18.C

Primary Factor Shares

Thomas Hertel and Marinos Tsigas

18.C.1 Overview and Motivation

In versions 1 - 3 of the GTAP data base, there was only one type of natural resource endowment identified, namely agricultural land. Because this factor was only used in agricultural production, it was also, by default, a sector-specific factor. The presence of a specific, or fixed, factor serves to dampen the supply response in the sector in question. When demand increases, part of that increase is translated into increased land rents. Indeed, the only way to increase agricultural output is to substitute other factors of production for land. This type of situation stands in sharp contrast to some manufacturing activities, say the production of wearing apparel, where supply can be increased indefinitely — provided the demand is there — by simply building new factories and hiring more workers. The only thing that forces the supply curve for such a sector to slope upward is the fact that as additional workers are bid away from other activities, wages will rise. This is a general equilibrium supply constraint.

Of course the presence of non-producible natural resource inputs arises in other sectors as well. Coal, oil, natural gas, minerals, fisheries and forestry are all examples of sectors where partial equilibrium supply response is constrained by the underlying natural resource input. As the range of GTAP applications has broadened, the supply response of these sectors has been called into question. In recent work conducting projections with GTAP, we have introduced specific factors in these sectors in order to restrain the responsiveness of supply to increases in the economy-wide capital stock (Dimaranan, 1998). Others conducting simulations of trade liberalization in resource-abundant economies have commented about the very large increases in production and export of extractive products following trade liberalization. It became clear that steps needed to be taken here as well.

Having identified the need to constrain supply response in the other natural resource sectors, it remains to determine how the relevant cost share was to be obtained. In the case of agriculture, a wide range of studies exist which estimate these cost shares — often as part of an econometric study of the sectoral cost function. However, such studies are not common in other natural resource sectors. Thus we decided to take a more indirect approach to the problem. We begin with the desired outcome, i.e. what is the target, partial equilibrium supply elasticity? We then compute the natural resource cost share which is implied by that target elasticity.

In partial equilibrium, with fixed prices for all mobile factors of production (non-natural resource inputs) and a fixed quantity of the natural resource input, supply response equals the negative of the own-Allen-Uzawa elasticities of substitution (AUES) for the natural resource input, so that:

$$q = -\eta_S \, p \tag{1}$$

where: q and p stand for the percentage change in quantity and price of the sectoral output respectively, and η_S, the supply elasticity, is equal to the negative of the AUES:

$$\eta_s = -\sigma_{RR} \tag{2}$$

The sectoral supply response is simply determined by the industry's ability to substitute away from the fixed factor. If $\sigma_{RR} = 0$, then no amount of price increase will be able to induce a supply response. But how does this Allen elasticity relate to the parameters in GTAP? This relationship is a function of the cost shares and elasticities of substitution in the nested CES production function. Specifically:

$$\sigma_{RR} = -\left(\sigma_{VA} \left[\theta_R^{-1} - \theta_{VA}^{-1} \right] + \sigma_T \left[\theta_{VA}^{-1} - \theta_O^{-1} \right] \right) \tag{3}$$

where σ_{VA} corresponds to the elasticity of substitution among components of value-added and σ_T corresponds to the elasticity of substitution between value-added and intermediates. The latter is zero in the standard GTAP model, so that the second term in parentheses falls out. The parameter θ_R corresponds to the cost share of the natural resource input. θ_{VA} refers to the cost share of value added, and the last parameter, θ_O, is the cost share of all inputs — or output — which is simply equal to one. Assuming σ_{VA} and σ_T are given by the GTAP data base, we can solve equations (2) and (3) for the natural resource share implied by a given supply elasticity. This is the general approach taken here. Of course, it may be that the required cost share exceeds the share of capital in the original data base — or even the share of all value-added! In order to eliminate such outcomes, we have taken two steps. First of all, rather than just taking the resource share out of capital (which is highly volatile and may even be negative in a bad year), we take it out of all value-added. Secondly, the elasticity of substitution in value-added is reduced from its value in the version 3 data base. In version 5 we have set this value equal to 0.2. When implemented, this procedure results in less than one-third of value-added going to the natural resource input in most cases. Of course there are still a few instances where a very low share of value-added in the source data results in a much higher share of value-added being assigned to natural resource inputs. Future refinements of this approach to calibrating supply response should seek to take into account regional variation in the targeted elasticity.

18.C.2 Non-Agricultural, Natural Resource-Based Sectors

Forestry: The first question which arises when one turns to specific sectors is: how large is the partial equilibrium supply response? In the case of forestry, we draw on econometric estimates as reported in column one of table 1 in Catimel (1996). The estimated supply elasticities are for the Canadian softwood timber industry and they range from 1.6 to 5.8, depending on the region of Canada and the nature of the product supply (e.g., logs vs. pulpwood). Discarding the high and low estimates and averaging the remaining elasticities gives a mean supply response of 2.5. This is the targeted elasticity in version 5 of GTAP, and it is imposed in every region of the data base. Therefore, equations (2) and (3) are solved for a cost share of natural resources which satisfies them in each region.

Fisheries: The case of fisheries is more difficult due to the fact that the response of supply to price varies depending on the management regime in place. Campbell (1996) explores this issue in considerable detail for the case of tuna. In the case of an “open access” fishery, anyone seeking to come and harvest the stock of fish can do so. Open access leads to essentially an infinite discount rate, over-fishing, and hence a very low supply response to price (0.29). On the other hand, some fisheries are managed by an industry group. When such a group operates as a single, profit-maximizing entity, supply is more responsive to price. In this type of “private management” regime, reductions in the discount rate will increase the responsiveness of supply. In the case of a zero discount rate and private management, Campbell computes a supply elasticity for tuna of 0.76. These represent the two extremes for the tuna industry. For purposes of GTAP version 5, we average the two and obtain an elasticity of supply equal to 0.525. Someone studying a question in which fisheries supply response is a crucial parameter could specify a distribution of supply elasticities, based on the Campbell study (e.g., triangular distribution with minimum value 0.29 and maximum value 0.72), thereby generating a distribution of possible outcomes (see Arndt and Pearson, 1996, for more details on how to conduct such systematic sensitivity analysis in GTAP).

Fossil fuels and mining: Whalley and Wigle (1991) spend considerable time studying the supply response of the fossil fuels sector in their attempt to assess the implications of taxation designed to reduce global carbon dioxide emissions. Because of the importance of this parameter to their study, they conduct a systematic sensitivity analysis for which they set the minimum value to 0.1 and the maximum to 1.5. Their central case is 0.5. This is the value which we choose as a target for version 5 of GTAP.

Unfortunately, a similar study was not available for the other mining sectors. However, in the case of many minerals, extensive deposits exist around the world and the owners are ready to bring some of these mines back on line (or temporarily shut some down) when prices rise (or fall). This suggests a higher supply response. We have adopted the value of 2.5 here, based on experience in Australia (Robert McDougall, personal communication).

18.C.3 Agriculture

Having gone to the trouble to target supply response in the non-agricultural, natural resource-based sectors, we found ourselves asking whether this might not also be a good idea in the case of agriculture. Of course the situation is somewhat different here, since we have additional information in the form of independent estimates of primary factor shares (see table 18.C.1). Since these are deemed more reliable than the estimated elasticities of substitution, we adjust the latter in order to achieve the targeted supply response. Furthermore, we only target the global supply elasticity for agriculture as a whole.

What degree of supply response is appropriate for agriculture? Despite the extensive literature on this topic, the agricultural economics profession is still far from agreement. Some argue that supply response is very low, even in the long run, while others argue that once full adjustment of labor and capital has occurred, the scope for sizable responses to price changes is considerable. Given the propensity of governments to intervene in agricultural markets, the degree of supply response is much more than an academic issue. Sizable long run supply elasticities translate into high costs for government price support schemes and distorted world markets. In this study, we target a global supply response for agriculture of 1.19, based on Peterson's (1988) cross-section, international study. This is larger than what some of the supply pessimists might like, but smaller than what the supply optimists would argue for. When applied to equations (2) and (3), using average shares for world agriculture, this yields a value of $\sigma_{VA} = 0.23$. This is substituted in the parameter file for the previous value which was larger (0.56 in versions 1 - 3). This smaller elasticity of substitution in production results in a smaller agricultural supply response in models based on the version 5 data.

There are two areas of agricultural supply response where broad agreement exists. We accommodate both of them in GTAP. First of all, supply response is relatively smaller in less industrialized economies, where agriculture is less commercialized. This feature comes through in GTAP, via the overall share of value-added in costs. In Sub-Saharan Africa, where purchased inputs are far less important, the share of value-added, and hence land, is much higher than in the United States. Consider the case of rice production. The global cost share of land in this sector is about 22 percent. However, in the US and Australia, this figure is only 10 percent, whereas in India it is 28 percent and the Indonesian rice sector has a cost share of land equal to 43 percent. Based on equations (1) - (3), supply response in the US and Australia will be much higher than in India and Indonesia, given a common elasticity of substitution in production.

A second point of general agreement is that supply response at the level of individual crops is much higher than for agriculture as a whole. This makes sense, since agricultural land (and farmers as well) can shift from one crop to another much more readily than they can shift into another sector, such as wearing apparel. Since agricultural land is sector specific in the GTAP model, those who choose to disaggregate agricultural subsectors will find that this proposition also holds. Namely, the supply response of individual agricultural activities is larger than for the sector as a whole. Land is no longer a fixed factor for individual crops as it may be bid away from competing crop or grazing activities. The degree of land mobility across subsectors is determined by the elasticity of transformation (ETRAE in GTAP notation), as discussed in the GTAP book (Hertel, 1997).

18.C.4 Summary

In summary, these changes substantially alter the performance of the natural resource-based sectors in applied GE models drawing on the version 5 data base. With less elastic supply, we expect larger price changes and smaller quantity changes for natural resource based products. These changes can also have macro-economic implications in economies which are heavily dependent on natural resources. Consider for example, the adjustment of an oil-exporting economy to a cut in its import tariffs. In order to pay for the increased imports, more oil must be exported. However, if supply of that product is less responsive, then the process of reestablishing external balance will be quite different. We will expect more of the adjustment to occur in the form of higher resource rents, and less in the form of higher exports and depressed product prices.

Table 18.C.1. Share of Primary Factors in Agricultural Value-Added

GTAP Region	Land	Labor	Capital	Reference Document or Source Region
AUS	21	51	28	ABS I-O table for labor; Ball (1996) for others
NZL	14	62	24	NZIER I-O table
CHN	29	59	12	Martin (1993)
HKG	38	54	8	(Taiwan)
JPN	18	51	31	Kuroda (1995) for labor; Ball (1996) for others
KOR	51	40	9	Ban (1979)
TWN	38	54	8	Lee and Chen (1979)
IDN	51	42	7	OECD (1993)
MYS	51	42	7	OECD (1993)
PHL	41	55	4	Crisostomo and Barker (1979)
SGP	51	42	7	(Thailand)
THA	51	42	7	OECD (1993)
VNM	51	42	7	(Thailand)
BGD	44	38	18	(India)
IND	44	38	18	Chadha, et al. (1997)
LKA	44	38	18	(India)
XSA	44	38	18	(India)
CAN	17	39	44	Narayanan and Kizito (1992)
USA	28	38	34	Ball (1988) for labor; Ball (1996) for others
MEX	28	47	25	Haley (1991) for South America
XCM	28	47	25	Haley (1991) for South America
COL	28	47	25	Haley (1991) for South America
PER	28	47	25	Haley (1991) for South America
VEN	28	47	25	Haley (1991) for South America
XAP	28	47	25	Haley (1991) for South America
ARG	28	47	25	Haley (1991) for South America
BRA	16	24	60	Brandao et al. (1994)
CHL	28	47	25	Haley (1991) for South America
URY	28	47	25	Haley (1991) for South America
XSM	28	47	25	Haley (1991) for South America
AUT	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
BEL	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
DNK	13	40	47	DIAFE
FIN	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
FRA	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
DEU	15	68	17	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
GBR	14	68	18	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
GRC	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
IRL	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
ITA	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
LUX	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
NLD	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
PRT	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
ESP	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
SWE	11	68	21	Heinrichsmeyer et al. (1988) for labor; Ball (1996) for others
CHE	27	35	38	OECD (1993)

Contd

Table 18.C.1. Share of Primary Factors in Agricultural Value-Added (Continued)

GTAP Region	Land	Labor	Capital	Reference Document or Source Region
XEF	27	35	38	OECD (1993)
HUN	35	53	12	OECD (1993)
POL	35	53	12	OECD (1993)
XCE	35	53	12	OECD (1993)
XSU	28	60	12	OECD (1993)
TUR	11	57	32	Haley (1991) for MEA
XME	11	57	32	Haley (1991) for MEA
MAR	11	57	32	Haley (1991) for MEA
XNF	11	57	32	Haley (1991) for MEA
BWA	15	40	45	(Rest of SACU)
XSC	15	40	45	Masters (1994)
MWI	15	60	25	(Zimbabwe)
MOZ	15	60	25	(Zimbabwe)
TZA	15	60	25	(Zimbabwe)
ZMB	15	60	25	(Zimbabwe)
ZWE	15	60	25	Masters (1994)
XSF	15	60	25	(Zimbabwe)
UGA	12	72	16	Haley (1991) for Sub-Saharan Africa
XSS	12	72	16	Haley (1991) for Sub-Saharan Africa
XRW	46	44	10	OECD (1993)

References

Arndt, C. and K.R. Pearson. 1996. "Implementing Systematic Sensitivity Analysis Using GEMPACK," GTAP Technical Paper #3, Center for Global Trade Analysis, Purdue University: http://www.agecon.purdue.edu/gtap/techpapr/index.htm.

Ball, V.E. 1988. "Modeling Supply Response in a Multiproduct Framework," *American Journal of Agricultural Economics*, 70(4):813-25.Ball, V.E. 1996. unpublished worksheets, personal communication, April 30.

Ban, Sung Hwan. 1979. "Agricultural Growth in Korea, 1918-1971," Chapter 4 in Y. Hayami, V.W. Ruttan, and H.M. Southworth, *Agricultural Growth in Japan, Korea, and the Philippines*, East-West Center.

Brandão, A.S.P., T.W. Hertel, A. Campos. 1994. "The Implications of International Agricultural Trade Liberalization for Brazilian Agriculture," in I. Goldin, O. Knudsen, and A.S. Brandao, (eds.), *Modeling Economy-Wide Reforms Development Centre of the Organization for Economic Co-Operation and Development*. Paris: Chapter 4, pp 193-222.

Campbell, H.F. 1996. "Prospects for an International Tuna Resource Owner's Cartel," *Marine Policy*, vol. 20, no.5, pp. 419-427.Catimel, Jerome. 1996. "Econometric Estimation of Canadian Softwood Timber Supply Curves: An Exploratory Analysis," Research Note No. 41, Canadian Forest Service, April.

Chadha, Rajesh, Sanjib Pohit, Alan V. Deardorff and Robert M. Stern. 1998. *The Impact of Trade and Domestic Policy Reforms in India: A CGE Modeling Approach*, The University of Michigan Press, Ann Arbor.

Crisostomo, C. and R. Barker. 1979. "Agricultural Growth in the Philippines, 1948-1971," Chapter 5 in Y. Hayami, V.W. Ruttan, and H.M. Southworth, *Agricultural Growth in Japan, Korea, and the Philippines*, East-West Center.

Dimaranan, B. 1998. "Implementing Comparative Static Projections Using GTAP," Forthcoming GTAP Technical Paper, Center for Global Trade Analysis, Purdue University.

Haley, S.L. 1991. "Capital Accumulation and the Growth of Aggregate Agricultural Production," *Agricultural Economics*, 6:129-157.

Henrichsmeyer, W. and A. Ostermeyer-Schlöder. 1988. "Productivity Growth and Factor Adjustment in EC Agriculture," *European Review of Agricultural Economics*, 15:137-54.Hertel, T.W. (Editor). 1997. *Global Trade Analysis: Modeling and Applications*, Cambridge University Press: New York, NY.

Higgs, P. J. 1986. *Adaptation and Survival in Australian Agriculture*, Oxford University Press.

Kuroda, Y. 1995. "Labor Productivity Measurement in Japanese Agriculture, 1956-90," *Agricultural Economics*, 12:55-68.

Lee, Teng-hui and Yueh-eh Chen. 1979. "Agricultural Growth in Taiwan, 1911-1972," Chapter 3 in Y. Hayami, V.W. Ruttan, and H.M. Southworth, *Agricultural Growth in Japan, Korea, and the Philippines*, East-West Center.

Martin, W. 1993. “Modeling the Post-Reform Chinese Economy,” *Journal of Policy Modeling* 15(5&6):545-579.

Masters, W. 1994. Government and Agriculture in Zimbabwe. Westport: Praeger.

Narayanan, S. and E. Kizito. 1992. "Multifactor Productivity for Canadian Agriculture: Update to 1990 with Analysis," Working Paper 1/93, Agriculture Canada, Policy Branch, Farm Economic Analysis Division, Ottawa, September.

Organization for Economic Co-Operation and Development. 1993. “GREEN: The User Manual,” Resource Allocation Division, Economics Department, OECD, Paris, France, 82 pages, May.

Willis Peterson. 1988. “International Supply Response,” *Agricultural Economics*, vol 2, pp. 365-374.

Whalley, J. and R. Wigle. 1991. “The International Incidence of Carbon Taxes,” in *Global Warming: Economic Policy Responses*, R. Dornbusch and J.M. Poterba, eds. MIT Press: Cambridge, Mass.