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Approximating the Effective Protection Coefficient without Reference to Technological Data

Patrick J. Conway and Malcolm Bale

When proposals for reform of tariff or subsidy policies are made, attempts to predict the effect on incentives are frequently hampered by the need for input-output technical data. This article develops and illustrates the use of a methodology for approximating effective protection coefficients (EPCs) when such data are unavailable or outdated. It derives the equations which approximate the EPC from statistical analysis of a cross section of existing EPC studies for four agricultural commodities: corn, cotton, rice, and wheat. Informational requirements for computing approximations include the nominal protection coefficients on output and tradable inputs and readily available macroeconomic data. These approximation equations perform well in an out-of-sample test.

Trade economists are constantly in search of empirical measures of the sectoral production incentives introduced by government trade, exchange rate, and input pricing policies. The effective protection coefficient (EPC), which is the ratio of domestic to world value added, is commonly accepted as the preferred metric for this purpose, despite its well-known drawbacks (Dixit 1985). EPCs have been calculated in most developed and developing countries for industrial products. They have been calculated less often for agricultural products, however, because necessary input-output information and farm management studies have often been unavailable.

In the absence of reliable EPC calculations, researchers have used the nominal protection rate (NPC), which is the ratio of the domestic to world price of the final good as a proxy. As the *World Development Report 1982* (World Bank 1982b, p. 49) notes:

Such effective protection coefficients are more difficult to compute because data on input uses in agriculture are more elusive. Research at the

Patrick J. Conway is an assistant professor of economics at the University of North Carolina at Chapel Hill and Malcolm Bale is an economist in the Latin America and the Caribbean Country Department I of the World Bank. Research for this study was undertaken while Bale was a staff member of and Conway a consultant to the Country Policy Department of the World Bank. The authors thank Dennis Appleyard, Alfred Field, Kenneth Harling, and Andrea Maneschi for perceptive comments, and Thérèse Bélot for statistical assistance.

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World Bank and elsewhere suggests, however, that the levels of traded inputs in agricultural outputs are relatively low in developing countries, so that the qualitative results of EPCs and NPCs are similar.

We develop and implement a methodology for improving upon the NPC in approximating the EPC without requiring "elusive" input-output information. Information on these input-output coefficients is embodied in calculated EPCs. We have formed a cross-sectional data base drawn from existing EPC studies and use statistical methods to derive approximation equations for the EPC that reflect this underlying technical information. We then demonstrate in an out-of-sample example that these approximations are both easily constructed and more precise than the use of NPCs.

The data base includes information on both cross-country and within-country protection which extends existing studies (World Bank 1982b, 1986), and our EPC approximation equations provide estimates of the impact of tariff and subsidy changes on producer incentives and thus inform policy prescription. Although this methodology is no substitute for the in-depth sectoral research of farm budget or input-output studies, it permits an initial screening of trade liberalization and subsidy elimination proposals for their sectoral incentive effects.

I. THE DETERMINANTS OF THE EFFECTIVE PROTECTION COEFFICIENTS

EPC estimates summarize the magnitude of producer incentives arising from government trade policy and the productive technology (that is, the use of tradable inputs). The NPC, which does not account for input pricing, will thus be an imprecise approximation when protection of tradable inputs increases costs and provides a significant disincentive to production, and when the productive technology varies systematically over time and place. This is best illustrated mathematically; we define the following variables for one crop in one country at one point in time.

P = Domestic price of agricultural output (after protection)

P^* = World price of agricultural output in home-currency units

q = Domestic price (vector) of input(s) to production divided by P (after protection)

q^* = World price (vector) of input(s) divided by P^*

α = (Vector of) units of input(s) used per unit of output¹

Domestic value added per unit of output can then be defined as $P(1 - q\alpha)$, and world value added per unit of output in home currency is defined $P^*(1 - q^*\alpha)$. The EPC is the ratio of domestic value added to world value added.²

1. The empirical EPC studies referenced below use a unique set of input-output coefficients for both domestic and world production.

2. For the case of multiple tradable inputs, α can be considered a row vector and q a column vector. Also, when nontraded goods exist and are handled in either of the Corden methods (see Tower 1984), this relation characterizes the EPC.

$$\begin{aligned}\text{EPC} &\equiv [P(1 - q\alpha)]/[P^*(1 - q^*\alpha)] \\ &\equiv \text{NPC} [(1 - q\alpha)/(1 - q^*\alpha)]\end{aligned}$$

The second identity highlights the close relation between the NPC ($= P/P^*$) and the EPC. Variation in the EPC, however, will also follow from movements in the domestic and world relative prices of inputs or from changing input-output coefficients. This is illustrated by approximating the above equation using a multivariate Taylor expansion:

$$\text{EPC} \cong \text{NPC} - \frac{\alpha}{1 - q\alpha} (q - q^*)$$

The EPC increases with the NPC and decreases as nominal protection on tradable inputs grows (as q rises). For a tariff system that has higher nominal protection on tradable inputs than on output ($q > q^*$), the EPC decreases as the use of tradable inputs (and α) rises.

Microeconomic theory suggests that the input-output coefficient, α , will respond systematically to four sets of determinants: relative input prices (q), the country's level of economic development (Y), economies of scale in domestic production (Q), and advances in the productive technology (T).

$$\alpha = \alpha(q, Y, Q, T)$$

- + ? -

The symbols above the determinants of α indicate the sign of the partial derivative (that is, the negative sign above T indicates that $\partial\alpha/\partial T < 0$). The positive effect of Y on α reflects a belief that tradable-input use increases with the level of development. A positive effect of Q would reflect decreasing returns to scale, whereas zero or negative effects would indicate constant or increasing returns. More modern techniques (higher T values) are assumed to allow greater output with an identical volume of tradable inputs.

Each EPC calculation assumes that the elements of α are fixed. However, if $q \neq q^*$ (that is, if nominal protection of output and inputs is not uniform) and the microeconomic determinants of α above are valid, changes in the relative price of inputs, the scale of production, or the level of development will have an impact on the value of α . This regularity can be exploited to ensure greater precision in approximating EPCs.

II. STATISTICAL ANALYSIS OF THE EFFECTIVE PROTECTION COEFFICIENTS

We have collected EPCs, NPCs, and related economic indicators for four agricultural crops—cotton, rice, corn (maize), and wheat—from the existing incentive studies cataloged in the bibliography for the sixteen countries listed in appendix A. Of these, eleven fall within the World Bank classification of developing country. There were some differences in the calculations of EPCs

across studies, but the methodology in all cases is substantially that drawn from Corden (1963) and Balassa and Associates (1971).³

Figures 1 through 4 plot the EPC against the corresponding NPC for the observations in each crop. There is an upward bias of the EPC to the NPC in corn, cotton, and rice; there is in addition significant deviation of the EPC from the corresponding NPC. If this deviation is systematic, the NPC's value as a proxy can be improved upon by reference to other determinants.

The conventional wisdom that EPCs in agriculture are less than unity and substantially lower in developing countries (Bale and Lutz 1981) is only partially borne out for these crops. Figures 5 through 8 show the EPC as a function of level of per capita gross national product (Y); the vertical line represents a dividing line between developing and developed countries. EPCs are not invariably less than unity for any crop. Observation suggests, however, that for traditional developing-country export crops (cotton and rice), the EPCs for developing countries are less than unity in the majority of instances; for the developing-country import substitutes (wheat and corn), the EPCs of developing countries are usually greater than unity. In industrial countries, the opposite pattern exists; for developing-country export crops, the industrial-country EPC is invariably greater than unity, whereas for the import substitute crops the industrial-country EPC is lower and often less than unity.

We choose for simplicity to construct linear EPC approximation equations. If we represent each crop with subscript i , the country with subscript j , and the time period with subscript t , we can define a linear EPC equation incorporating the NPC and technological effects outlined above as

$$EPC_{ijt} = \beta_0 + \beta_1 NPC_{ijt} + \beta_2 (q_{jt} - q_t^*) + \beta_3 Y_{jt} + \beta_4 Q_{ijt} + \beta_5 T_t$$

We have made several simplifications in our application of the estimator. First, α should depend negatively on q . To avoid multicollinearity, we did not introduce q_t and $(q_t - q_t^*)$ separately into the regression but used only the latter. Second, the returns to scale effect, Q_{ijt} , should be measured by output per farm. That information was not available, so we used aggregate country output of the crop in that year, appropriately scaled. Although not precise, this has the advantage of being readily available. We were able to collect systematic information only on fertilizer input prices, and these are used to define $(q_{jt} - q_t^*)$. The development indicator (Y_{jt}) used is constant-dollar per capita gross national product. Technical advances, T_t , are represented by a time trend defined by the calendar year of the study minus 1965. We also examined other country-specific and development indicators including the labor share in agriculture and the share of imports in gross domestic product. We considered relative gasoline prices as an alternative imported input price. In all cases, these additional measures were so highly correlated with the reported regressors as to add

3. One difference across studies is the definition of α . Some studies appear to have used unadjusted domestic input-output coefficients; others (for example, Harling 1981 and Stryker and others 1975) have adjusted domestic observed α to reflect costs of production at world prices. This difference does not invalidate the procedure that follows, as it is a manipulation based on the variables q and q^* .

Figure 1. *Effective and Nominal Protection, Corn*

Figure 2. *Effective and Nominal Protection, Cotton*

Figure 3. *Effective and Nominal Protection, Rice*

Figure 4. *Effective and Nominal Protection, Wheat*

Figure 5. *Effective Protection Coefficient and Country Level of Development, Corn*

Figure 6. *Effective Protection Coefficient and Country Level of Development, Cotton*

Figure 7. *Effective Protection Coefficient and Country Level of Development, Rice*

Figure 8. *Effective Protection Coefficient and Country Level of Development, Wheat*

Table 1. *EPC Approximation Equations*

Coefficient	Corn	Rice	Cotton	Wheat
β_0 (intercept)	0.37 (1.48) ^a	0.09 (0.47)	-0.28 (2.21)	0.95 (1.74)
Nominal protection coefficient ^b β_1 (NPC _{ijt})	1.20 (8.18)	1.17 (8.90)	1.05 (9.03)	0.80 (4.11)
Input protection ^c β_2 ($q_{jt} - q_t^*$)	-0.018 (0.50)	-0.029 (0.97)	-0.001 (0.96)	-0.07 (0.80)
Country development ^d β_3 (Y_{jt})	0.004 (0.28)	0.03 (2.88)	0.02 (3.35)	-0.01 (0.27)
Scale ^e β_4 (Q_{ijt})	-0.002 (0.15)	0.53 (2.36)	1.47 (6.22)	0.13 (1.86)
Technology ^f β_5 (T_{ijt})	-0.05 (2.91)	-0.03 (3.30)	0.008 (1.22)	-0.06 (2.57)
$\bar{R}^2$	0.70	0.88	0.92	0.70
F-value	16.45	33.7	66.5	17.2
Observations	34	24	30	36
Critical T value	2.05	2.10	2.06	2.04
Standard error of estimate	0.32	0.16	0.12	0.40

a. T-statistics are in parentheses. The critical T value is defined for a two-tailed test with a 95 percent confidence level.

b. NPC, the nominal protection coefficient, is the ratio of the domestic to world output price.

c. The relative protection of inputs to that of outputs, ($q - q^*$), is based on domestic and world fertilizer prices relative to output prices.

d. Y, the country's level of economic development, is proxied by constant-dollar per capita gross national product (thousands of 1982 U.S. dollars).

e. Q, the indicator of economies of scale in production, is measured as aggregate country output of the crop.

f. T, the indicator of advances in productive technology, is measured by the year of observation less the base year, 1965.

unacceptable multicollinearity to the regression. The data sources and computations are detailed in appendix B.

We use least-squares regression to obtain estimates of the parameters β , and these are reported in table 1.⁴

The estimates of the coefficients on NPC are all insignificantly different from unity, as the unit coefficient on NPC in the Taylor expansion above suggested, but illustrate as well the tendency for EPC to exceed NPC for corn, rice, and cotton. Scale and development effects enter positively for the most part, consistent with theoretical prediction if fertilizer inputs receive on average higher nom-

4. Specification of a regression equation in this way is not an indication of causality, but simply an efficient way to characterize the partial correlations between EPCs and the readily observable variables.

inal protection than output (as was true for the majority of our observations).⁵ These effects are significant for rice and cotton but not for corn and wheat.

The relative input price effect is negative but insignificantly different from zero in all cases. This insignificance may reflect the fact that the direct effect of protection of inputs in taxing the activity that converts inputs into outputs is largely offset by the indirect effect of substitution away from the protected inputs. The negative sign suggests the dominance of the direct effect.

The "vintage" effect is negative and significant in three of the cases, as theory suggests. This vintage effect is not a statement that developed countries have access to more advanced, import-using technology; the level of development is accounted for by the inclusion of Y . Rather, it indicates that there has been a diffusion in recent years of more import-using technologies, with low-income countries recently having a greater access than in previous years. EPCs fall as a consequence, because for constant input prices the domestic value added is reduced.

These regressions reinforce the distinction between developing-country export crops (cotton and rice) and import substitute crops (wheat and corn). The scale and development indicators play a more important and significant role in the export crop equation, providing a more precise restatement of the difference in EPC behavior noted in figures 5 through 8. The export crop equations are also more precise in-sample estimators, as is evident in the R^2 statistics and standard errors of estimate. The precision of the in-sample EPC prediction is measured by the standard errors of the estimates, and it suggests placing a greater degree of confidence in approximations based on these equations for the export crops.

A natural comparison, given the discussion above, is with the NPC's approximation success. We derive an upper bound on the NPC's explanatory power by regressing EPC on NPC and an intercept, and then comparing the explanatory power of the non-NPC variables through use of an F test.⁶ The results are reported in table 2. The non-NPC explanatory variables prove to be significant additions to the NPC in approximating the EPC in all cases examined.

III. OUT-OF-SAMPLE TESTING OF THE EFFECTIVE PROTECTION COEFFICIENT APPROXIMATION

The approximation equations of table 1 can be combined with readily available information to offer an estimate of the EPC that improves upon the simple use of the NPC. They do so by identifying systematic covariation of unobserved input-output coefficients with readily available indicators. The best test of the

5. Given the definition of domestic and world variables, the positive differential may be due to greater transport costs as well as greater tariffs on fertilizer.

6. This is an upper bound for the NPC's forecast power, for it in effect defines an approximation equation $\Psi_0 + \Psi_1 \text{ NPC}$. Using the NPC as the predictor for the EPC sets $\Psi_0 = 0$ and $\Psi_1 = 1$ and is found to be less effective than using the estimated values of the parameters.

Table 2. *F-statistics for Significance of Country-Specific Variables and Vintage Effects*

<i>Statistic</i>	<i>Corn</i>	<i>Rice</i>	<i>Cotton</i>	<i>Wheat</i>
F-statistic	3.16	5.31	21.52	4.06
Critical F(4,n)	2.71	2.93	2.79	2.69

Note: n is the number of degrees of freedom. The F-statistics were calculated by comparing the residual sum of squared errors from regressing EPC on NPC, and from regressing EPC on NPC, Q , Y , $(q - q^*)$, and T in a Chow test. The critical values reflect a 95 percent level of confidence.

policy application of these explanatory equations is out-of-sample forecasting of agricultural EPCs. Data on the NPC, EPC, and the other relevant indicators used in our methodology are available for Turkey's agricultural sector in 1978; these data were not included in the estimation data base. Using the forecasting equations to predict EPCs yields the results summarized in table 3. Turkey at that time had fertilizer subsidies exceeding 60 percent of the border price (World Bank 1982a, p. 302), leading to large negative values of $(q - q^*)$. Protective tariffs favored rice and corn production, with wheat receiving lower nominal protection and cotton unprotected by tariffs. In each case, the approximate EPC derived from the equations of table 1 improved upon the NPC alone. As the calculations for corn indicate, however, there can remain quite large gaps between actual EPC and the derived approximation. The estimation results of table 1 predict that these gaps will be larger on average for corn and wheat.

These equations can also be used to approximate the changes in protective incentives created by changes in input price subsidy programs. The resulting estimates are long-term in nature, for they allow for the indirect effects of changes in relative input protection on the technological coefficient, α , as well as direct effects on relative input prices. For example, suppose that elimination of fertilizer price subsidies for Turkey is proposed. Removal of these would raise the values of $(q - q^*)$ reported in table 3 to -0.47 , -0.26 , 0 , and -0.18 respectively and lower the EPC approximation calculated from the regressions of table 1. The statistical evidence suggests that removal of these subsidies would in the long run reduce EPCs by relatively small amounts: rice

Table 3. *Forecasting Turkish Effective Protection Coefficients*

<i>Variable</i>	<i>Corn</i>	<i>Rice</i>	<i>Cotton</i>	<i>Wheat</i>
Actual EPC	2.51	1.88	1.06	1.49
Table 1 approximation	1.56	1.84	1.01	1.37
Turkish data				
NPC	1.50	1.77	1.00	1.18
Scale, Q (10^7 mt)	0.13	0.03	0.05	1.68
Input protection, $(q - q^*)$	-0.85	-0.40	-0.12	-0.59
Country development, $Y = 1.37$				
Technology, $T = 13$				

Note: See table 1 for definitions of the variables. See appendix B for explanation of variables' measurement.

and cotton EPCs would fall by less than 1 percentage point, corn EPC by about 1 percentage point, and wheat EPC by 3 percentage points.

IV. CONCLUSIONS

This article has derived and demonstrated a methodology for approximating EPCs through the use of readily available information. The results will prove useful to economists examining agricultural incentives in a country lacking farm budget or input-output technological data. These results may also be used to approximate the current EPC or to predict the effect of changes in tariff or subsidy policies on agricultural production incentives.

We recognize that in most cases the problem in calculating EPCs is not that input-output data are unavailable but that they are either out of date or calculated for another country. The choice facing an economist for Togo (for example) may well be calculating 1988 EPCs either based upon 1970 Togolese input-output coefficients or upon 1980 Ghanaian input-output figures. The equations presented here provide a third, readily calculable approximation. They could be useful, for example, in providing an approximation of the incentive effects of tariff reductions negotiated by each country in the Uruguay Round of trade negotiations. They may also be used to approximate the incentive effects of cuts in tariffs or subsidies on tradable inputs. We suggest use of these approximation equations in concert with other measures of agricultural price incentives, both as a check upon the accuracy of the other methods and as an indicator of the longer-term effects of tariff and subsidy policies.

The quality of these EPC approximations is limited by the availability of data. The effectiveness of our methodology can be improved by extending the data base to include both more agricultural EPC studies and relative-price differentials for other important tradable inputs in agriculture.

Our research was motivated in part by the observation that existing EPC studies now represent an important source of information on agricultural (and industrial) pricing incentives. Our approximation equations represent a first step in harnessing that information. The data collected from EPC studies and other sources is available from the authors to those wishing to further this work.

APPENDIX A. DATA CHARACTERISTICS

Country	Years	Observations
Argentina	1965-69av., 1970-74 av.	2
Australia	1973/74-80/81	8
Canada	1975-77av.	1
Côte d'Ivoire	1972	1
Egypt, Arab Rep.	1971-76	6
Germany, Fed. Rep.	1972-75av., 1975-77av.	2
Mali	1972	1
Mexico	1966-70	5
Nigeria	1979-81	3
Pakistan	1965/66, 1970/71, 1975/76	3
Paraguay	1979-81	3
Philippines	1973-79av.	1
Senegal	1972	1
Thailand	1981	1
United Kingdom	1975-77av.	1
United States	1968, 1971, 1975, 1978	4

Commodity	Number of countries	Observations
Wheat	10	36
Maize (corn)	10	34
Rice	8	24
Cotton	11	30

Note: Sources are given in appendix C. Australia and Pakistan report their data for agricultural years (July-June), so the years are listed in pairs (for example, 1970/71). Some countries reported EPC and NPC figures as averages for a number of years; these are indicated by the suffix "av."

APPENDIX B. DATA SOURCES

EPC_{ijt} and NPC_{ijt} figures are drawn from the studies listed in appendix C.

Figures on gross national product in thousands of constant 1982 U.S. dollars and population used to compute Y_{jt} are drawn from the World Bank data base. (This is the same base used to compute appendix tables in, for example, the *World Development Report*).

The relative fertilizer price differential is calculated as

$$(q_{jt} - q_t^*) = (P_{Fjt} - P_{Ft}^* \text{NPC}_{ijt}) / P_{ijt}$$

where P_{Fjt} is the domestic price of fertilizer, P_{Ft}^* the world price of fertilizer (both per metric ton equivalent of nutrient), NPC_{ijt} is as defined above, and P_{ijt} is the domestic farm-gate price of output. P_{ijt} is drawn from FAO (various years). P_{Fjt} is a country-specific index based upon domestic prices of different forms of fertilizer weighted by percentage use in aggregate production, all drawn from FAO (various years). P_{Ft}^* is an index of prices taken from World Bank (1983), weighted in a similar fashion and converted to home currency with official exchange rates drawn from the World Bank data base.

The scale effect (Q_{ijt}) is measured by the volume of output (in units of 10^7

metric tons) of crop i in country j in time t and is drawn from FAO (various years).

Vintage (T) is defined as calendar year of the study minus 1965. For observations with fiscal years different from calendar years, the initial calendar year is used; if the observation is an average for a number of years, the middle year is used.

Our compiled data base includes a number of variables not used in this analysis. For documentation on the complete data base, contact the authors.

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