If the price increase were initiated by foreign suppliers, then there might be substitution from imported energy towards domestic supplies, with a reduction in the proportion α of foreign energy purchases. Moreover, the increased energy receipts accruing to (inter alia) foreign energy suppliers in regimes EC, LEC, DC (with Cobb-Douglas technology), DEC, and DLC might result in increased "recycling," with consequent increases in imports X and investments I. (In regimes SC and LC with Cobb-Douglas technology, there might be reductions as the energy receipts fall.) But we abstract from formal consideration of these possibilities.

8.1 Possible policy measures

We assume that the aim of macroeconomic policy is to reduce unemployment and inflation and to increase output. In the short run, energy will only be of concern if its supply frustrates this aim or if the economy is seen to be too dependent on foreign supplies. We cannot do more than sketch possible policy because our model takes prices as fixed, with no endogenous price changes: inflation is exogenous. (It would be a simple matter to extend the model to include Walrasian price adjustment, as Marks [1979] has done for a closed economy and as Solow [1980] has done for an economy with completely elastic energy supply, but this is beyond the present paper.)

The government cannot, by executive fiat, increase the supply of energy, but it does, in the short run, have some instruments for ameliorating the effects of adverse supply shocks. These can loosely be divided into demand-side and supply-side instruments. (We do not consider the possibility of an interventionist monetary policy, assuming instead a permissive policy.) Through fiscal actions of increasing government purchases G, reducing other tax revenues T, and by reducing the rate τ of energy excise, the government can increase the level of autonomous demand for output. Reduction of the rate of energy excise will also have the supply-side effect of reducing the real price of energy somewhat, which will partly offset both the increased cost of energy and possible cost-push effects on the price of output. The government can also to some extent raise and lower the level of the real energy price through exchange rate policy: a devaluation will increase the domestic nominal price of energy V in the case of non-zero energy imports and will lead to some upwards pressure on the nominal price of output P. (We do not consider here the other costs and consequences of devaluation.) It may also attempt to control the price of energy (and perhaps wages and prices in general) directly, but we do not consider this possibility here. It can reduce the proportion of foreign energy supply by means of import quotas and tariffs (at the cost of increasing prices further), but our model is not formulated to analyse the imposition of tariffs on energy imports explicitly.

We now examine more closely the two regimes EC and DEC, since in both of these the market for labour services is a buyers' market, with unemployment, and the market for energy flow is a sellers' market, with unfulfilled effective demand for energy as an input factor. These regimes may correspond closely to the states of many energy-importing economies during the two "oil shocks:" in regime EC there is excess demand for output, in regime DEC, excess supply.

From Table 3, in regime EC the quantity of output traded is a decreasing function of the real wage and an increasing function of the supply of energy flow, as is the level of employment. Thus, a fall in the real wage (through a fall in the nominal wage or a rise in the nominal price of output) will result in increases in employment and in output traded. Given a completely inelastic supply of energy flow in the short run, the levels of output and employment are completely inelastic with respect to the real energy price, in contrast to the regime SC of classical unemployment. A rise in autonomous demand for output will have no effect on the level of activity of the economy, although it will increase excess aggregate effective demand for output.

In regime DEC, the quantity of output traded is equal to the autonomous demand, which from Table 3 is a decreasing function of the real energy price. The level of employment is an increasing function of the autonomous demand and a decreasing function of the energy supply; output and employment are completely unaffected by changes in the real wage. We can compare this with regime DC of Keynesian unemployment in which a fall in real wage has the effect of raising output and employment (and lowering energy use). The responses of output and employment levels to changes in the real wage, the real energy price, and the autonomous demand for output differ in every case between the two regimes EC and DEC.

We conclude by examining the different responses of the level of employment across the regimes. From Table 3 we see that a rise in the real energy price will tend to decrease employment in regimes SC and DEC, but will tend to increase employment in regime DC (at least for Cobb-Douglas technology); it will not affect employment in any other regime. (Malinvaud [1977] claims that this distinction was responsible for much confusion in the policy debates of the thirties.) A fall in energy supply will tend to reduce employment in regime EC, to increase it in regime DEC, while not affecting it in other regimes. A fall in autonomous demand for output will tend to reduce employment in regimes DC and DEC, but will not affect it in other regimes.

In a recent paper examining the implications of different assumptions concerning the relative speeds of price and quantity adjustment in the output and labour markets, Corden [1978] attempts to allocate "responsibility" for unemployment—whether the government or households (through the autonomous demand for output), or "big business" (through the price of output), or trade unions (through the wage). In an analogous manner we could ascribe unemployment in, say, the SC regime of classical unemployment to the cost of input factors: if either the real wage or the real energy price fell, output and employment would increase; a fall of the real wage in regimes EC and DC would likewise increase employment. But it is difficult in our model, with two variable input factors, to ascribe "responsibility" for unemployment to any single group. Rather, the regime in which the economy finds itself is a function of the supplies and real prices of energy and labour, the exogenous demand for output, and the degree of leakage of aggregate demand.

We have attempted to describe the complex behaviour of the model economy with exchange and production at non-market-clearing prices. We do not suggest that our fix-price model (or its behaviour) should be taken as a true description of a real economy, but we hope that the analysis above will indicate that simpler models, models which ignore the possibility of a second variable input factor, energy, might well lead to erroneous interpretation and policy prescription.

APPENDIX

The eight regimes described above can be derived from the solution of a constrained maximization problem as faced by the representative firm:

$$\max \pi = Y - w\,L - v\,E, \tag{A1}$$

such that $Y = F(L, E)$,

$$L \leq \bar{L}^S,$$

$$E \leq \bar{E}^S,$$

$$Y \leq Y^A \equiv \bar{Y} - \beta v\,E.$$

Solution of this will yield the actual levels of the quantities traded. These will be the quantities on the unconstrained, short side of each market: further analysis is necessary to determine the effective demand (supply) schedules on the constrained, long side of each market.

The Lagrangian £ is:

$$£ = Y - wL - vE - \lambda_1 Y - F(L, E) - \lambda_2 - \lambda_3 - \lambda_4. \tag{A2}$$

Differentiation of £ with respect to Y, L, and E gives the Kuhn-Tucker conditions:

$$\lambda_1 + \lambda_4 = 1, \qquad \lambda_1 > 0, \tag{A3}$$

$$\lambda_1\,F_L = w + \lambda_2,$$

$$\lambda_1\,F_E = v + \lambda_3,$$

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

$$\lambda_2\,(L - \bar{L}^S) = 0, \qquad \lambda_2 \geq 0,$$

$$\lambda_3\,(E - \bar{E}^S) = 0, \qquad \lambda_3 \geq 0,$$

$$\lambda_4\,(Y - Y^A) = 0, \qquad \lambda_4 \geq 0.$$

Then the eight regimes can be characterized by the possibilities of the Kuhn-Tucker conditions.

(i) *Regime SC, "classical unemployment."* With $\lambda_2 = \lambda_3 = \lambda_4 = 0$, the firm is unconstrained in any market. Solution of the conditions yields:

$$L = L^{SCD} < \bar{L}^S, \tag{A4}$$

$$E = E^{SCD} < \bar{E}^S,$$

$$Y = F(L, E) = Y^{SCS} < Y^A,$$

where

$$F_L = w, \tag{A5}$$

$$F_E = v.$$

Standard analysis yields the comparative statics equations:

$$\partial L|\ \partial w = \partial L^{SCD}|\ \partial w = (F_{EE})/D_1 < 0, \tag{A6}$$
$$\partial L/\partial v = \partial L^{SCD}|\ \partial v = -(F_{LE})/D_1 < 0,$$
$$\partial E/\partial w = \partial E^{SCD}|\ \partial w = -(F_{LE})|\ D_1 < 0,$$
$$\partial E|\ \partial v = \partial E^{SCD}|\ \partial v = (F_{LL})/D_1 < 0,$$
$$\partial Y/\partial w = \partial Y^{SCS}|\ \partial w = (w\, F_{EE} - v\, F_{LE})/D_1 < 0,$$
$$\partial Y/\partial v = \partial Y^{SCS}|\ \partial v = (v\, F_{LL} - w\, F_{LE})/D_1 < 0,$$

where $D_1 \equiv F_{LL}\, F_{EE} - (F_{LE})^2 > 0$, from equation (7).

(ii) *Regime EC.* With $\lambda_4 = \lambda_2 = 0$, $\lambda_3 > 0$, the firm is constrained in the energy resource flow market, but unconstrained in the other two. Solution of the conditions yields:

$$L = L^{ECD}(w, \bar{E}^S) < \bar{L}^S, \tag{A7}$$
$$E = \bar{E}^S < E^{SCD},$$
$$Y = F(L, E) = Y^{ECS}(w, \bar{E}^S) < Y^A,$$

with

$$F_L = w, \tag{A8}$$
$$F_E > v.$$

Standard analysis yields the comparative statics equations:

$$\partial L/\partial w = \partial L^{ECD}|\ \partial w = 1/(F_{LL}) < 0, \tag{A9}$$
$$\partial L/\partial v = \partial L^{ECD}|\ \partial v = 0,$$
$$\partial L/\partial \bar{E}^S = \partial L^{ECD}|\ \partial \bar{E}^S = -(F_{LE})/(F_{LL}) > 0,$$
$$\partial Y/\partial w = \partial Y^{ECS}|\ \partial w = (F_L)/(F_{LL}) < 0,$$
$$\partial Y/\partial v = \partial Y^{ECS}|\ \partial v = 0,$$
$$\partial Y/\partial \bar{E}^S = \partial Y^{ECS}|\ \partial \bar{E}^S = -(F_L\, F_{LE} - F_E\, F_{LL})/(F_{LL}) > 0.$$

(iii) *Regime LC.* With $\lambda_4 = \lambda_3 = 0$, $\lambda_2 > 0$, the firm is constrained in the labour market, but unconstrained in the other two. Solution of the conditions yields:

$$L = \bar{L}^S < L^{SCD}, \tag{A10}$$
$$E = E^{LCD}(v, \bar{L}^S) < \bar{E}^S,$$
$$Y = F(L, E) = Y^{LCS}(v, \bar{L}^S) < Y^A,$$

with

$$F_L > w, \tag{A11}$$
$$F_E = v.$$

Standard analysis yields the comparative statics equations:

$$\partial E/\partial w = \partial E^{LCD}|\ \partial w = 0,$$
$$\partial E/\partial v = \partial E^{LCD}|\ \partial v = 1/(F_{EE}) < 0,$$
$$\partial Y/\partial w = \partial Y^{LCS}|\ \partial w = 0,$$
$$\partial Y/\partial v = \partial Y^{LCS}|\ \partial v = (F_E)/(F_{EE})<0. \tag{A12}$$

(iv) *Regime LEC, "repressed inflation."* With $\lambda_2 > 0$, $\lambda_3 > 0$, $\lambda_4 = 0$, the firm is constrained in both factor input markets, but not in the output market. Solution of the conditions yields:

$$L = \bar{L}^S < L^{ECD},$$
$$E = \bar{E}^S < E^{LCD},$$
$$Y = F(L, E) = Y^{LECS}(\bar{L}^S, \bar{E}^S) < Y^A, \tag{A13}$$

with

$$F_L > w,$$
$$F_E > v. \tag{A14}$$

Standard analysis yields the comparative statics equations:

$$\partial Y/\partial w = \partial Y^{LECS}|\ \partial w = 0,$$
$$\partial Y/\partial v = \partial Y^{LECS}|\ \partial v = 0,$$
$$\partial Y/\partial \bar{E}^S = \partial Y^{LECS}|\ \partial \bar{E}^S = F_E > 0. \tag{A15}$$

This regime can only occur when

$$\bar{Y} > F(\bar{L}^S, \bar{E}^S). \tag{A16}$$

(v) *Regime DC, "Keynesian unemployment."* With $\lambda_2 = \lambda_3 = 0$, $\lambda_4 > 0$, the firm is constrained in the output market, but unconstrained in the other two. Solution of the conditions yields:

$$L = L^{DCD}(w/v, Y^A) < \bar{L}^S,$$
$$E = E^{DCD}(w/v, Y^A) < \bar{E}^S,$$
$$Y = F(L, E) = Y^A < Y^{SCS}, \tag{A17}$$

with

$$F_L = w/\lambda_1,$$
$$F_E = v/la1, \quad 0<\lambda_1 le1. \tag{A18}$$

Second-order conditions for profit maximization in the DC regime are assured by the strict convexity of the production function. Standard analysis yields the comparative statics equations:

$$\partial L/\partial Y^A = \partial L^{DCD}|\ \partial Y^A = (v\, F_{LE} - w\, F_{EE})/D_2 > 0, \tag{A19}$$

$$\partial E/\partial Y^A = \partial E^{DCD}|\ \partial Y^A = (w\, F_{LE} - v\, F_{LL})/D_2 > 0,$$

$$\partial Y^A|\ \partial w = -\beta v\, \partial E^{DCD}|\ \partial w < 0,$$

$$= -\beta v\, (F_L\, F_E)/\{1 + \beta v\, (\partial E^{DCD}|\ \partial Y^A)\}\ D_2 < 0,$$

$$\partial Y^A|\ \partial v = -\beta E^{DCD}\ \{1 + v\, (\partial E^{DCD}|\ \partial v)|\ E^{DCD}\},$$

$$= \beta (v\, (F_L)^2 - E^{DCD}\ D_2)/\{1 + \beta v\, (\partial E^{DCD}|\ \partial Y^A)\}\ D_2,$$

$$\partial L/\partial w = \partial L^{DCD}|\ \partial w = -\,(F_E)^2|\ D_2 + (\partial L^{DCD}|\ \partial Y^A)\, (\partial Y^A|\ \partial w) < 0,$$

$$\partial L/\partial v = \partial L^{DCD}|\ \partial v = (F_L\, F_E)/D_2 + (\partial L^{DCD}|\ \partial Y^A)\, (\partial Y^A|\ \partial v),$$

$$\partial E/\partial w = \partial E^{DCD}|\ \partial w = (F_L\, F_E)/D_2 + (\partial E^{DCD}|\ \partial Y^A)\, (\partial Y^A|\ \partial w) > 0,$$

$$\partial E/\partial v = \partial E^{DCD}|\ \partial v = -\,(F_L)^2|\ D_2 - (\partial E^{DCD}|\ \partial Y^A)\, (\partial Y^A|\ \partial v) < 0,$$

where $D_2 \equiv v.\, F_L.\, F_{LE} + w.\, F_E.\, F_{LE} - v.\, F_E.\, F_{LL} - w.\, F_L.\, F_{EE}\ > 0$.
Note that the DC regime can only occur when

$$\bar{Y} - \beta v * \bar{E}^S\ <\ F(\bar{L}^S, \bar{E}^S). \tag{A20}$$

(vi) *Regime DEC.* With $\lambda_2 = 0$, $\lambda_3 > 0$, $\lambda_4 > 0$, the firm is constrained in the output and energy resource flow markets, but unconstrained in the labour market. Solution of the conditions yields:

$$L = L^{DECD}(Y^A, \bar{E}^S)\ <\ \bar{L}^S, \tag{A21}$$

$$E = \bar{E}^S\ <\ E^{DCD},$$

$$Y = F(L, E) = Y^A\ <\ Y^{ECS},$$

with

$$F_L = w/\lambda_1, \tag{A22}$$

$$F_E\ >\ v/\lambda_1, \qquad 0 < \lambda_1 \leq 1.$$

Standard analysis yields the comparative statics equations:

$$\partial\, Y/\partial w = \partial Y^A|\ \partial w = 0, \tag{A23}$$

$$\partial Y/\partial v = \partial Y^A|\ \partial v = -\beta \bar{E}^S < 0,$$

$$\partial Y/\partial \bar{E}^S = \partial Y^A|\ \partial \bar{E}^S = -\beta v < 0,$$

$$\partial L/\partial Y^A = \partial L^{DECD}|\ \partial Y^A = 1/(F_L) > 0,$$

$$\partial L/\partial w = \partial L^{DECD}|\ \partial w = 0,$$

$$\partial L/\partial v = \partial L^{DECD}|\ \partial v = (\partial Y^A|\ \partial v)\, (\partial L^{DECD}|\ \partial Y^A) < 0,$$

$$\partial L/\partial \bar{E}^S = \partial L^{DECD}|\ \partial \bar{E}^S = -\,(F_E + \beta v)/(F_L) < 0.$$

Note that the regime DEC can only occur when

$$\bar{Y} - \beta v * \bar{E}^S < F(\bar{L}^S, \bar{E}^S). \tag{A24}$$

(vii) *Regime DLC.* With $\lambda_3 = 0$, $\lambda_2 > 0$, $\lambda_4 > 0$, the firm is constrained in the output and labour markets, but unconstrained in the energy resource flow market. Solution of the conditions yields:

$$\begin{aligned} L &= \bar{L}^S < L^{DCD}, \\ E &= E^{DLCD}(Y^A, \bar{L}^S) < \bar{E}^S, \\ Y &= F(L, E) = Y^A < Y^{LCS}, \end{aligned} \tag{A25}$$

with

$$\begin{aligned} F_L &> w/\lambda_1, \\ F_E &= v/\lambda_1, \qquad 0<\lambda_1 \le 0. \end{aligned} \tag{A26}$$

Standard analysis yields the comparative statics equations

$$\begin{aligned} \partial E/\partial Y^A &= \partial E^{DLCD} | \, \partial Y^A = 1/(F_E)>0, \\ \partial Y/\partial w &= \partial Y^A | \, \partial w = 0, \\ \partial Y/\partial v &= \partial Y^A | \, \partial v = -\beta E/(1 + \beta v/(F_E))<0, \\ \partial E/\partial w &= \partial E^{DLCD} | \, \partial w = 0, \\ \partial E/\partial v &= \partial E^{DLCD} | \, \partial v = (\partial Y^A | \, \partial v) \, (\partial E/\partial Y^A)<0. \end{aligned} \tag{A27}$$

Note that the DLC regime can only occur when

$$\bar{Y} - \beta v * \bar{E}^S < F(\bar{L}^S, \bar{E}^S). \tag{A28}$$

(viii) *Regime DLEC.* With $\lambda_2 > 0$, $\lambda_3 > 0$, $\lambda_4 > 0$, the firm is constrained in all three markets. Solution of the conditions yields:

$$\begin{aligned} L &= \bar{L}^S < L^{DECD}, \\ E &= \bar{E}^S < E^{DLCD}, \\ Y &= F(L, E) = Y^A \le Y^{LECS}, \end{aligned} \tag{A29}$$

with

$$\begin{aligned} F_L &= (w + \lambda_2)/\lambda_1, \\ F_E &= (v + \lambda_3)/\lambda_1, \qquad 0<\lambda_1 le 1. \end{aligned} \tag{A30}$$

But this system of equations is over-determined. Only if autonomous demand equals full-employment output

$$Y^A = F(\bar{L}^S, \bar{E}^S) \tag{A31}$$

will the system be consistent. But in this case we can think of the firm as being constrained by the supplies of factor inputs, not by the autonomous demand for output. Then $\lambda_1 = 1$ and both marginal products are greater than their respective real prices. But the regime DLEC can only occur when equation (A31) holds, and there is general market clearing, with

$$\begin{aligned} Y^A &= Y^{LECS} = F(\bar{L}^S, \bar{E}^S), \\ \bar{L}^S &= L^{DECD}(Y^A, \bar{E}^S), \\ \bar{E}^S &= E^{DLCD}(Y^A, \bar{L}^S). \end{aligned} \tag{A32}$$

If $Y^A > F(\bar{L}^S, \bar{E}^S)$ we have regime LEC, and if $Y^A < F(\bar{L}^S, \bar{E}^S)$, regime DC.

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