ANNEX D

The OECD Policy Evaluation Model

The *Policy Evaluation Model* (PEM) is a partial equilibrium model of agricultural production that is designed to connect the data in the PSE database with economic outcomes in terms of production, trade and welfare in a stylised manner. It uses the PSE classification scheme as an organising principle to represent the agricultural policies in selected countries in such a way that the economic distinctions that guide the PSE classification are highlighted. Specifically the model takes into account the initial incidence of a policy, such as whether it is directed at land, input use or output, and whether the policy should affect current resource allocation decisions, primarily driven by whether policies require or not current production as a condition of eligibility.

For the United States, the PEM includes wheat, coarse grains (over 95% of which is corn), oilseeds (essentially soybeans), rice, milk and beef. The model uses the PSE database for the years 1986 to 2008, including those policies where the categorisation is deemed sufficient to allow for a representation of the policy in the model. Some policies are omitted from the model where their role in agricultural production is unclear (category F), or when restrictions on input use make their impact difficult to estimate (most policies where "voluntary" or "mandatory" input constraints are in place). For this reason, the term "Modelled PSE" is used to indicate that portion of the PSE that is represented in PEM.

D.1. Representation of risk effects of policies

For the policy simulations carried out in this study, the PEM was modified to take into account a significant feature of certain agricultural policies in the United States; payments that are made in a counter-cyclical fashion to current prices reduce the risks faced by producers. Risk-reduction is an objective of agricultural policy in many countries and provides benefits to risk-averse producers by making payments when prices are low, thus reducing the net effects of negative price shocks. Such payments can be made either according to current production, as for the loan rate (LR) programmes, or on the basis of historical production, as is the case for the Counter-cyclical Payment (CCP), paid on the basis of base acres according to current prices.

The approach taken is to consider the effect of the two main risk-reducing programmes, LR and CCP, on the profit-maximising decision of a producer of multiple commodities, potentially possessing base acres in each. It is assumed that producers are risk averse with a utility function compatible with constant absolute risk aversion (CARA) preferences, which exclude the complicating factor of wealth effects of risk. Wealth effects have been shown to be small relative to the insurance effect (OECD, 2002). This approach builds on that used in the OECD study (OECD, 2002), a primary difference being the multi-commodity approach taken here.

Begin by considering the profit function of a representative farm:

$$\tilde{Y} = \sum_{i=i}^{n} [\tilde{P}_i Q_i - C(Q_i]| + \sum_{i=1}^{n} LR_i(\tilde{P}_i) Q_i^0 + CCP_i(\tilde{P}_i) Q_i^0 + \gamma \tag{1}$$

where Y is farm income, P_i, Q_i and $C(Q_i)$ are the price, quantity produced and cost of production of commodity *i*, respectively and the tilde indicates a random variable. The LR payment is defined for each commodity and paid on the basis of current price per unit of current output. The CCP payment is defined for each commodity as a function of the current price of commodity *i* and paid on the basis of base area of commodity *i*, Q_i^0. The additional term γ represents other sources of income. For simplicity it is assumed that the only source of risk is price risk, such that the price of the commodity is a random variable but the quantity produced is not. A utility function with CARA preferences defined by parameter α may be expressed as a mean-variance utility function as follows:

$$\breve{Y} = \bar{Y} + \frac{1}{2}\alpha V(\tilde{Y}) \tag{2}$$

that is to say, certainty-equivalent income equals expected income minus the variance of income times one half the CARA parameter. The variance of income will is derived by application of the law of sums and products of random variables to the variance of (1), and involves several covariance terms between the different commodity prices, the loan rate and the CCP:

$$\begin{aligned} V(\tilde{Y}) = {} & \sum_i Q_i^2 V(\tilde{P}_i) + \sum_i Q_i^{0^2} V(CCP_i(\tilde{P}_i)) + \sum_i Q_i^2 V(LR_i(\tilde{P}_i)) \\ & + \sum_i \sum_{j \neq i} Q_i Q_j COV(\tilde{P}_i, \tilde{P}_j) + \sum_i \sum_{j \neq i} Q_i Q_j COV\left(LR_i(\tilde{P}_i), LR_j(\tilde{P}_j)\right) \\ & + \sum_i \sum_{j \neq i} Q_i^0 Q_j^0 COV\left(CCP_i(\tilde{P}_i), CCP_j(\tilde{P}_j)\right) + 2 \sum_i \sum_j Q_i Q_j COV(\tilde{P}_i, LR(\tilde{P}_j)) \\ & + 2 \sum_i \sum_j Q_i^0 Q_j COV\left(CCP_i(\tilde{P}_i), LR_i(\tilde{P}_i)\right) \; 2 \sum_i \sum_j Q_i Q_j^0 COV(\tilde{P}_i, CCP(\tilde{P}_j)) \end{aligned} \tag{3}$$

With the variance defined, the first order condition with respect to Q_i is found by taking the derivative of the certainty-equivalent utility function (2) after substituting (3) and cleaning up terms:

$$\begin{aligned} & \frac{\partial \breve{Y}}{\partial Q_i} \\ & = P_i - C'(Q_i) \\ & \underbrace{- \alpha \left[\sum_j \{ Q_j [COV(\tilde{P}_i, \tilde{P}_j) + COV(LR_i, LR_j) + COV(\tilde{P}_i, LR_j)] + Q_j^0 [COV(\tilde{P}_i, CCP_j) + COV(CCP_i, LR_j)] \} \right]}_{\phi} \end{aligned} \tag{4}$$

The risk effects can be characterised as an add wedge in the risk-free price = marginal cost condition. The underlined term in (4), ϕ, contains all the relevant variance and covariance terms multiplied by the CARA parameter. Taking a closer look at the components of ϕ indicates that a higher covariance in prices, indicating higher variability of market revenue, reduces optimal quantity produced. The loan rate potentially adds to that variability by adding a revenue stream with its own covariance, Cov(LR,LR), that is counteracted by the negative – by design – covariance of the loan rate with prices, Cov(P,LR). Similarly with the CCP, its negative covariance with prices reduces overall variability, while the covariance term Cov(CCP,LR) is potentially positive. Covariance terms involving the CCP are multiplied by base area, while other terms are multiplied by the current output of the commodity with respect to which the covariance is taken. The producer responds to lower overall variability with greater production. This is the essence of risk aversion – lower variability is equivalent to a higher price. In general for a risk averse firm under price uncertainty C′(Q)>E(P) and output is less than in the case of certain prices.

Treating the risk effects ϕ as a simple price premium related to price variability provides a straightforward means of including these effects in the PEM. By calculating the variance and covariance terms to determine an explicit value for ϕ, the model can be recalibrated to include this element as part of the initial market equilibrium. In policy simulations, changes in the covariance terms that result from changes in policies will affect the incentive price for producers. Equation (4) yields a premium that may be calculated for each commodity in the model. The zero-profit condition in the model connects quantity supplied and price and is the natural insertion point for ϕ by simply using the incentive price implied by (4):

$$Q * (P - \phi) - \sum_i r_i X_i = 0 \tag{5}$$

The risk premium appears only in the supply side of the model – it does not impact consumer price.

To calculate ϕ an estimate of the value of the CARA parameter α is required. This parameter defines the relative importance of income and variance of income in the utility function, serving to scale the impact of risk according to the degree of risk aversion and the magnitude of income variation. Risk aversion can be quantified by the specification of a risk premium (the amount a risk-averse individual is willing to pay to avoid a fair gamble) or a probability premium (the amount above the actuarially fair amount the probability of winning a gamble must be to make the risk-averse individual indifferent between taking the gamble or not). The CARA parameter is a function of these measures of risk aversion (expressed in percent) and the standard deviation of returns – essentially the magnitude of the risk taken. Babcock, Choi and Feinerman (1993) provide the following relationship between the risk premium θ, the CARA parameter α, and the standard deviation of returns σ:

$$\theta = \frac{\ln\left[\frac{1}{2}\left(e^{-\alpha\sigma} + e^{\alpha\sigma}\right)\right]}{\alpha\sigma} \tag{6}$$

This equation has to be solved implicitly for α based on an assumed value of θ; results for $\theta = 0.01$ are shown in Table D.1. Notice that the CARA parameter increases exponentially with the value of the risk premium – higher risk premiums means the variance of income is relatively more important in (2). The CARA parameter α for the utility function in (2) can be estimated based on the variation of returns to all the commodities in PEM and a chosen value of θ. In order to calculate the CARA parameter for each year the variation in returns for the previous 8 years was used. This required revenue data back to 1979 for early years in the study period.

The second component of ϕ that needs to be calculated is the set of covariances identified in (4). The covariances of prices are calculated on the basis of the prior eight years observations, while covariances between the LR, CCP, and prices are calculated using the observed distribution of prices and the specified loan rates and target prices for each commodity. That is, using the observed mean and the calculated standard deviation of prices (based on last 8 years observations) for each year, and assuming a normal distribution, a series of 3 000 prices were drawn, and the implied LR and CCP payments calculated.[1] The covariances between these payments and prices are then calculated using these 3 000 synthetic observations.

Table D.1. **CARA parameters for 1% risk premium ($\theta = 0.01$), 1986-2008**

	CARA Parameter α	Standard Deviation of Revenue σ
1986	0.00000378	5 287.0
1987	0.00000380	5 270.1
1988	0.00000434	4 605.7
1989	0.00000413	4 838.7
1990	0.00000367	5 449.8
1991	0.00000364	5 489.2
1992	0.00000309	6 475.1
1993	0.00000319	6 275.2
1994	0.00000356	5 622.8
1995	0.00000335	5 971.1
1996	0.00000287	6 959.1
1997	0.00000278	7 190.2
1998	0.00000290	6 908.1
1999	0.00000347	5 765.3
2000	0.00000371	5 384.3
2001	0.00000584	3 422.1
2002	0.00000599	3 339.0
2003	0.00000323	6 200.3
2004	0.00000231	8 642.4
2005	0.00000203	9 851.6
2006	0.00000178	11 237.1
2007	0.00000078	25 533.1
2008	0.00000066	30 476.4

Source: OECD, *PSE Database*, own calculations.

Observed prices and payment rates are not used in this calculation as for many commodities and years, no CCP payments have been made, so a calculation based on observed values would yield a covariance of zero, indicating the programme has no impact on producers. This does not correspond with the fact that the payment has a risk-reducing effect that provides a value to producers. Consider farmers with base in wheat; while they have never received a CCP payment on the basis of wheat price, they would not be indifferent to the elimination of the CCP. The insurance effect of the programme remains valuable to them. The model therefore relies on expected values for the programme, rather than observed values that are contingent on the particular price draws observed by history.

Milk and beef do not receive CCP or LR payments, so the covariance of these programmes with respect to these commodities is zero. These covariances and the estimate of α, combined with information on base acres and production are sufficient to calculate ϕ and calibrate the model using (5). Values for ϕ can be negative when there exists a natural hedge between commodity prices that have negative covariances (Table D.3). This is true for milk and beef for some years in the study period, as livestock prices can move in the opposite direction from crop prices. The prices of the crops in PEM tend to move

Table D.2. **Covariance matrices, 2008**

Cov(Pi,Pj)	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef	**Cov(LRi,LRj)**	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef
Wheat	3 133	1 875	3 771	4 749	2 393	12 389	Wheat	0.8	0.6	1.1	2.5	0	0
Coarse grains	1 875	1 199	2 348	2 782	1 279	7 137	Coarse grains	0.6	1.4	2.5	2.3	0	0
Oilseeds	3 771	2 348	5 296	5 899	2 734	17 834	Oilseeds	1.1	2.5	19.5	15.2	0	0
Rice	4 749	2 782	5 899	8 322	3 589	25 567	Rice	2.5	2.3	15.2	73.9	0	0
Milk	2 393	1 279	2 734	3 589	3 310	12 388	Milk	0	0	0	0	0	0
Beef	12 389	7 137	17 834	25 567	12 388	112 193	Beef	0	0	0	0	0	0

Cov(Pi,LRj)	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef	**Cov(LRj,CCPi)**	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef
Wheat	–11.1	–14	–69.9	–180.4	0	0	Wheat	2.1	1.1	0.8	2.8	0	0
Coarse grains	–6.6	–10	–45.9	–104.0	0	0	Coarse grains	2.4	1.7	1.2	3.4	0	0
Oilseeds	–12.6	–18	–107.3	–223.9	0	0	Oilseeds	9.5	7.5	8.3	18.2	0	0
Rice	–15.7	–19	–107.7	–330.3	0	0	Rice	22.0	11.3	11.8	57.5	0	0
Milk	–8.1	–8	–45.3	–131.5	0	0	Milk	0	0	0	0	0	0
Beef	–35.2	–43	–335.9	–1 040.5	0	0	Beef	0	0	0	0	0	0

Cov(Pi,CCPj)	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef	**Cov(CCPi,CCPj)**	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef
Wheat	–102.5	–72.3	–62.5	–333.1	0	0	Wheat	16.7	9.2	6.4	26.7	0	0
Coarse grains	–61.7	–47.7	–40.1	–195.4	0	0	Coarse grains	9.2	8.0	5.1	16.8	0	0
Oilseeds	–121.7	–92.2	–92.1	–412.0	0	0	Oilseeds	6.4	5.1	7.3	14.6	0	0
Rice	–152.8	–104.8	–96.5	–578.3	0	0	Rice	26.7	16.8	14.6	103.7	0	0
Milk	–77.6	–46.8	–41.9	–254.6	0	0	Milk	0	0	0	0	0	0
Beef	–384.0	–256.7	–287.8	–1 767.1	0	0	Beef	0	0	0	0	0	0

Source: OECD, *PSE/CSE Database*, own calculations.

strongly together. The major component of ϕ comes from the covariance of prices – the covariances introduced by the loan rate and CCP are relatively small and make up a correspondingly small part of ϕ.

As the model is recalibrated to include ϕ, simulations related to the risk effects of programmes can be made by changing exogenously the values of the covariance terms shown in Table D.2. Setting the policy-related covariances to zero for example will eliminate any risk reducing effects of these policies, increasing the variance of returns as expressed by ϕ and thus lowering the incentive price for the producer. The loan rate and CCP programmes have two components in the model. In addition to the risk effect, there is also a direct effect when a payment is made that generates a budgetary transfer to producers. A policy simulation that reduces or eliminates these programmes would shift both of these elements. For example, the risk effects shown in Figure 2.14, Chapter 2, are calculated by comparing a "with risk effect" scenario where the budgetary transfer and all covariances related to the loan rate and CCP programme are set to zero with a "no risk effect" scenario where only the budgetary payment is eliminated.

Table D.3. **Price premium ϕ as used in PEM**

USD/tonne; % of price

	Wheat	Coarse grains	Oilseeds	Rice	Milk	Beef
1986	34.33	176.49	57.96	10.12	12.49	87.83
	32.1%	***246.0%***	***32.1%***	***6.2%***	***4.5%***	***4.6%***
1987	33.25	149.56	58.68	9.29	18.63	62.99
	31.9%	***177.6%***	***27.1%***	***4.7%***	***6.7%***	***2.8%***
1988	22.23	71.39	38.34	4.87	13.57	42.44
	15.6%	***66.9%***	***14.1%***	***3.0%***	***5.0%***	***1.7%***
1989	32.80	132.39	54.82	5.67	16.39	57.04
	23.5%	***139.7%***	***26.2%***	***3.1%***	***5.5%***	***2.2%***
1990	35.22	127.47	49.74	4.65	16.70	66.90
	35.8%	***140.1%***	***23.5%***	***2.6%***	***5.5%***	***2.3%***
1991	17.42	75.64	25.91	3.83	7.94	96.04
	15.7%	***81.1%***	***12.6%***	***2.1%***	***2.9%***	***3.3%***
1992	20.43	86.91	26.82	3.54	6.67	95.33
	17.1%	***106.4%***	***13.1%***	***2.1%***	***2.3%***	***3.5%***
1993	19.97	58.14	19.95	3.52	5.95	77.44
	16.6%	***59.4%***	***8.5%***	***1.7%***	***2.1%***	***2.7%***
1994	9.83	37.84	11.33	0.41	1.12	25.20
	7.7%	***42.4%***	***5.6%***	***0.2%***	***0.4%***	***1.0%***
1995	9.93	33.63	11.84	1.71	–2.18	–10.10
	5.9%	***26.3%***	***4.8%***	***0.8%***	***–0.8%***	***–0.4%***
1996	17.03	52.38	20.48	3.09	6.11	–18.70
	10.8%	***49.3%***	***7.6%***	***1.4%***	***1.9%***	***–0.8%***
1997	19.94	52.25	26.12	3.41	7.06	–19.32
	16.0%	***54.3%***	***11.0%***	***1.6%***	***2.4%***	***–0.8%***
1998	27.99	77.77	38.85	2.91	–6.70	–4.36
	26.7%	***94.2%***	***19.6%***	***1.5%***	***–2.0%***	***–0.2%***
1999	34.76	109.98	50.47	5.87	–16.58	2.62
	32.6%	***133.7%***	***24.1%***	***3.3%***	***–5.2%***	***0.1%***
2000	45.12	148.26	70.02	7.30	–7.20	–1.22
	40.9%	***175.9%***	***32.7%***	***3.7%***	***–2.6%***	***0.0%***
2001	64.51	220.73	108.74	11.71	–9.96	–27.82
	61.0%	***266.0%***	***52.6%***	***6.8%***	***–2.9%***	***–1.0%***
2002	40.97	142.47	99.12	8.93	–4.08	–26.42
	31.2%	***154.7%***	***48.7%***	***5.2%***	***–1.5%***	***–1.0%***
2003	23.23	61.03	66.57	3.38	–5.46	37.65
	18.4%	***63.4%***	***24.7%***	***1.4%***	***–1.8%***	***1.2%***
2004	12.19	30.71	53.77	2.35	0.08	57.31
	9.6%	***33.7%***	***25.1%***	***1.3%***	***0.0%***	***1.8%***
2005	11.25	15.76	44.05	2.81	8.01	69.10
	8.9%	***16.7%***	***21.1%***	***1.6%***	***2.4%***	***2.1%***
2006	15.62	47.92	47.45	5.14	3.84	73.16
	10.0%	***39.9%***	***20.0%***	***2.3%***	***1.3%***	***2.3%***
2007	43.22	177.48	82.90	8.84	63.42	59.26
	18.1%	***107.2%***	***22.3%***	***3.1%***	***15.0%***	***1.7%***
2008	65.94	190.67	99.66	13.51	71.22	55.39
	26.4%	***123.8%***	***29.1%***	***3.7%***	***17.6%***	***1.6%***

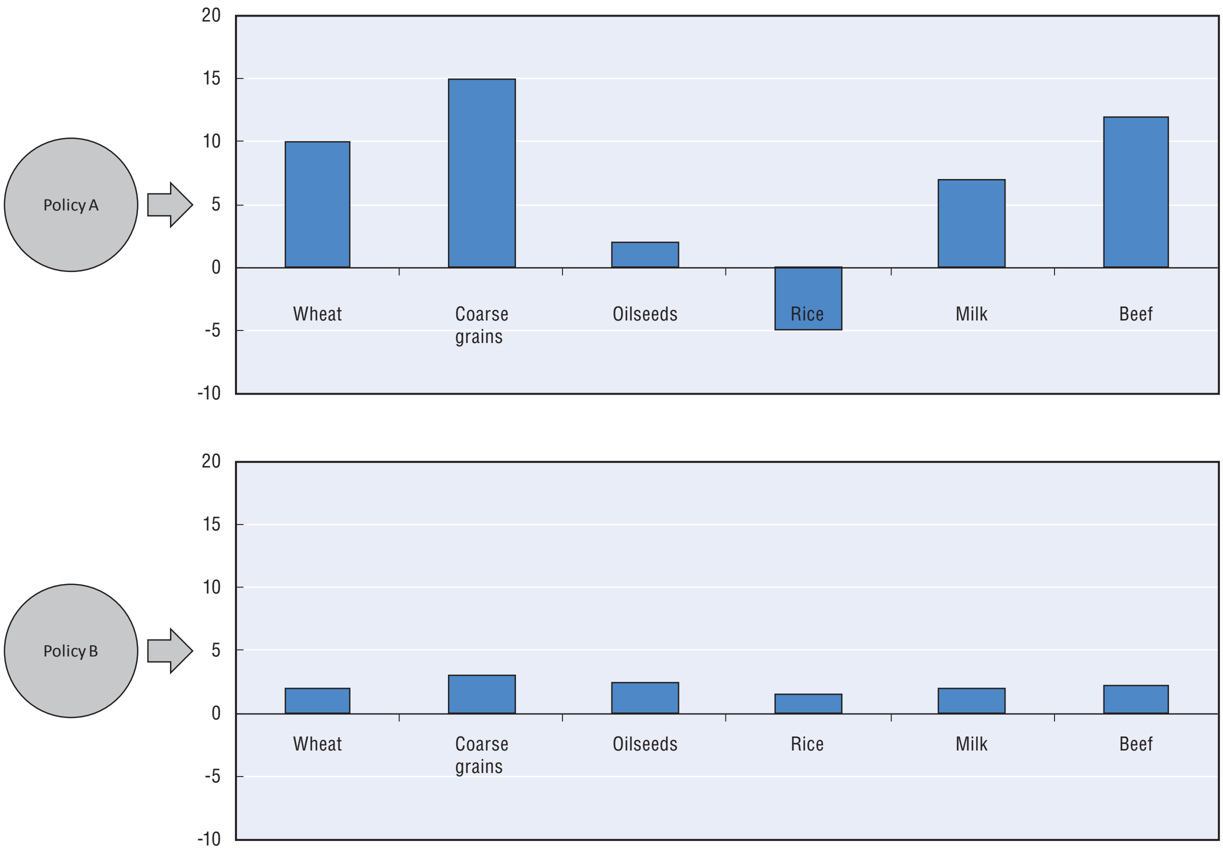
Source: OECD, *PSE/CSE Database*, own calculations.

D.2. Calculation of indices of support

Support indices used in the report, termed iso-production, iso-trade, or iso-income, are measures of the impact of the entire policy set on those outcomes. These are calculated by finding the level of MPS support that generates the same impact on the outcome of interest as does the existing policy set. This level of MPS serves as an index measuring the impact of the policy set on this outcome.

Consider two policies, A and B, which have different impacts on production as estimated by the model (Figure D.1). The different impacts will have to do with the level of support provided by each policy and how they are implemented. For example, Policy A may be deficiency payments offered to different commodities at different rates. Policy B may be a broad payment to all farms, perhaps not requiring production. How do we compare the effects of these two polices? Policy A has a generally larger impact, but not always, and in some cases may have a negative impact. Policy B has a generally smaller but more consistent impact.

Figure D.1. **Hypothetical impacts of two policies**



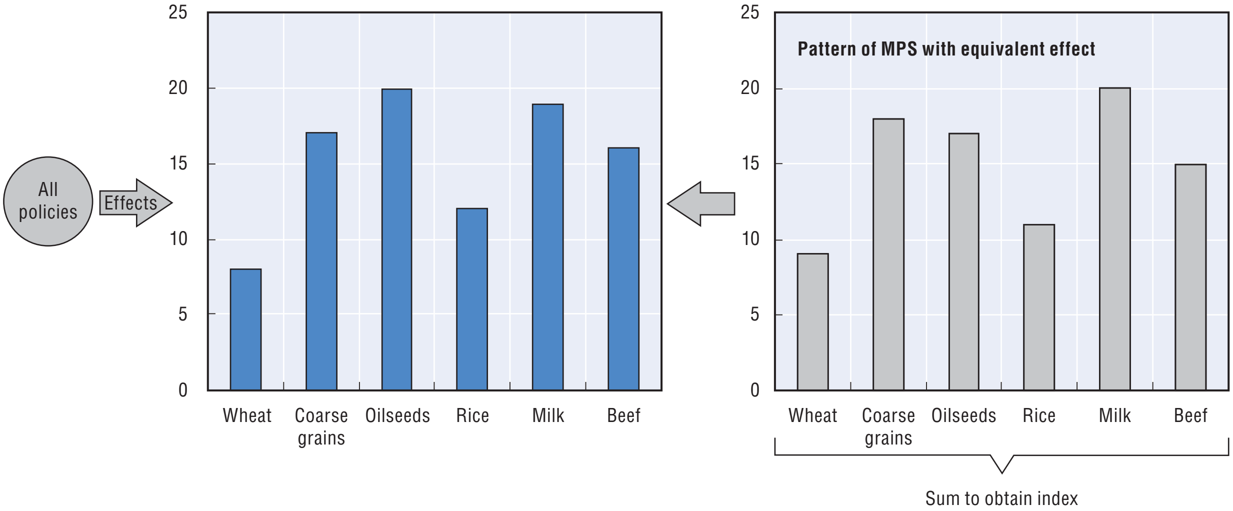
Formal comparison requires a way to describe the patterns of impact shown in Figure D.1 in a way that is consistent for all years and all countries. This may be done by choosing another policy to become a basis for comparison, and apply it such that it reproduces the same pattern of impact as for Policy A. Specifically, the amount of MPS is found that, when applied to wheat will have the same production impact on wheat as does

Policy A, the amount of MPS for coarse grains, and so on. This yields a quantity of MPS for each commodity such that, if they were applied in the model, would result in the same pattern of production changes as was the case for Policy A. Importantly, this does not change how Policy A is represented in the model nor its effect – it is simply a means to characterise the result of the policy. If this process is repeated for Policy B, then the amount of MPS required to reproduce its impact *versus* that for Policy A becomes a way of comparing the two policies.

Now imagine that Policy A, instead of being a single policy, represents the entire policy set in the country, and the impacts shown in Figure D.1 show the net impact of all the policies operating together. The exact same procedure may be done, finding the level of MPS for each commodity such that the same overall result is obtained. Simply summing up the amount of MPS for each commodity yields a total level of MPS that serves as a measure of the impact of the policy set (Figure D.2).

The key analytical questions motivating this analysis and guiding the setup of simulation experiments is "*how have policies changed over time?*" and "*what has been the effect of these changes?*". This approach of finding a level of MPS that represents in some way the impact of the policy set is a way to answer these questions. However, in order to answer these questions, one must first identify what is the "policy effect" that is being measured. The example above discussed the production impact, but one could choose as well trade, welfare or other possible impacts. In each case, the pattern and size of impact will be different, and therefore so will the level of MPS that reproduces it. There is no level of MPS that can replicate all impacts at the same time, so this process must be repeated for each policy indicator of interest. Here, three indicators are produced, one based on net trade, one on production and one on farm income, called respectively: *Iso-trade, Iso-production* and *Iso-farm income*.

Figure D.2. **Hypothetical policy set**

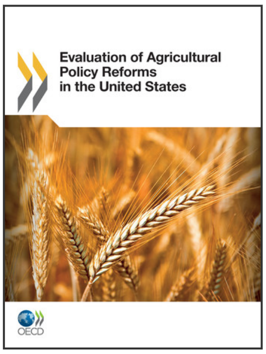


How is the value of this index calculated in practice? As a first step, either the volume of production, value of trade, or farm income from policy is held fixed in the model. In the second step, the rates of market support for each commodity are required to adjust in order to hold constant whatever was chosen in the first step. That is, if one were to "take away" a little support of one kind in the model, the model will "add back" enough MPS to hold constant whatever was chosen in the first step. The third step is to impose a policy 'shock' on the model eliminating the entire policy set. Now, as all support is removed in this shock, the MPS in the model will adjust to hold fixed the policy outcome of interest. How much MPS must change serves as the measure of the effect of the policy set, the iso-index.[2] While the result is precisely an index of effect, it can also be interpreted as a "composition adjusted" PSE, as shall be seen below.

When expressed as a percentage of the level of the PSE, the index can be interpreted as measuring the production-neutrality of the PSE, or its efficiency in transferring income. Taking the case of transfer efficiency for example, if the index indicates that it requires 200% of the level of the PSE in MPS to maintain the same level of farm income, this means that the current policy set is twice as effective as MPS in transferring income to producers. A smaller number indicates lower transfer efficiency. A value of 100% would mean that the current policy set and MPS alone are equally efficient at transferring income. Equally for production distortion, if the index is 50% of the PSE, this means the current policy set is only half as distorting as MPS.

Notes

1. The standard deviation of prices was calculated using the previous eight years' data, but the mean price was calculated using the past three years' data, under the assumption that farmers do not use prices in the far past to form expectations.
2. In the case of production and trade, the pattern of production and trade for each commodity must be the same before and after the policy shock. Farm income in the model accrues from returns to several different inputs that are owned by the household. In order to hold constant farm income, equations representing the change in producer surplus for all these elements are introduced, and their total for each commodity is held constant. Thus the distribution of overall farm income by commodity is maintained, but the distribution of the various *sources* of income may change.



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