Natural Resources and Taxation in Computable General Equilibrium Models of Developing Countries

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This paper surveys the application of computable general equilibrium (CGE) models to questions of natural resources and taxation in developing countries. The applications to natural resource questions fall into three categories: (1) energy management models that highlight the role of natural resources as inputs into the production process; (2) "Dutch disease" models that capture the effects of the windfall that accrues to exporters when the price of oil rises; and (3) optimal depletion models that take into account the exhaustibility of the resource and the link between optimal extraction and investment decisions. Insights are gleaned from each of these classes of models that could not have been obtained from partial equilibrium models. The application of CGE models to taxation can be divided into: positive analyses, which shed light on the link between fiscal and trade policies and the impact of a tax change on prices and incomes; and normative analyses, which compute "optimal" taxes in revenue-constrained economies. These are found to be at variance with proposals for tax reform that are based on rules-of-thumb.

1. INTRODUCTION

During the last 15 years, issues of natural resources and taxation have dominated the economic landscape of developing countries. The fourfold increase in the price of oil in 1973–74 and the ensuing convulsions in the world economy focused attention on the importance of natural resources to an economy. The subsequent doubling of the oil price in 1979, and the dismal economic performance of developing countries following it, heightened this concern. When oil prices started falling in 1982, the problems of oil producers became more apparent, which only increased the number of countries concerned with natural resource issues.

Taxation, similarly, has come to play a major economic role as a

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result of world events. The "debt crises" of the 1980s have highlighted the fact that much of the foreign borrowing by developing countries was to finance fiscal deficits. Some of these deficits could have been avoided, or at least reduced, had the governments been able to raise taxes. The need to meet debt-service payments today, moreover, has required governments to alter the level and pattern of taxation. Finally, many international lending agencies, as part of their program of debt relief, have required countries to reform their tax systems in order to improve the efficiency of their economies.

The concern with natural resources and taxation has given rise to a number of computable general equilibrium (CGE) models of developing countries that highlight these issues. This is not surprising, given that natural resources have economy-wide effects and that a general equilibrium model is the appropriate tool for analyzing questions of this kind. Similarly, taxes affect relative prices in the economy, so that a price-endogenous, multisectoral approach is called for in this case. Nevertheless, as we will see, the application of CGE models to natural resource and tax questions illustrates the limitations of the CGE approach.

The purpose of this paper is to survey the application of CGE models of developing countries to issues of natural resources and taxation. Section 2 treats natural resources and section 3 deals with taxation. In each case, I identify the questions asked of the models, present some examples of models and their results, and discuss extensions and some unsolved problems. In section 4, I attempt to draw the two strands together and propose an agenda for further research.

2. NATURAL RESOURCES

2.1 The Questions

The natural resource questions asked of CGE models fall into three categories. First are the questions that deal with the resource as an input to production. What is the impact of an increase in the world price of oil on the supply of and demand for oil as well as other sources of energy? What are the benefits of increasing use of nuclear power?

A second category of questions relates to the resource as a source of revenue to the country. Here, the issue is not the impact on input costs of an increase in the price of oil but rather the impact of increased export revenues to oil producers. What are the effects of this "windfall" on the rest of the economy? The syndrome whereby a primary product export boom leads to the decline of the traditional traded goods sector has come to be called the "Dutch disease" (although, as will be pointed out later, it is neither Dutch nor a disease). Many of the questions asked in this category concern the nature of the Dutch disease in a particular country.

The third, and perhaps most fundamental, class of questions arises from the fact that the supply of most natural resources is finite. At what rate should they be depleted? With perfect capital markets, economic theory tells us, this question is independent of the rest of the economy; a general equilibrium model is unnecessary.[1] However, since in most countries capital markets are imperfections, and other distortions exist as well, the resource depletion question is intimately linked with the country's savings and investment decisions, and a general equilibrium model is the appropriate tool.

2.2. Models

The types of models used to analyze natural resource issues mirror the three categories of questions. In this section, I identify the salient features of the three classes of models, describe some of their results, and point to some of the limitations of each approach.

2.2.1. ENERGY MANAGEMENT MODELS Models that highlight the role of natural resources as inputs to the production process can be described as energy management models. In general, these models contain an extremely detailed treatment of energy demand and supply. For example, several sources of energy supply (oil, natural gas, coal, electricity) are identified, and their behavior is modeled. Similarly, energy demand is given painstaking attention. The different end-users (households, industries, and so on) are separated, and their behavior is modeled individually. From this modeling, the derived demand for the various energy sources is estimated. Finally, supply and demand for each source are brought into balance, with prices determined endogenously.

In contrast to the detailed treatment these energy management models give to the energy sector, they treat the rest of the economy in a fairly coarse fashion. The non-energy sector is frequently treated as exogenous. When it is not, the feedback effects between the two sectors are rather weak. For example, energy demand is influenced by

[1]The original statement of this result is by Hotelling (1931). See Solow (1974) for an heuristic treatment and Devarajan and Fisher (1981) for extensions.

income in the non-energy sector, but energy prices have little effect on this income. Most of these models do not distinguish between the government's and the private sector's budget constraint, so that the effects of variations in tax revenue (often associated with changes in energy prices) are not captured.

Another striking feature of these models is that they generally have little connection with the theory of international trade. A large number of models assume that the economy is closed to foreign trade at the margin. If the economy were open, the domestic prices of energy sources would equal the (exogenous) world price. In some models, the economy is "semi-open," inasmuch as some imported energy sources compete, albeit imperfectly, with domestic sources. Even these models, however, do not capture the implications of the trade deficit on the economy (through appreciation of the real exchange rate).

Examples of energy management models of developing countries include those of Blitzer and Eckaus (1983), Blitzer (1986), de Lucia and Jacoby (1982), and Hughes (1986a, 1986b). These and other energy management models are surveyed by Kim (1986). When these models focus on the impact of change in the world price of crude oil, they derive the result that this impact depends crucially on the degree of substitutability/complementarity between oil and other factors of production, a result that is familiar from the developed country literature (Hogan and Manne 1979; Hudson and Jorgenson 1978).

Another use of these models is for the determination of domestic fuel prices. Hughes (1986a, 1986b) and Dixit and Newbery (1984) illustrate how the "optimal" domestic price need not be the fuel-equivalent world price because of second-best considerations. That is, when there are other distortions in the economy, the optimal domestic fuel price may involve a tax or subsidy to compensate for these other distortions. These can be viewed as special cases of the tax models discussed in section 3 of this paper.

In sum, energy management models are valuable tools for tracing through the effects of a change in one natural resource market on the overall energy balance in an economy. Yet they are better at modeling the energy system than the functioning of the whole economy. When the energy sector's role in the rest of the economy is significant, as in the case of a major oil producer, energy management models are less appropriate, and another class of models—which I will call "Dutch-disease models"—takes over.

2.2.2. DUTCH-DISEASE MODELS Unlike energy management models, Dutch-disease models are based explicitly on international trade theory.[2] The reason for this is simple. The phenomenon these models capture—the Dutch disease—follows directly from the principles of international trade. The idea can be expressed in the following diagram from Corden and Neary (1982) (see Figure 1). The economy outside the resource sector is divided into two sectors: tradables and nontradables.[3] The production possibilities are represented by the transformation frontier AB. The initial equilibrium, C, is given by the mutual tangency between this frontier and the (single) consumer's indifference curve. An increase in export revenues from oil, say, leads to a vertical translation of the transformation frontier to A′B′. The new equilibrium is C′. Note that at this equilibrium, the real exchange rate, the price of tradables relative to the price of nontradables, has appreciated. Production of nontradables has increased; the traditional tradable sector has declined. In short, the economy has contracted the Dutch disease.

Corden and Neary (1982) identify two effects that give rise to this phenomenon. First, there is the "resource movement effect." As the oil sector becomes more profitable, it draws resources away from the other sectors. Since the tradable sector's price is given by the world price, this movement of resources leads to contraction of the tradable sector. Second, there is a "spending effect." To the extent that some of the oil revenues are spent on nontradables, this bids up the price of nontradables. Again, this hurts the tradable sector, as resources are attracted to the nontradable sector. In general, the spending effect leads to an appreciation of the real exchange rate, which adversely affects the exporting and import-substituting sectors.

This discussion of the Dutch disease illustrates why it is a problem ripe for general equilibrium analysis. Both the resource movement and spending effects are general equilibrium effects; they cannot be captured by a partial equilibrium model. Moreover, the appreciation of the real exchange rate is exactly the type of relative price shift that CGE models are designed to capture.

In trying to portray the Dutch disease in a developing country, Benjamin, Devarajan, and Weiner (1986) observe that several alterations need to be made to the Corden–Neary framework. First, in many developing countries, the oil sector is an enclave. Most of its inputs—

[2]To be sure, some of the energy management models referenced in the preceding section incorporate Dutch-disease effects (e.g., Blitzer and Eckaus 1983). However, they do so at the expense of the rich specification of energy supply and demand that we have come to expect of these models.

[3]There can be more than one traded good; if each faces a parametrically given world price, they can be aggregated to a single sector.

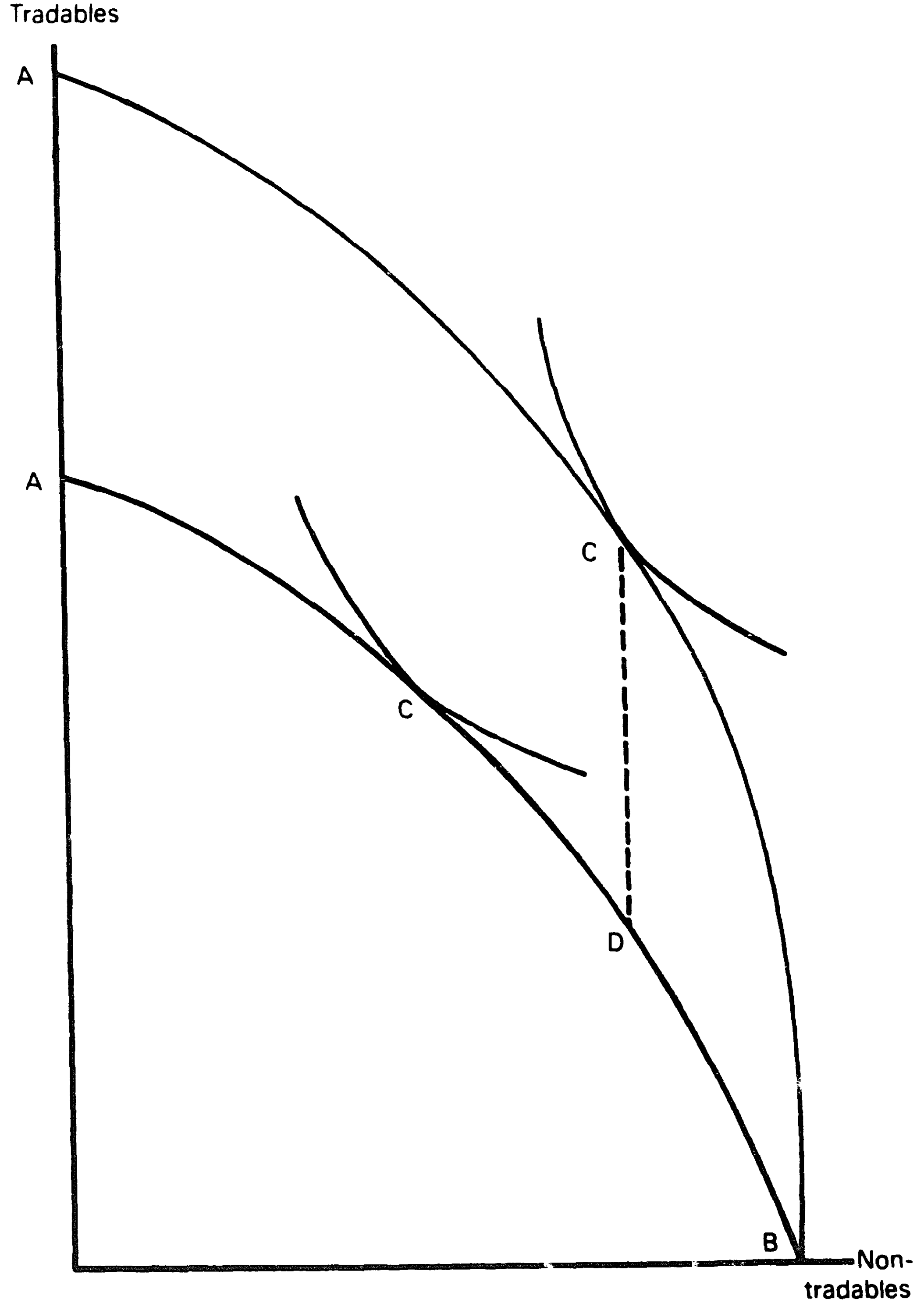

Figure 1. Dutch-disease models of international trade theory. *Source*: Corden and Neary (1983).

capital, labor, and intermediate goods—are imported. Hence the resource movement effect is not observed. Only the spending effect remains. Second, the Corden–Neary model assumes that imported goods and domestically produced goods in the same sector are perfect substitutes. In developing countries, this assumption is hard to sustain. At the very least, differences in quality between imports and their domestic "substitutes" make it plausible that the two goods will not command the same price.

By incorporating these two changes to the Corden–Neary framework, Benjamin, Devarajan, and Weiner show that some of the traditional Dutch-disease results may be reversed. Their conclusion can best be understood with the aid of the following simple model (which is a two-sector version of their, and others, multisectoral CGE model).

There are two sectors, tradables (T) and nontradables (N). Each sector's output is produced through a Cobb–Douglas production function. Labor (L) is the only mobile factor. Capital is sector-specific and fixed in the short-run. Hence, the capital term is suppressed in the following two equations:

$$T = L_T^{\alpha} \tag{1}$$

$$N = L_N^{\beta}. \tag{2}$$

With perfect competition and profit maximization, the value of the marginal product of labor is equated between the two sectors:

$$\alpha P_T T / L_T = \beta P_N N / L_N. \tag{3}$$

There is full employment:

$$L_T + L_N = \bar{L}. \tag{4}$$

National income is equal to the value added in the two sectors plus oil revenues, F:

$$Y = P_T T + P_N N + F. \tag{5}$$

The fraction of this income that is spent on nontradables is γ:

$$P_N N = \gamma Y. \tag{6}$$

Equation 5 and $\gamma > 0$ ensure that the spending effect is captured by this model. Finally, the imperfect substitutability between the tradable good T and imports M is expressed by the assumption that consumers have a CES utility function between the two goods. This gives rise to the demand function

Table 1: The "Dutch Disease" in Cameroon

	Percentage Change in Output	
Sector	**Fixed Capital**	**Flexible Capital**
Food Crops	0.75	0.73
Cash Crops	−2.47	−10.73
Forestry	−0.66	−1.33
Food Processing	−0.57	−1.08
Consumer Goods	−0.14	−0.46
Intermediate Goods	−0.27	−1.03
Cement/Base Metals	−0.61	1.12
Capital Goods	7.32	7.80
Construction	7.67	8.18
Private Services	−0.01	−0.81
Public Services	0.07	0.07

Source: Benjamin, Devarajan, and Weiner (1986) and Devarajan and Offerdal (1987).

$$T/M = k(P_M/P_T)^{\sigma}, \tag{7}$$

where σ is the elasticity of substitution and P_M is the price of the import.

Solving this system in log–linear form gives rise to the following relationship between the percentage change in the output of the T sector ($\hat{T}$) and a percentage change in oil revenues ($\hat{F}$):

$$\hat{T} = \frac{A}{B - \sigma C}\hat{F} \tag{8}$$

where A, B, and C are positive constants. Note that for σ low enough, T can actually *expand* for a given increase in F. With the full employment assumption, this implies that the N sector contracts. Thus, the traditional Dutch-disease result is reversed. Note further that as σ approaches infinity (the Corden–Neary assumption), this outcome becomes less and less likely.

That this is more than just a theoretical possibility is demonstrated by Benjamin, Devarajan, and Weiner's empirical application to an eleven-sector model of Cameroon. The first column (fixed capital) of Table 1 shows the response of each sector's output to a doubling of oil revenues.

The only pure nontraded goods are construction and public services. Yet, the capital goods sector enjoys an increase in its output as a result of this infusion of oil revenues. The reason is that, in this experiment, the oil revenues were assumed to be spent on investment goods, a major portion of which comes from the capital goods sector. In addition, since these capital goods are imperfect substitutes for imports, not all the extra demand went for imports. Enough of it went to the domestic capital goods sector that the sector grew, despite the real exchange rate appreciation accompanying this oil "boom."

This result illustrates another point that may be relevant in trying to predict the impact of oil revenues on a developing country's economy. Whereas output in most of the industrial sectors declined only slightly, the cash crop sector suffered quite severely. This points to an asymmetry between exporting and import-competing sectors in terms of their response to an oil boom. The exporting sector (96 percent of the cash crop sector's output is exported) faces world competition and hence is hurt by the real exchange appreciation. The import-competing sectors face less competition by virtue of their imperfect substitutability with imported goods. Thus, the real exchange rate appreciation hurts them less. This may be one explanation for the fact that after the oil price hikes of the 1970s, the agricultural sectors in all oil-exporting countries declined, whereas the industrial sectors in most of these same countries actually expanded (World Bank 1985).

Interesting and plausible as it may be, the Benjamin, Devarajan, Weiner result leaves two questions unanswered: (1) How robust is their result? and (2) What are its policy implications? While a complete answer to the first question would require testing every assumption of the model, a partial answer is provided by a recent paper by Devarajan and Offerdal (1987), in which they test the assumption of fixed, sector-specific capital. If capital were allowed to flow to equalize rates of return across sectors, the relative price of nontradables might not rise, thereby negating the Dutch disease effects observed in the Benjamin, Devarajan, Weiner model. However, Devarajan and Offerdal show that this does not happen. When the assumption of fixed, sector-specific capital is relaxed, the appreciation of the real exchange rate is dampened but not reversed. The corresponding quantity shifts are in fact accented in this model (see column 2, Table 1).

What are the policy implications? Indeed, there is no reason to believe a priori that policy intervention is warranted. The decline in the cash crops sector is simply a response to a change in the country's endowment and relative prices. There would be a case for policy intervention only if the oil revenues exacerbated an existing distortion in the economy. It is in this sense that the "Dutch disease" is not necessarily a disease.

One such distortion is suggested by van Wijnbergen (1984). If there is learning-by-doing in the traded goods sector, then its decline in the wake of an oil boom will impose an externality, thus justifying government intervention. To model this situation, van Wijnbergen postulates that technical progress in the traded goods sector is a function of the scale of production of that sector. Thus, there is a nonconvexity in the technology, private and social benefits diverge, and public intervention is warranted. In concrete terms, the government may wish to protect the traded goods sector so that, when oil prices decline (or the oil runs out), this sector is in a position to resume its role as the country's main foreign exchange earner.

To conclude, Dutch-disease models provide a useful and interesting picture of what will happen to an economy in response to a boom in its natural resource sector. However, they do not, by themselves, provide much insight into the types of policies that a government should pursue. Virtually all these policy issues, moreover, are of an intertemporal nature and therefore are best treated in the context of optimal-depletion models, where time plays a critical role.

2.2.3. OPTIMAL-DEPLETION MODELS If Dutch-disease models leave out the policy, it could be said that optimal-depletion models are about nothing *but* policy. Essentially, these are intertemporal Dutch-disease models. Oil revenue, F, in each period is linked to the depletion of oil from a finite stock, $\bar{S}$. As we observed earlier, however, if capital markets were perfect, the oil depletion problem would be independent of the rest of the economy. Assuming capital markets are not perfect, therefore, these models tie the depletion question with the economy's borrowing and investment strategies. In this sense, these models are normative, since they answer the question "What should a country do?" rather than "What will happen if . . . ?"

The formal structure of these models can be seen in the following simplified model. Being normative, the model has an explicit objective function, in this case the intertemporal utility of consumption:

$$\Sigma \frac{U_t^{1-\phi}}{1-\phi} \frac{1}{(1+\delta)^t}, \tag{9}$$

where $U_t = N_t^{\gamma} T_t^{1-\gamma}$.

Note that this objective function is the same as that used in the intertemporal models reviewed by de Melo (1987).[4] The model then consists

[4]In section 6.1 of his paper, de Melo discusses the significance of ϕ for intertemporal smoothing.

of maximizing equation (9), subject to equations (1–8) and the following additional equations:

$$F_t = R_t + B_t - rD_t, \quad (10)$$

where R is the revenue from the natural resource, B is foreign borrowing, D is the total debt, and r is the world interest rate;

$$R_t = P_t^R Q_t, \quad (11)$$

where P^R is the price of the resource and Q the quantity sold.

$$\Sigma Q_t - \bar{S}, \text{ and} \quad (12)$$

$$D_t - D_{t-1} = B_t. \quad (13)$$

The capital market imperfections can be introduced by postulating limits on the amount of debt a country can hold. A common specification is that a country's debt not exceed some fraction λ of its capital stock.

It should be noted that whereas the model in equations (1–8) had no savings or investment, these are crucial to the present model. Hence, the capital stock should be updated each year by the level of investment:

$$K_{t+1} = K_t + I_t, \quad (14)$$

and investment, in turn, is financed by the sum of private and foreign savings:

$$I_t = S_t + F_t. \quad (15)$$

Finally, private savings reduces the amount of income available for consumption, so that equation 5 has to re-expressed as

$$P_N N = \gamma(Y - S). \quad (5_1)$$

As before, this relatively simple model can be used to derive a rich menu of results about the intertemporal profile of oil depletion, foreign borrowing, and investment. It will also generate a path for the associated prices over time. For example, Martin and van Wijnbergen (1986) calculate the path of the real exchange rate over time in their application of the model to Egypt (Figure 2).

Note that while the real exchange rate—under any definition—appreciates initially, it depreciates at different rates depending on which definition is used. The price of nontraded goods relative to traded goods continues to rise as when Egypt's oil reserves run dry in the early 21st century because nontradables are more energy intensive than tradables and the world price of energy is rising in this scenario.

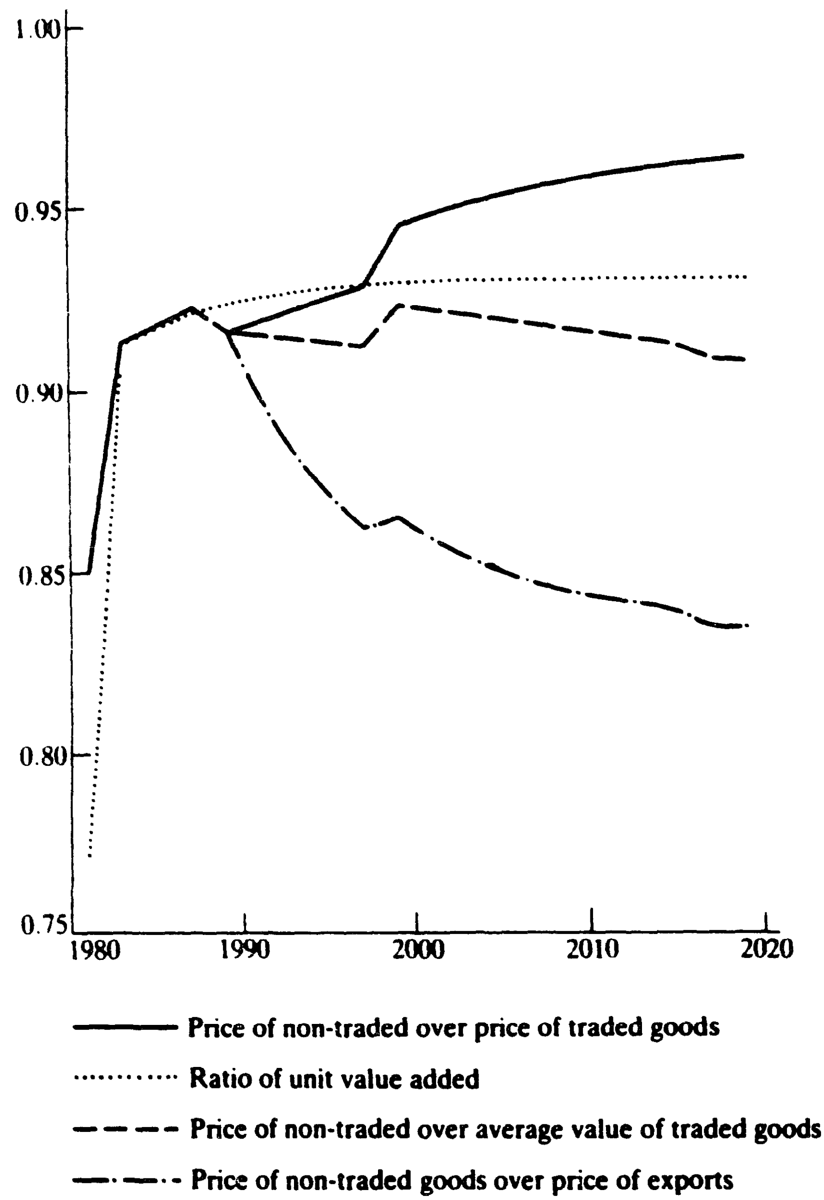

Figure 2. Real exchange rates: price of non-traded goods in terms of various traded goods, 1981–2019. *Source*: Martin and Wijnbergen (1986).

Meanwhile, the price of nontradables relative to exports falls with depleting reserves because the country has to reallocate resource to the traditional export sector to make up for declining oil revenues.

The Martin–van Wijnbergen exercise also sheds light on the accounting rate of interest (ARI), a crucial parameter for project evaluation. The ARI is the rate at which the shadow price of capital changes over time. In an intertemporal optimum, it is related to the consumption rate of interest (CRI), the rate at which the value of consumption is changing, by the equation

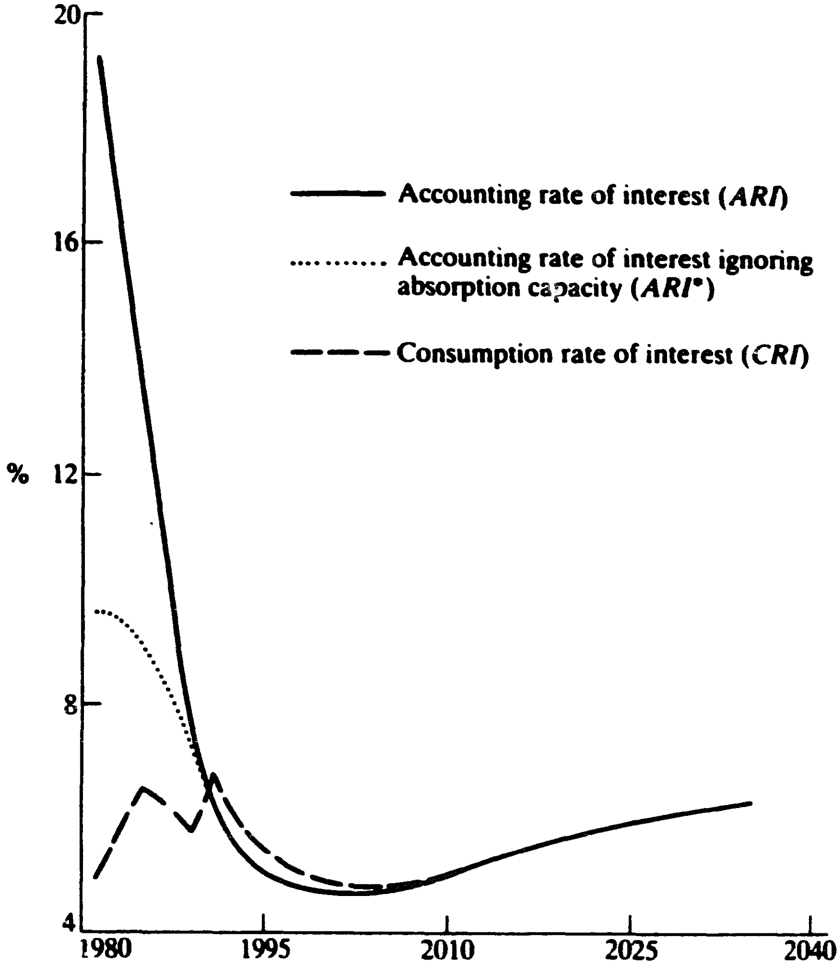

Figure 3. *ARI*, *ARI** and *CRI* in the base run. *Source:* Martin and Wijnbergen (1986).

$$\text{ARI} = \text{CRI} - \dot{s}/s, \tag{16}$$

where s is the value of consumption in terms of capital. However, when there are constraints on the ability to transform consumption to capital—absorptive capacity constraints, for example—the ARI and CRI will diverge (see Figure 3).

The Martin–van Wijnbergen simulation also shows that the accounting rate of interest is not constant over time for this economy. This is because of the temporary windfall of oil revenues and the absorptive capacity constraints that have been incorporated into their model. While the actual values of the ARI are probably debatable, that it varies over time is not. This is an important lesson emerging from these modeling exercises, all the more so because project analysts frequently use a constant ARI in their cost–benefit calculations.

Finally, it is worth examining how this intertemporal optimizing model behaves when it is "shocked." Suppose world oil prices were

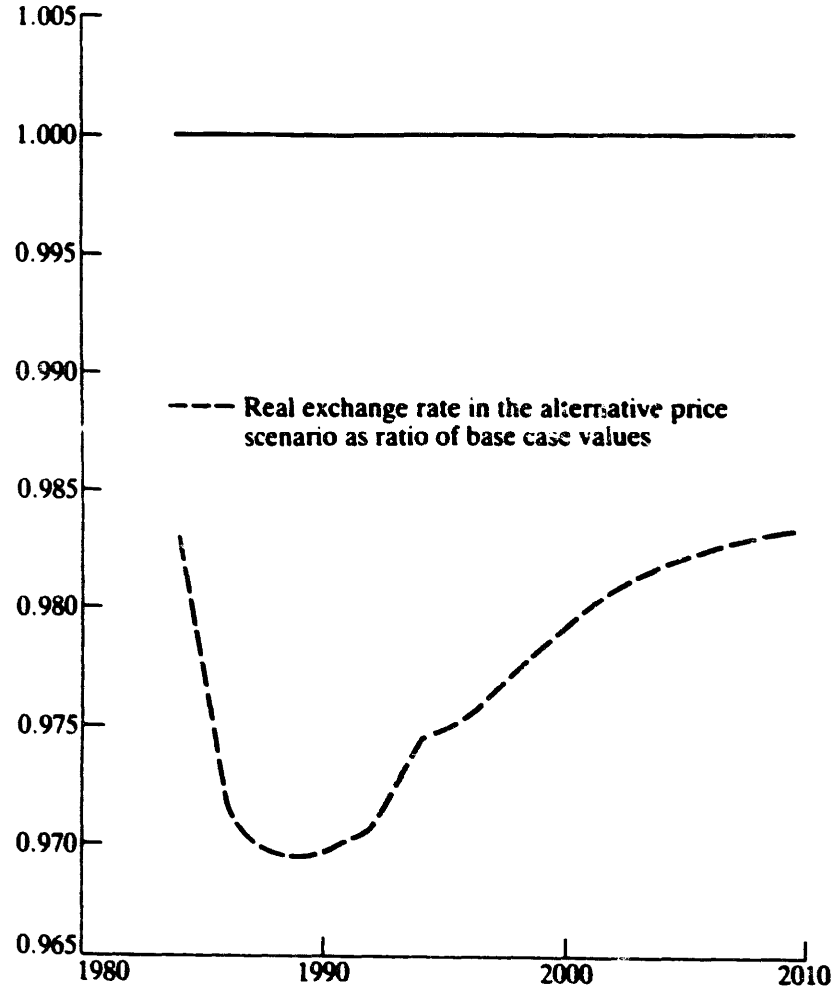

Figure 4. The real exchange rate (P_n/P_t) under different oil price scenarios. *Source*: Martin and Wijnbergen (1986).

persistently lower than in the base case. On the one hand, borrowing then becomes costlier to Egypt since the traded goods required to meet debt-service payments are dearer. This would call for lower current account deficits and, hence, a depreciated real exchange rate (relative to the base case). On the other hand, when Egypt was to become a net importer of oil the lower oil prices would be a "windfall." This indicates that higher borrowing and an appreciated real exchange rate are sustainable. As Martin and van Wijnbergen show (Figure 4), the former effect dominates. The real exchange rate is everywhere depreciated relative to its base case value. Nevertheless, the gap narrows toward the end of the horizon, suggesting that the second scenario comes into play then.

Overall, then, optimal-depletion models are a powerful tool with which to discuss simultaneously a country's resource depletion, foreign borrowing, and investment strategies. As with most powerful tools, however, these models hit computational constraints, requiring the modeler to keep the *intra*temporal aspect of the model rather simple. This is why most of these models have no more than two or three sectors. As we saw from the Dutch-disease models, aggregating to two or three sectors might hide some of the interesting intersectoral effects arising from expenditure out of oil revenues. Clearly, there is a trade-off, and the modeler has to choose the levels of aggregation and of intertemporal detail to suit the question at hand.

2.3. Unsolved Problems

Despite the contributions that CGE models have made to our understanding of the interaction between natural resources and the economy, there remain at least two unsolved problems. The first is uncertainty. Virtually all the CGE models surveyed assume there is no uncertainty. All decisions are made with perfect information about the future price of oil, interest rates, and so on. Yet uncertainty about these very variables has been an overriding concern among policymakers in the last 15 years. If CGE models are to continue to shed light on natural resource questions, they should be able to incorporate some form of stochastic decision-making into their specification.

The second, and related, issue is the behavior of natural resource markets. One reason we are uncertain about the price of oil is that we do not understand how the oil market functions. Is it competitive? Is it dominated by a cartel? Most CGE models take the world oil market as exogenous. Nevertheless, some insight may be gained by trying to make the oil market endogenous.

Neither of these extensions requires a CGE models for its achievement. In fact, both will require a variety of different techniques: stochastic modeling in one case, partial equilibrium market analysis in the other. The point is that once these areas are better understood, we can build richer and more insightful CGE models to study natural resource questions.

3. TAXATION

Taxes have been a major component of virtually all CGE modeling exercises. Indeed, CGE models of *developed* countries arose from an explicit concern with the welfare implications of tax changes (see, for example, Shoven and Whalley 1984). In developing countries, the issues surrounding tax reform are different. First, limited administrative capacity prevents most developing countries from instituting a consumption tax, or even a viable income tax; indirect taxes are the more commonly used instruments. This has implications beyond simply the defining of experiments to be run with a CGE model. The assumption, frequently made in exercises with developed-country models, that the tax revenue is rebated in a lump-sum fashion can no longer be made. After all, if the government has access to lump-sum transfers, it should also be able to levy lump-sum taxes. Hence, the revenue implications of tax reform become crucial. Second, the effects of a tax change on the distribution of income are clearly more important in developing countries. Third, since most developing countries are open economies, the impact of tax reform on foreign trade receives much attention. Only recently, however, have CGE models of developing countries looked at *all* aspects of tax reform, namely, the welfare, revenue, equity, and foreign trade implications.

3.1. The Questions

The uses of CGE models to study issues of taxation can be classified into two categories: those that look at taxes as a way to correct market failures and those that look at taxes as sources of government revenue. Under the first category, the most prevalent distortions are related to protection of infant industries and efforts to increase market power in world markets. The infant industry argument is often invoked to justify import tariffs or other forms of protection of domestic industry. Curiously, most CGE models of developing countries do not explicitly incorporate an infant-industry specification of technology.[5] Nevertheless, virtually all the models include tariffs on imported goods. As for market power in world markets, this leads to questions of an optimal export or import tax. Partial equilibrium results also indicate the magnitude of the tax—the inverse of the elasticity of demand/supply. In some cases (see below), however, general equilibrium models show that this is not true. The reasons have to do with how the government disposes of the tax revenue and the other suboptimal taxes in the system.

The more common role for taxes in CGE models, therefore, is as a source of government revenue.[6] This, in turn, leads to a variety of questions to be asked of the models. First, which tax instruments should be used to raise revenue? It is well known that lump-sum taxes are

[5] The one exception I know of is Dervis and de Melo (1977).

[6] Mitra (1987) looks at revenue raising and protective tariffs in a CGE model of India.

the least distorting, but they are almost impossible to administer. In the absence of lump-sum taxes, what are the "second-best" instruments? Diamond and Mirrlees (1971) have shown that these are consumer taxes; however, in many developing countries, even consumer taxes are difficult to administer. In this case, a whole array of indirect taxes (producer taxes, export taxes, import tariffs) has to be used. Even if we can identify the instruments, the question of the level of taxation remains. Furthermore, no country reforms all its taxes at once. If some taxes will remain suboptimal, how does this affect the level of taxes that *can* be changed? Finally, government deficits are intimately linked to current account deficits. If, at the margin, a unit decrease in the fiscal deficit leads to a unit decrease in the current account deficit, a tax change can also affect a country's current account position, possibly in perverse ways.

Clearly, this second category of questions provides a fertile ground for CGE models. For the most part, these models encompass the first category as special cases. We turn therefore to an examination of some of the models that deal with taxes as sources of revenue to the government.

3.2. Methods

The methods for examining tax questions with CGE models can be described as either positive or normative. The former simply asks "what if" questions; the latter attempts to derive optimal taxes for a given economy.

3.2.1. POSITIVE MODELS An example of a positive model that is both generic and yet illustrates some interesting points is provided by Devarajan and de Melo (1987). Theirs is a two-sector model, not unlike that in equations (1–8). However, their tradable sector is a pure traded good; all of its output is exported:

$$E = L_1^{\alpha}. \tag{12}$$

Output of the second sector is labeled D (for domestic):

$$D = L_2^{\beta}. \tag{13}$$

As before, there is full employment:

$$L_1 + L_2 = \bar{L}. \tag{14}$$

Again, the value of the marginal product of labor is equated between the two sectors. The export sector faces an export tax at a rate s:

Table 2: Percentage Change (+ or −) in the Balance of Trade and the Real Exchange Rate from a One Percent Change in the Exogenous Variables

Increase in:	Effect on F	$\pi(1-s)/P$
G	+	−
π	+	−
s	−	+
t	−	+

Source: Devarajan and de Melo (1987).

$$\alpha\pi(1-s)E/L_1 = \beta PD/L_2. \tag{15}$$

Imports compete with consumers' demand for the domestic good, C. There is an import tariff of t:

$$C/M = k(P^*(1+t)/P)^{\sigma}. \tag{16}$$

Government purchases an exogenous amount, G, of the domestic good:

$$D = C + G. \tag{17}$$

Finally, it is assumed that the private sector balances its budget, but the government does not. The government's budget constraint, then, is

$$s\pi E + tP^*M + F = PG. \tag{18}$$

From Walras' Law, it follows that F is also equal to the trade deficit.

This simple model brings to light two important features of CGE models applied to taxation. First, the particular closure rule that is chosen will be crucial. In this case, Devarajan and de Melo assume that the government can borrow from abroad at the margin, so that the trade deficit is endogenous. Second, the distinction between the public and private budget constraint is critical. With this distinction, various canons of trade theory, including Lerner symmetry, break down.

The behavior of the Devarajan–de Melo model can be seen by examining the table of multipliers below (Table 2). This table gives the signs of the percentage changes in the balance of trade (F) and the real exchange rate [π(1-s)/P] for a one percent change in the four exogenous variables.

Note that an increase in the export tax, t, lowers the trade deficit. In fact, it could raise the level of exports. This is because of its effect on the government budget. The increased revenue permits the government to borrow less, thus depreciating the real exchange rate, and lowering costs to exporters. The breakdown of Lerner symmetry is not obvious from the signs above, but is clear from the numerical results presented in Devarajan and de Melo (1987). Again, this is due to the differential impacts of import tariffs and export taxes on the government budget. Hence, the effect of raising the export tax by x percent is different from that of raising the import tariff by x percent because the fiscal implications of the two are different. Again, this points to the value of a general equilibrium approach rather than simple rules of thumb.

Another important contribution to this genre of models is that of Bovenberg (1987). He focuses on offsetting distortions in a CGE model of Thailand. In examining the welfare implications of a tax change on the deadweight loss created by other taxes in the system, Bovenberg derives the useful result that the welfare and revenue implications move in the same direction. That is, a particular tax change will increase the deadweight loss associated with another tax only if it also lowers the revenue collected from this tax. This is a particularly useful finding to present to policy makers who are unconvinced by arguments based on deadweight losses; they will usually find arguments based on revenue terms more persuasive.

Most positive tax models tell us in which direction the economy will move for a given change—usually small-in a tax instrument. The question of how much a tax should be changed remains unanswered. For that, we turn to the second class of models, the normative models.

3.2.2. NORMATIVE MODELS Normative models can be viewed as positive models with an objective function. They answer the question, "What is the optimal tax rate for an economy like the one described under the positive models, where 'optimal' is defined in terms of a well-specified objective function?" As always, the choice of objective function is crucial. In keeping with Diamond and Mirrlees (1971), the utility of consumption would be the appropriate function. But in addition to the obvious problem of making interpersonal utility comparisons,[7] there is a further problem: if consumption includes only today's

[7]The choice of utility function is important not only when there is more than one type of consumer. If all consumers were identical, but there was a public sector that also consumed goods and services, its consumption would have to be valued vis-a-vis the private sector's. Jorgensen and Slesnick (1983) provide a fruitful approach for making interpersonal utility comparisons.

consumption, the model will attempt to impose a huge tax on investment goods (which are not consumed today). There are two ways to address this problem: to impose a constraint on the taxation of investment goods or to include future consumption as an argument in the objective function.[8]

Dahl, Devarajan, and van Wijnbergen (1986) adopt the former solution in their effort to compute optimal, "third-best" taxes using a CGE model of Cameroon.[9] Their results (reproduced in de Melo 1987, Table 4) provide several insights that are consistent with other studies of this type. First, the other suboptimal taxes in the system exert a strong influence on the optimal tax rate. For example, when only import tariffs were changed, the optimal levels were those that compensated for the distortions created by the fixed producer taxes in Cameroon. In the cash crop sector, where the producer tax was highest, the optimal (revenue-neutral) tariff was negative. Second, although the model assumed finite export demand elasticities, it derived optimal export taxes that were not exactly equal to the inverse of the elasticity of demand. As mentioned before, this is due both to the existing taxes in the system and to the government's inability to dispose of the export tax revenue in a nondistortionary manner. Third, the results show that adhering to simple rules of thumb, such as unifying tariff rates, can be misleading. The optimal tariff structure, when there are other taxes that cannot be reformed, is by no means uniform. Indeed, Dahl, Devarajan, and van Wijnbergen show that unifying tariff rates will lead to a welfare loss relative to the status quo. Fourth, despite the welfare loss from unifying tariff rates, in general, the model shows that the welfare changes from partial tariff reform are relatively small. This is because a particular tax change may exacerbate other distortions in the economy, neutralizing the welfare gains from the reform.

3.3. Extensions

This discussion of optimal tax models suggests several areas for further work. First, our modeling of export markets is still some-

[8]It should be noted here that not all optimal tax exercises use CGE models. In particular, the detail required for some tax reform programs prevents the use of a CGE model as an analytical tool. A good example of this is Ahmad and Stern's (1986) study of tax reform in Pakistan. They derived optimal consumer taxes at a very high level of disaggregation. They assumed a linear production structure, so a CGE model was not necessary to complete their analysis.

[9]Mitra (1987) adopts the second approach, obtaining similar results. His paper also contains a comparison of revenue-raising and protective tariffs.

what rough. Finite export demand elasticities are useful—indeed, sometimes necessary—to get a model to track the actual behavior of an economy. These same finite elasticities, however, give rise to optimal export taxes that are sometimes at unrealistic levels. Moreover, if the export taxes are set to zero, other taxes behave like export taxes when they are optimally set. The question is, what is the true export demand curve faced by developing countries? As with natural resources, this requires further study of how world markets operate.

The treatment of dynamics also deserves further attention. As mentioned earlier, this is essential if we wish to understand the relationship between taxes on investment and taxes on consumer goods. Furthermore, just as public and private budget constraints are important, so too is the intertemporal budget constraint faced by each agent. In particular, any increase in foreign borrowing has to be repaid. How does this affect the positive and normative results cited above? The repayment of foreign debt is captured by the optimal-depletion models cited in section 2.2. An obvious extension would be to use these models to derive optimal taxes as well.

Third, the small changes in welfare obtained for large shifts in the pattern of taxation is a troubling result. At the very least, it makes one question why so much effort is devoted to tax reform by policy makers and the public. Looked at another way, are the CGE models missing something that is central to policy makers' view of the world? With their assumptions of perfect competition and supply–demand equilibrium, CGE models may be understating the "true" welfare gains from tax reform. Adding more realistic distortions and rigidities to the model may change these calculations.

4. CONCLUSION

To sum up, a recurring theme in both the natural resource and the tax literature is the need for more work on dynamics. In natural resources, this will help to integrate the Dutch-disease models with the optimal depletion models. In taxation, we must deal with the impact of taxes on investment versus consumer goods, as well as the impact of taxation on savings and capital formation.

One way to proceed is to construct CGE models in which all goods are "dated." In this way, when solving for equilibrium prices, we are solving for prices that clear markets at all points in time. Simply adding a time subscript to all variables is not sufficient, however. Intertemporal budget constraints must be added. Moreover, the role of expectations is surely a crucial element, and this is not captured by dating commodities. Since CGE models cannot be solved for an infinite horizon, terminal conditions have to be specified. Often these drive the model. Finally, as most of these models will be incorporating foreign borrowing, the issues of sovereign debt and repudiation need to be faced. Again, this would be a departure from the standard Arrow–Debreu framework of dated commodities, but nevertheless it is a realistic, institutional feature.

A second issue that is suggested by both natural resource and tax models is the role of nonconvexities in the economy. This issue has arisen several times in our discussion: learning-by-doing in the tradable sector in Dutch-disease models, infant industries as a justification of tariff protection in tax models, and the nature of export markets in developing countries. However, our ability to specify these nonconvexities in a relistic and sensible (not to mention tractable) form is still embryonic.

Finally, the question of market structure arose more than once in our discussion. Our understanding of both domestic and foreign markets is limited. At one level, we need to know how these markets actually function. The focus on macroeconomic issues in the last decade and a half has perhaps distracted us from these microeconomic concerns. At another level, we have to work on specifying alternative market structures in CGE models. With a few exceptions (Harris 1984), most models assume that all markets are competitive. Modeling the other extreme—perfect monopoly— would be easy. But most markets in developing countries (and everywhere else for that matter) lie in the middle. The question thus becomes, "What is the appropriate conjectural variation?" Deriving conjectural variations that match with certain stylized facts about market forces, and are at the same time tractable in a modeling sense, is a task that will reap rich rewards if successful.

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