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DO DIRECT PAYMENTS HAVE INTERTEMPORAL EFFECTS ON U.S. AGRICULTURE?

Terry Roe
University of Minnesota

Agapi Somwaru
USDA/ERS

Xinshen Diao
International Food Policy Research Institute

Trade and Macroeconomics Division
International Food Policy Research Institute
2033 K Street, N.W.
Washington, D.C. 20006, U.S.A.

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Abstract

The question whether production flexibility payments to farmers are likely to be minimally trade distorting is considered in an inter-temporal and economy wide context. Our contribution lies in showing the circumstances, over time, under which a minimally trade distorting result is likely to obtain. If agricultural capital markets are complete, we find that payments have long run effects on land values and land rental rates, but they have no effect on production. If capital markets are not complete, we find production effects, but they are small (0.2 percent) in the short run and disappear in the long-run. The only permanent effects are on land rental rates and land values that increase by about 10 percent in the short run tapering off to slightly above 8 percent in the long run.

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1.The Issue

The 1996 Federal Agriculture Improvement and Reform (FAIR) Act introduced new instruments of producer supports, including fixed payments, known as "production flexibility contract" payments (PFC), tied to historical "base" acreage and yields[1]. The general issue here is whether the PFC payments to farmers have inter-temporal effects on resource allocation and production to the extent that they may not be in compliance with the Uruguay Round Agreement (URA) on Agriculture's "minimally trade distorting" criteria for "Green Box" designation. These payments have been viewed as decoupled from production, and thus designated "Green Box" which, in contrast to "Amber Box" policies, exempts them from payment limits under the WTO. The question is not whether PFC payments change the consumption patterns of recipients of program payments, which they almost surely do, nor necessarily whether payments change their investment patterns or labor -- leisure choices. Instead, the question is whether these payments have effects on agricultural markets. The purpose of this paper is to contribute to this debate by considering the inter-temporal effects of decoupled payments on market behavior.

We begin with a discussion of basic concepts to help clarify the nature of market linkages between the taxpayers and recipients of PFC payments. The second section reports the results from calibrating to U.S. data a simple inter-temporal model of the Ramsey variety[2] with adaptations to account for sector-specific factors of production, multiple sectors, and segmented capital markets.

We suggest that if markets are complete, and taxed and recipient households have similar preferences, then PFC effects on market outcomes, even over time, likely meet the "minimally trade distorting" criteria. A possible exception is the indirect effects on land values that can potentially increase farmer's access to credit. In the real economy, farmers may hold expectations about the nature of future farm programs that can couple PFC payments to production decisions. Further, markets are not complete due, for example, to the presence of fixed costs, absent and incomplete risk markets, and the fact that agricultural capital markets differ from capital markets for the corporate manufacturing and service sectors of the economy. For these and other reasons, this paper contributes to the debate as opposed to answering the question as to whether PFC payments are "minimally trade distorting."

[1] See Orden et al., 1999, for a discussion of these programs.
[2] See Barro and Sala-I-Martin, 1995, chapters two and three for the basic features of the model.

2. Basic Concepts

Over time, the recipients of transfer payments are likely to consume more goods, including leisure, and increase savings. However, whether these individual decisions affect resource allocation and supply at the market level depends on the behavior of those that are taxed to provide the transfer.

The reason is that investment and consumption effects of those taxed can be exactly offset by recipients so, post transfer, resource allocation and production at the market level are unaffected. In principle, this outcome is expected to prevail when capital markets work perfectly in allocating savings to investors in all sectors of the economy, risk markets are complete in the sense of opportunities to insure against future contingencies, and when the representative rural household (or recipient of the transfer) has beliefs and consumption – savings preferences that are indistinguishable from other households. Under these circumstances, the wealth effect of a transfer on recipient behavior is offset by the negative wealth effect of those taxed to provide the transfer. If individuals vary in their beliefs and consumption – savings preferences, then direct payments can, in principle, have market level effects because the decrease in savings of individuals taxed can depart from the increase in savings of recipients[3].

Of course, in real economies ideal market conditions do not prevail. Should the lack of ideal conditions render what is in principle a decoupled instrument an Amber Box designation? A policy instrument might cause trade distortions due to market failures, which if corrected, could render a Green Box designation. This argument has received some acceptance in trade negotiations. For example, public support of agricultural R&D has a Green Box designation, presumably because of the widely recognized fact that market forces alone lead to under investment. Still, other market inefficiencies are endemic to even the most advanced economies. These include information, risk and capital markets.

As Stiglitz (1985, p.21) argued years ago, markets fail in the optimal provision of information, and "theory is not robust to slight alterations in informational assumptions." Empirical estimates of the value of information in risky markets by Antonovitz and Roe (1986) support subsequent work that agent's subjective forecasts of future events, i.e., the importance of information, dominates the small effects of risk preferences on production decisions. From the time of Sandmo (1971) for the case of the individual risk averse agent, and Hirshleifer (1989) for the case of the market, it has been known that individual and market behavior under risk is affected by specific features of capital markets, such as the presence of liquidity constraints. Other forms of market failure include fixed costs, a point raise by Chau and de Gorter (2000). Further, the presence of other Amber Box policies help also to place the question of whether PFC payments are minimally trade distorting in the world of "second best" (Mas-Colell, A. M. Whinston and J. Green, 1995,

[3] More specifically, if individual preferences are identical but non-homothetic, then marginal propensities to consume and save can differ among individuals of different income levels. In this case, the behavior of recipients can differ from that of those taxed with the result that transfer payments can affect market allocations over time.

p. 710). Then, policies that are viewed as trade distorting in an ideal economy can be welfare enhancing in a real economy. In our view, these conditioning factors should, in principle, be evaluated when analyzing whether an instrument is likely to be minimally trade distorting.

In perhaps the most serious econometric analysis to date, Goodwin and Mishra (2002, p. 17) conclude from their analysis of the Agricultural Resource Management Survey data that PFC payments seem to have modest effects on production for most farms. The mechanism through which this occurs, and how the conditioning factors mentioned above affect this result, is difficult to address with these data. Their analysis also suggests that effects of PFC payments on the decision to purchase land are positive, and statistically significant. This may suggest that, all else equal, farmers have a preference for investing the incremental increase in their savings due to PFC payments in agriculture relative to the rest of the economy.

We wish to investigate two additional factors that may cause PFC payments to distort markets. One is the fact that agricultural capital markets differ from non-farm capital markets. The other is that payments are linked to land that was formerly planted to program crops. We now turn to a discussion of these two issues.

Farmers cannot issue securities or bonds to finance farm activities as can corporations, and instead, must rely more heavily on land and other assets for collateral. Corporations tend not to invest directly in the production of program crops, although contract production in broiler, egg and hog production is common. Thus, the effect on individuals outside of agriculture that are taxed can have different capital market effects than on recipients in agriculture. This effect might be greater if, all else equal, farmers face liquidity constraints or if they have a preference for investing in agriculture the proportion of PFC payments not allocated to consumption, as the results of Goodwin et al seem to suggest. The difference in these markets does not imply that returns to capital in agriculture departs from returns in other sectors of the economy, at least in the longer run, since farm households also invest in stocks, bonds and other economy-wide financial instruments (see Collender and Morehart, 2002, for a discussion of farm portfolios). In the short run, the increase in agriculture's capital stock should have output, and hence market effects. The question is whether these effects are large.

A related issue is that direct payments are targeted to land formerly planted to program crops. This linkage is important because land is an asset, and as such, individuals should, in principle, attempt to equate the rate of return to a unit of securities and other financial instruments to: (a) the rate of return per dollar invested in a unit of land plus (b) the gain (loss) due to the change in the price of land. This condition is expected to prevail among assets when capital markets work perfectly in maximizing returns to savings[4]. Since direct payments are targeted to land formerly planted to program crops, the cash rental rate that a tenant is willing to pay for an acre of land is affected by the payment, and consequently, so is the price of land. A change in the price of land affects its value as an asset, which affects wealth, and can consequently affect investment and consumption

[4] Barro and Sala-I-Martin, 1995, page 99, discuss the implications of this condition for the case of capital.

behavior. Since land is used as collateral, payments can, in principle, increase farmer's access to credit. In another recent paper, Goodwin et al (2002) find that PFC payments have small effects on land values, ranging from 2 to 6 percent in the Northern Great Plains and Corn Belt regions. Our analysis suggests even larger effects.

3. Analysis

First, we evaluate Minnesota data on land values and government payments to see if any linkage is suggested. Then, since the above discussion implies that an economy-wide approach is required to assess whether direct payments are likely to affect resource allocation and production, we report the results from an inter-temporal multi-sector model of the U.S. economy. Savings are endogenous, and assets are aggregated into three broad categories, capital inside and outside of agriculture, and land. We fit two versions of the model to data. One version presumes that capital market for agriculture and the rest of the economy are perfectly integrated so that any differences in their short run rates of return to capital and land are instantly arbitraged to zero. In the second version, we relax this assumption so that the arbitrage condition only holds in the longer run. Otherwise the models are identical. Households are presumed to hold identical – homothetic preferences over their consumption of goods and services. Most of the model's parameters are based on the year 1997, while rates of growth in total factor productivity, growth in the U.S. labor force, and selected other parameters are taken from other research (see Roe, 2001 for an overall discussion of the basic framework, and the Appendix for a sketch of the analytical model). The model is found to reproduce some of the key outcomes observed for the actual economy for the years 1997 to 2001.

3.1 Land values appear to be linked to government payments

Using data from statistical reporting "districts" in Minnesota for the period 1994 to 2000, the average change in the value of land planted to crops (over 8 million acres), and the change in total government payments associated with these lands are charted in Figure 1. Nominal land values have appreciated at the rate of about 6.6 per cent per year. The years in which land appreciation was the highest were the two years following the enactment of the 1996 farm bill.

The positive correlation shown by the chart is confirmed by a simple regression analysis. Analysis suggests that between 1994 and 2000, a ten percent change in government payments tends to cause, a 3.24 percent change in land values. Since the chart shows this positive correlation persists after the enactment of the 1996 farm bill, we conclude that transfer payments affect land values. This appreciation affects wealth and can consequently affect investment and consumption behavior. Since land is used as collateral, payments can, in principle, increase farmer's access to credit. This possibly important link is not captured by our simple model.

3.2 Effects of PFC payments on resource allocation and production are surprisingly small

We make the assumption that PFC payments, equal to $6.112 billion in 1997, are made to farmers in each period of time from 1997in perpetuity. Thus, the results from this exercise should be interpreted as suggesting the *directional* effects of direct payments as opposed to placing undue emphasis on magnitude. All of the reported results are compared to the base. The base is the path of the economy in the absence of direct payments to farmers.

The case of integrated capital markets

This analysis presumes that investors allocate savings at each instant of time so as to arbitrage away any differences in rents to the three assets. Effectively, at each instant of time, the rate of return to agricultural capital is equated to the returns to capital in the rest of the U.S. economy. Since preferences are identical, consumption and investment behavior of the recipients of PFC payments are exactly counter balanced so that no net resource allocation effects are observed. This is the case where payments are completely decoupled, even inter-temporally. However, since payments are linked to land planted to program crops, land values are affected, thus supporting the result reported in Figure 1, and the work of Goodwin et al. (2002). The result is shown in Figure 2. We find that the $6.112 billion dollar payment, in the short run, causes land values to exceed their values in the base run by almost 9 percent, and then taper off to about 8.3 percent above their long-run base value.

These effects are due solely to payments. Competition for land, and thus a right to the transfer, causes renters to pay higher rates to owners. If the land is sold, the buyer is willing to pay more if the payment remains tied to land. Since the base run also accounts for growth in agriculture's total factor productivity and capital deepening over the period, this reported rise in land values is due only to government payments.

Of course, PFC payments and the rise in land values change recipient consumption patterns and level of assets (Figure 3). Our results suggest that in the short run, asset values of recipient households rise by about two percent above their base values, due mostly to the rise in land values. Most of the payments are spent on final goods. This proportion rises over time while the proportion saved falls. Total consumption expenditures are about 0.8 percent higher than expenditures in the absence of transfers. The rise in recipient household asset holdings should also increase their access to credit. If liquidity constraints are binding, then this aspect of PFC payments may not in fact be decoupled.

The case of segmented capital markets

The analysis above reproduces the directional effects that Goodwin et al. (2002) find on land values, but it does not reproduce changes in production. We repeat the analysis, but no longer allow agricultural capital markets to be perfectly arbitraged with capital markets in the rest of the economy at each instant of time, although they are in the longer run. Within agriculture, and within the rest of the economy, all capital rents are arbitraged away.

Returning to Figure 2, we see for this case that the value of land exceeds the value of land when markets are perfectly arbitraged by roughly one percent in the short run. The reason for this result can be seen from Figures 4 and 5.

Figure 4 shows the percent change from the base of PFC payments on the capital rental rate outside of agriculture, on the rental rate in agriculture and, more generally, on the index of wages and other prices. The results show that, within the first ten years of payments in equal amounts, the rental rate on agricultural capital declines by a modest 0.1 percent below the capital rental rate observed in the base solution. This rate equaled 6.48 percent in year five. The effect on the capital rental rate outside of agriculture, and the price index of goods, is almost imperceptible. Notice that even though the direct payments in equal amounts continue throughout the period, agriculture's capital rental rate slowly converges to that of the rest of the economy. In other words, in spite of the presumed differences between agriculture and the rest of the economy, in the long run, direct payments do not distort the rate of return to capital in agriculture.

The decline in agriculture's rate of return to its capital stock affects the price of land via the market clearing condition for maximizing returns to savings. This condition amounts to equating the rate of return to agriculture's capital stock to the ratio, return to land including PFC payments divided by the price of land, plus the rate of change in the price of land, or as follows:

$$r(t) = \frac{\pi(t)}{P(t)_{land}} + \frac{\dot{P}(t)_{land}}{P(t)_{land}}$$

where r is the rate of return of land, π is the rental rate of land, P_{land} is the price of land while $\dot{P}_{land}$ is the change in price of land. The "solution" to this differential equation yields the evolution in the price of land over time. As the interest rate falls, all else constant, the rental rate of land rises due to capital deepening, which in turn causes the value of land to rise. Since this analysis captures farmer's preferences for investing some of their savings in agriculture relative to the rest of the economy,[5] all else constant, the diminishing returns to the growth in agriculture's capital stock (shown in Figure 5) causes the rate of return to decline and land prices to rise to a greater extent than in the case where capital markets are presumed to be *non-segmented* (Figure 2).

Figure 5 shows why direct payments cause the rental rate of agricultural capital to decline. In early periods, farmers tend to allocate a relatively larger proportion of their payments to investment in agricultural capital than in latter periods. In the short run, the amount of capital invested in agriculture reaches a modest maximum of about 0.25 percent of the capital stock that would otherwise be accumulated (i.e., relative to the

[5] Or equivalently, if PFC payments help to relax the otherwise binding liquidity constraints, farmers will tend to increase agriculture's capital stock at a slightly higher rate.

base). As additional capital investments lead to diminishing returns to capital stock, farmers save less and spend a larger and larger share of their PFC payment on final goods. In the long run, the amount of capital employed in agriculture is equal to the amount that would be employed in the absence of transfer payments, i.e., payments do not affect the long-run level of capital stock in the sector. Nevertheless, the half-life of the adjustment is about twenty years because the depreciation rate for buildings and structures is relatively small. The effect on capital stocks in the rest of the economy is almost imperceptible.

As farmers increase the level of capital stock, more labor hours, relative to the base, are also allocated to production. This is shown in Figure 6. The relative increased hours accrues from a decrease in leisure time and/or an increase in hired labor.[6] Again, the magnitude is relatively small. However, as Figure 7 shows, PFC payments encourage the employment of capital relative to labor. That is, the capital to labor ratio rises, relative to the base, because the presumed preference for investing in agriculture cause the rate of return to capital to fall slightly relative to the change in wages. The change in this ratio encourages an increase in the substitution of capital for labor relative to the base. In the long run, the ratio converges to the level expected in the absence of payments.

Finally, do the resource re-allocation effects of PFC payments affect aggregate agricultural production? Figure 8 suggests that U.S. agricultural production rises by a maximum of about 0.18 percent of its base value in the short run, and then in the longer-run, returns to levels that would prevail in the absence of payments. That is, even if payments are made into the indefinite future to farmers at approximately the levels of 1997, they have no long-run effect on production. The effects that prevail into the long run are the elevated price of land (Figure 2), and land rental rates (Figure 8).

4. Conclusions

The general question addressed is whether PFC payments to farmers are likely to cause market effects that are in excess of what might be termed “minimally trade distorting.” We consider this question in an economy-wide context because the market effects of those taxed to provide the transfer might just offset the market effects of the recipients. If this result obtains, PFC payments can be thought of as an efficient policy instrument to transfer resources from one segment of the population to another with no dead weight losses, and hence minimally trade distorting. Since the real economy is obviously complicated and encumbered with incomplete markets that makes this a complex question, our contribution lies in showing the circumstance, over time, under which a minimally trade distorting result is likely to obtain, and for the case where capital markets are not complete and/or liquidity constraints prevail in agriculture, just how distorting might these payments actually be.

[6] Since leisure is typically found and treated here to be a normal good, the combination of wealth and price effects leave the average level of leisure consumed by farmers to be virtually unchanged. The slight increase in labor, relative to the base, comes from the labor market. Nevertheless, in absolute terms, in all of the analysis, there is an out migration of labor from agriculture.

We find empirical evidence, using data from Minnesota farms, to support the notion that direct payments to farmers affect land prices, a result obtained recently by others using a broader more comprehensive data set (see also USDA/ERS, 2001a). Our economy-wide analysis finds that if agricultural capital markets are perfectly integrated with capital markets in the rest of the economy, and if the taxed and recipients hold identical and homothetic preferences over goods and services, then the key effects of payments over time are to increase the value of land by about 8 percent, and of course, to increase the wealth and expenditures on final goods of program recipients. None of these effects are trade distorting. The exception, which we do not investigate, is that land is a collateralizable asset, and as such, it potentially provides farmers access to more credit than would otherwise be the case.

If we presume that farmers, all else constant, prefer to invest in agriculture the increment of the PFC payments not spent on consumption, which they may due for any number of reasons including the presence of liquidity constraints, then we find some evidence that payments cause resource allocation and output effects. But, these effects are small, and they only persist in the short run.

In this case, in the short to intermediate run, direct payments tend to cause capital deepening, to increase the employment of labor, and to increase agricultural output. However, these effects are extremely small. They cause aggregate agricultural production to rise by less than 0.2 percent in the short run. In the long run, payments cause no resource allocation and output effects. The only long-term effect of payments is to increase land values and land rental rates.

We conclude that direct payments are a relatively efficient policy instrument for transferring income from the rest of the economy to farmers, efficient in the sense that they have relatively small effects on agricultural resource allocation and production. As other analyses have shown, for example USDA/ERS 2001b, instruments affecting market access, export subsidies and farm support that directly influences farmer's incentives are far more “distortionary” and thus far less efficient instruments to transfer income to farmers.

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Appendix

A.1 The Analytical Model

The analytical model underlying the results presented in the various figures is briefly sketched here. No comparative static results nor proofs of existence are presented. The basic model is presented first, followed by a discussion of the two adaptations to account for PFC payments, and PFC payments in the presence of segregated capital markets.

A.1.1 The Environment

The model depicts an open economy in which agents consume and produce at each instant of time a manufacturing good, an agricultural good and a home good. The manufacturing good can also be allocated to capital. The agricultural and manufacturing good can be traded internationally at given prices, p_m, p_a. Labor services are not traded internationally and domestic residents own the entire stock of domestic assets. The home good is only traded in the domestic economy at endogenously determined price p_s. These goods are indexed, $j = m,a,s$, respectively. Households are of two types, indexed $i = u,r$. They may be thought of as denoting urban households that do not own land, and other mostly rural households that own land. The only feature distinguishing type is their endowments of labor, and the assets capital and agricultural land. Their utility functions describe identical preference relations. Households purchase goods C_{ij}, consumption, and earn income from providing labor services L_i in exchange for wages w earn interest income at rate r on capital assets A_i and receive rents π_i from agriculture's sector specific resource, land T. The manufacturing and home good sectors employ labor and capital services while in addition, agriculture employs the services of land. Two basic versions of the model are considered, one in which the arbitrage condition between assets is presumed to hold, and another where the market for agricultural capital can clear at a rate of return different than the capital employed in the manufacturing and service sectors of the economy.

Firms

The manufacturing and home good sectors $(j = m,s)$ employ constant returns to scale technologies that, at the sector level, can be expressed as

$$Y(t)_j = F^j\left(A(t)L(t)_j, K(t)_j\right), j = m,s \tag{1}$$

where labor productivity grows at the exogenous rate x,

$$A(t) = e^{xt}$$

Omitting the (t) notation, except for emphasis, it is convenient to express the production functions (1) in efficiency units per worker (or units per effective worker) as follows:

$$\hat{y}_j = \frac{Y_j}{A(t)L} = l_j f^j\left(\hat{k}_j\right) = \frac{L_j}{L} F^j(1, \frac{K_j}{A(t)L_j}) \tag{2}$$

Output $\hat{y}_j$ is now expressed in units per effective worker in the economy where L is total labor supply, l_j is the share of total labor employed in sector j and $\hat{k}_j$ denotes the amount of capital stock per effective worker employed in sector j. For purposes here, the technologies are assumed to satisfying the conditions

$$\frac{\partial f^j\left(\hat{k}_j\right)}{\partial \hat{k}_j} \to \infty \ as \ \hat{k}_j \to 0 \ and \ \frac{\partial f^j\left(\hat{k}_j\right)}{\partial \hat{k}_j} \to 0 \ as \ \hat{k}_j \to \infty, j = m, s \tag{3}$$

Agriculture's sector level technology is taken to be CRS in all of its arguments, although land, T which can be rented among farmers, is assumed to be specific to the sector. The technology

$$Y(t)_a = F^a(A(t)L_a, K_a, A_a(t)T)$$

can be expressed in per capita terms as

$$\hat{y}_a = l_a f^a(\hat{k}_a, \hat{T}_a) \tag{4}$$

where $l_a = L_a / L$ is the share of total labor employed in agriculture and land, in effective units per worker in agriculture, is denoted by $\hat{T}_a = A_a(t)T / A(t)L_a$. Thus, in addition to exogenous growth in labor's productivity at the same rate as other sectors, $A(t)$, land's productivity can also grow exogenously as determined by[7]

$$A_a(t) = e^{\gamma t}$$

As above, (4) satisfies (3) for $j = a$ and

$$\frac{\partial f^j\left(\hat{k}_a, \hat{T}_a\right)}{\partial \hat{T}_a} \to \infty \ as \ \hat{T}_a \to 0 \ and \ \frac{\partial f^j\left(\hat{k}_a, \hat{T}_a\right)}{\partial \hat{T}_a} \to 0 \ as \ \hat{T}_a \to \infty$$

Households

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[7] Thus, the framework allows growth in agriculture's total factor productivity (i.e. Solow's residual) to equal or exceed that of manufacturing and services, as has been found in other studies.

For reasons that are apparent later, it is useful to also express households' choice variables in efficiency units. The typical *i-th* household's utility from consuming the sequence $\{\hat{c}_{im}, \hat{c}_{ia}, \hat{c}_{is}\}_{t=0}^{t=\infty}$ is expressed as a weighted sum of all future flows of utility

$$\int_{t=0}^{t=\infty} \frac{u(\hat{c}_{im}, \hat{c}_{ia}, \hat{c}_{is})^{1-\theta} - 1}{1-\theta} e^{(n-p)t}\, dt \tag{5}$$

where goods, $\hat{c}_{ij} = C_{ij} / A(t)l_i$, are expressed in efficiency units per household member. The number of members are assumed to grow at the exogenously given positive rate *n*,

$$l_i = e^{nt}, \quad i = u, r$$

and to discount future consumption at the rate $\rho > 0$. The elasticity of intertemporal substitution is given by $1/\theta$, where $1 \geq \theta > 0$. For the purpose of this analysis, we specify a constant returns to scale (CRS) Cobb-Douglas form of $u(\hat{c}_{im}, \hat{c}_{ia}, \hat{c}_{is})$, and normalize the number of household members in such a way as to equal the number of workers.

Each household's flow budget constraint expresses savings $\dot{A}_i$ at an instant of time as the difference between income and expenditure E_i on goods. The urban household's flow budget constraint is

$$\dot{A}_u = wl_u + rA_u - E_u \tag{6}$$

where A_u denotes total household assets. Since capital assets are not traded internationally, $A_u = K_u$ *and* $\dot{A}_u = \dot{K}_u$. Expressing this constraint in terms of units per effective household member/worker, we obtain[8]

$$\dot{\hat{k}}_u = \hat{w} + \hat{k}_u(r - x - n) - \hat{E}_u \tag{7}$$

where $\hat{w} = w / A(t), \hat{k}_u = K_u / A(t)l_u$ and $\hat{E}_u = E_u / A(t)l_u$

The rural household's flow budget constraint is

$$\dot{A}_r = wl_r + rA_r + \pi T - E_r \tag{8}$$

where π is the land rental rate. In terms of units per effective household member/worker, we obtain

[8] This result follows from solving $\dot{\hat{k}}_u = \frac{d}{dt}(\dot{K}_u / Al_u)$ for K_u / Al_u, recognizing that $\dot{A} / A = x$, and $\dot{l}_u / l_u = n$, and substituting the result into the budget constraint.

$$\dot{\hat{k}}_r = \hat{w} + \hat{k}_r(r - x - n) + \pi\hat{T} - \hat{E}_r \tag{9}$$

where $\hat{T} = T / A(t)l_r$.

Household expenditure at an instant of time is defined in the typical way as

$$\hat{E}_i = \mu(p_m, p_a, p_s)\hat{c}_i \equiv \underset{\{c_{ij} \geq 0\}}{Min}\left\{\sum_j p_j \hat{c}_{ij} \mid \hat{c}_i \leq u(\hat{c}_{im}, \hat{c}_{ia}, \hat{c}_{is})\right\}$$

Behavior of households and firms

Households choose positive values of the sequence $\{\hat{c}_{im}, \hat{c}_{ia}, \hat{c}_{is}\}_{t=0}^{t=\infty}$ to maximize (5) subject to their respective budget constraint (7) or (9) the stock of initial assets $\hat{k}_i(0)$, $\hat{T}$, and a limitation on borrowing. The first order conditions obtained from the present-value Hamiltonian yield the following Euler equation

$$\frac{\dot{\hat{E}}_i}{\hat{E}_i} = \frac{1}{\theta}(r - \rho - x),\ i = u, r \tag{10}$$

describing the path of expenditures over time for each household. If at an instant of time returns to capital services are relatively high, $(r - \rho - x) > 0$, the household forgoes expenditures $\hat{E}_i$ to accumulate assets for future consumption, the magnitude of which depends on the elasticity of inter-temporal substitution, $1/\theta$. In the long-run, we expect $(r - \rho - x) = 0$. The transversality condition places a limit on borrowing and assures that the maximand is bounded,

$$\lim_{t \to \infty}[\nu(t)_i \hat{k}_i(t)] = 0$$

where the costate variable $\nu(t)_i$ is the present value shadow price of income.[9]

Competition in factor markets among firms in manufacturing and services implies that the cost function for each sector $j = m, s$ is given by

$$c^j(\hat{w}, r)\hat{y}_j \equiv \underset{(l_j, \hat{k}_j)}{Min}: \left\{l_j\left(\hat{w} + r\hat{k}_j\right) \mid \hat{y}_{j\,j} \leq l_j f^j(\hat{k}_j)\right\}$$

where, as above, $\hat{w} = w / A(t)$ is the effective wage rate.
Competition among firms in agriculture implies that gross returns are just sufficient to cover total factor cost, including returns to land. In this case, the sector's GDP function,

[9] See Barro and Sala-I-Martin, 1995, p. 63 for the derivation of the Euler condition and the transversality condition.

in units of effective total labor, can be expressed as:

$$\hat{\pi} = \pi(p_a, \hat{w}, r)\hat{T} \equiv \underset{\{l_a, \hat{k}a\}}{Max}\, l_a \left\{ p_a f^a(\hat{k}_a, \hat{T}_a) - \hat{w} - r\hat{k}_a \right\}$$

where $\hat{T} = A_a(t)T / A(t)L$. The land rental rate $\pi(p_a, \hat{w}, r)$ is the rate per effective unit of land per capita required for the rental market among farmers to clear. The gradients of $\pi(p_2, \hat{\omega}, r)$ yield agricultural supply, and labor and capital demand per effective unit of land per capita.

A.1. 2 Equilibrium

Definition

A competitive equilibrium for this economy is a sequence of positive values for prices $\{p_s^*, \hat{w}^*, r^*, P_{land}^*\}_{t=0}^{t=\infty}$, firm allocations $\{\hat{y}_m^*, \hat{y}_a^*, \hat{y}_s^*, \hat{k}_m^*, \hat{k}_a^*, \hat{k}_s^*, l_m^*, l_a^*, l_s^*\}_{t=0}^{t=\infty}$ and household allocations $\{\hat{k}_u^*, \hat{k}_r^*, \hat{c}_{um}^*, \hat{c}_{ua}^*, \hat{c}_{us}^*, \hat{c}_{rm}^*, \hat{c}_{ra}^*, \hat{c}_{rs}^*\}_{t=0}^{t=\infty}$ given economy-wide aggregates $\left\{p_m, p_a, \hat{k}(0), \hat{T}(0)\right\}$ such that for at each instant of time t,

1. Given prices, all firms maximize profits subject to their technologies, yielding zero profits
2. The discounted present value of household utility, subject to the mentioned constraints, is maximized
3. Markets clear for
    a. Labor

$$\sum_{j=m,a,s} l_j^* = 1$$

    b. capital

$$\sum_{j=m,a,s} l_j^* \hat{k}_j^* = \sum_{i=u,r} \frac{l_i}{L} \hat{k}_i^* = \hat{k}$$

and c. home goods

$$\hat{y}_s^* = \sum_{i=u,r} \frac{l_i^*}{L} \hat{c}_{is}^*$$

4. The value of excess demand for manufacturing goods equals the value of excess demand for agricultural goods (Walra's law)[10]

[10] This presumes a country has balanced trade, a condition which the data typically reject. The closure rule chosen is determined in the calibration of the model to data.

$$p_m\left(\hat{y}_m^* - \sum_{i=u,r} \frac{l_i}{L}\left(\hat{c}_{im}^* + \dot{\hat{k}}_i^*\right)\right) + p_a\left(\hat{y}_a^* - \sum_{i=u,r} \frac{l_i}{L}\hat{c}_{ia}^*\right) = 0$$

5. And the no-arbitrage condition between the assets of capital and land to assuring the optimal allocation of savings (i.e., that the returns to the two types of investment are equalized)

$$r^* = \frac{\pi(p_a, \hat{w}^*, r^*)}{P_{land}^*} + \frac{\dot{P}_{land}^*}{P_{land}^*} \tag{11}$$

This equation is implicit in the statement of *r-th* household's budget constraint.[11] It states that returns to savings are maximized when the income in $t + dt$ from one unit of income invested in physical capital equals r which must equal the same return in $t + dt$ to a unit of income invested in land. The returns to a one unit of income invested in land is $\pi(p_a, \hat{w}, r) / P_{land}$ plus capital gains in the amount of $\dot{P}_{land} / P_{land}$ per unit of land.

Characterization

Given the endogenous sequence $\left\{\hat{k}, \hat{E}_u, \hat{E}_r\right\}_{t=0}^{t=\infty}$, the five variable sequence of positive values $\{\hat{w}, r, \hat{y}_m, \hat{y}_s, p_s\}_{t=0}^{t=\infty}$ must satisfy the following six intra-temporal conditions at each instant of time:

zero profits in manufacturing and services

$$c^j(\hat{w}, r) = p_j, j = m, s \tag{12}$$

clearing of the labor market

$$\sum_{j=m,s} \frac{\partial}{\partial \hat{w}} c^j(\hat{w}, r)\hat{y}_j - \frac{\partial}{\partial \hat{\omega}} \pi(p_a, \hat{w}, r)\hat{T} = 1 \tag{13}$$

clearing of the capital market

$$\sum_{j=m,s} \frac{\partial}{\partial r} c^j(\hat{w}, r)\hat{y}_j - \frac{\partial}{\partial r} \pi(p_a, \hat{w}, r)\hat{T} = \hat{k} \tag{14}$$

---

[11] An equivalent statement of the rural household's budget constraint is

$$\dot{\hat{a}}_r = \hat{w} + \hat{a}_r(r - x - n) - \hat{E}_r$$

where $\hat{a}_r = \hat{k}_r + P_{land}\hat{T}_a$. Then, use the no-arbitrage constraint (11) to obtain the budget constraint (9).

clearing of the market for home-goods

$$\sum_{i=u,r} \frac{\partial}{\partial p_s} \hat{E}_i \frac{l_i}{L} = \hat{y}_s \tag{15}$$

This system of five endogenous variables in five equations appears similar to a static general equilibrium model. The system can, in principle, be solved to express each endogenous variable $\{\hat{w}, r, \hat{y}_m, \hat{y}_s, p_s\}$ as a function of the exogenous variables $\left(p_m, p_a, \hat{T}\right)$ and the remaining endogenous variables $\left(\hat{k}, \hat{E}_u, \hat{E}_r\right)$.

We now derive the system for the remaining endogenous variables which, together with (12) to (14) will constitute a solution to the entire sequence of endogenous variables.

Use (12) to express $\hat{w}$, and r as a function of p_s. We omit exogenous variables to minimize clutter. Call this result

$$\hat{w} = W(p_s) \tag{16}$$

$$r = R(p_s) \tag{17}$$

Substitute (16) and (17) for $\hat{w}$ and r into the factor market clearing conditions (13) and (14) and solve these conditions for $\hat{y}_m$ and $\hat{y}_s$. Denote the solution for $\hat{y}_s$ as a function of the endogenous variables p_s and $\hat{k}$.

$$\hat{y}_s = Y^s\left(p_s, \hat{k}\right) \tag{18}$$

Then, substitute (18) for $\hat{y}_s$ in the home good market clearing condition (15). Total differentiate the result with respect to time. Remaining terms include, $\dot{\hat{E}}_i / \hat{E}_i, i = u, r$, and the total change in capital stock $\dot{\hat{k}}$. Substitute the Euler conditions (10) for $\dot{\hat{E}}_i / \hat{E}_i, i = u, r,$ and the household budget constraints (7) and (9) for $\dot{\hat{k}}$. Simplify to obtain the differential equation for the price of home-goods as a function of the endogenous variables p_s and $\hat{k}$, the exogenous variables $\left(p_m, p_a, \hat{T}\right)$, and parameters of the system, including θ, ρ and x. Denote the result as

$$\dot{p}_s = p^s\left(p_s, \hat{k}\right) \tag{19}$$

The economy's budget constraint is given by the sum of the household's budget constraints (6) and (8), expressed in efficiency units per worker,

$$\dot{\hat{k}} = w + r\left(\frac{l_u}{L}\hat{k}_u + \frac{l_r}{L}\hat{k}_r - x - n\right) + \pi(p_a, \hat{w}, r)\hat{T} - \sum_{i=u,r} \frac{l_i}{L}\hat{E}_i \tag{20}$$

Notice that the home good market clearing condition (15) implies

$$\frac{\lambda_s}{p_s}\sum_{i=u,r} \frac{l_i}{L}\hat{E}_i = Y^s\left(p_s, \hat{k}\right) \tag{21}$$

where λ_s is the share of expenditures on home goods. Solve (21) for $\hat{E}_i$ and substitute this result into (20). Finally, also substitute (16) and (17) for $\hat{w}$ and r, respectively, into (20). Express the resulting differential equation as

$$\dot{\hat{k}} = k\left(p_s, \hat{k}\right) \tag{22}$$

The two differential equations (19) and (22) are non-autonomous and thus difficult to solve directly. The procedure is to use the time-elimination method which converts the system, without loss of generality, into an easily solved autonomous system[12]. The solution yields the sequence $\left\{p_s^*, \hat{k}^*\right\}_{t=0}^{t=\infty}$ given by

$$p_s = P^s(t) \tag{23}$$

and

$$\hat{k} = K(t) \tag{24}$$

Knowing (23) and (24) allows the derivation of $\left\{\hat{E}_u^*, \hat{E}_r^*\right\}_{t=0}^{t=\infty}$. Together with the intra-temporal system, the remaining sequence of factor payments, firm and household allocations are determined. Finally, knowing these sequences allows us to use (11) and obtain that sequence of land prices $\{P_{land}\}_{t=0}^{t=\infty}$.

The steady state

The steady state solution can be found in two ways, both of which are useful in checking for analytical and computational errors. The first is to recognize that if a steady state exists, then the Euler conditions (10) and (11) imply

$$r_{ss} = \rho + x$$

which in turn implies from (16) and (17) that

[12] See Barro and Sala-I-Martin, 1995, pp. 488-491 for a rigorous presentation of this method.

$$p_{s,ss} = R^{-1}(\rho + x)$$

and

$$\hat{w}_{ss} = W(p_{s,ss})$$

where the subscript ss denotes steady state. From these values, all of the remaining variables can be computed.

The second method is to find the roots $\left(p_{s,ss}, \hat{k}_{ss}\right)$ satisfying (19), and (22) for the case where $\dot{p}_s = \dot{\hat{k}} = 0$. And then, computing the remaining variables of the system. The two methods should give exactly the same results.

If the steady state exists, the rate of growth in all level variables (expenditure, income, output supply, and factor demand) in the long-run is given by, for example,

$$\left(\frac{\dot{\hat{k}}}{\hat{k}}\right)_{ss} = \frac{d}{dt}\ln[\hat{k}_{ss}] = \frac{d}{dt}\ln[\frac{K}{A(t)L}] = \frac{\dot{K}}{K} - (x+n) = 0 \Rightarrow$$

$$\frac{\dot{K}}{K} = x + n$$

while $\dot{w}/w = x$, and $\dot{r}/r = \dot{p}_s / p_s = \dot{P}_{land} / P_{land} = 0$.

These long run growth rates have important implications to resource adjustments in agriculture relative to the rest of the economy and the extent to which farm policy may serve to "hold" excess resources in agriculture.

A.2 Accounting for Direct Payments

The model is calibrated to U.S. data for 1997 and solved under the assumption of no PFC payments. This generates a base sequence of the endogenous variables defined above. Then, PFC payments are added to the model. The urban and rural household budget constraints (6) and (8) are changed according to

$$\dot{A}_u = wl_u + rA_u - PFC - E_u \tag{25}$$

and

$$\dot{A}_r = wl_r + rA_r + \left(\pi + \frac{PFC}{T}\right)T - E_r \tag{26}$$

respectively. This presumes (i) a lump-sum transfer of PFC from non-land owning households to land owning households, (ii) that the transfer is tied to the ownership of land, and (iii) that this payment is made at each instant of time in perpetuity.

The no-arbitrage condition between assets (11) now becomes

$$r = \frac{\pi(p_a, \hat{w}, r) + PFC/T}{P_{land}} + \frac{\dot{P}_{land}}{P_{land}} \tag{27}$$

Through the household budget constraints, the transfer term, PFC also enters the model's system of equations. While key household variables, such as the sequence $\left\{\hat{k}_i, \hat{c}_{ij}\right\}_{t=0}^{t=\infty}$ are changed by the payments, the negative effects on urban households are just off-set throughout the sequence by positive effects on rural households, as reported in the Figures. This results because household's preferences are identical and homothetic (although their consumption and expenditure levels vary) and no market failures are present. Thus, the sequence of key variables $\left\{\hat{w}, r, \hat{k}_j, p_s, \hat{y}_m, \hat{y}_a, \hat{y}_s\right\}_{t=0}^{t=\infty}$ remain the same as in the base solution. The only affected variable is the price of land obtained from (27).

The next experiment entails segregating agriculture's capital market from that of the rest of the economy. Effectively, this means that the non-land owning urban households do not invest in agricultural capital $\hat{k}_a$ over the period of analysis. In addition to changes in household budget constraints, the market clearing equation for capital (14) is replaced by the following two equations

$$\sum_{j=m,s} \frac{\partial}{\partial r} c^j(\hat{w}, r_{ms})\hat{y}_j = \hat{k}_{ms} \tag{28}$$

$$-\frac{\partial}{\partial r}\pi(p_a, \hat{w}, r_a)\hat{T} = \hat{k}_a \tag{29}$$

The first is the capital market clearing equation for the manufacturing and home good sectors while the latter is the market clearing condition for agriculture alone. Notice that these two markets can clear at different interest rates, r_{ms} and r_a. The Euler conditions (10) now become

$$\frac{\dot{\hat{E}}_u}{\hat{E}_u} = \frac{1}{\theta}(r_{ms} - \rho - x)$$

$$\frac{\dot{\hat{E}}_r}{\hat{E}_r} = \frac{1}{\theta}(r_r - \rho - x)$$

The no-arbitrage condition (27) becomes

$$r_a = \frac{\pi(p_a, \hat{w}, r_a) + PFC / T}{P_{land}} + \frac{\dot{P}_{land}}{P_{land}}$$

The systems two main differential equations (19) and (22) are now increased by two additional equations, and the system is solved to generate results appearing in Figure 2 through Figure 8. In the steady state, $r_{ms} = r_r = \rho + x$.

Figures

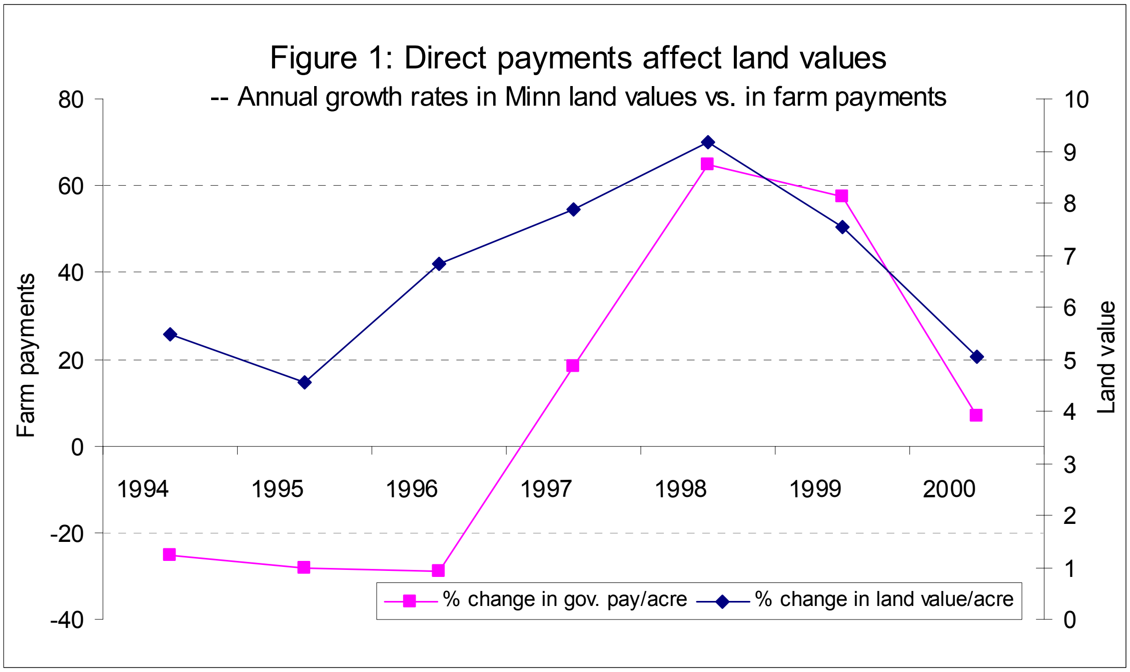

Figure 1: Direct payments affect land values
-- Annual growth rates in Minn land values vs. in farm payments
80
60
40
20
0
-20
-40
Farm payments
10
9
8
7
6
5
4
3
2
1
0
Land value
1994
1995
1996
1997
1998
1999
2000
% change in gov. pay/acre
% change in land value/acre

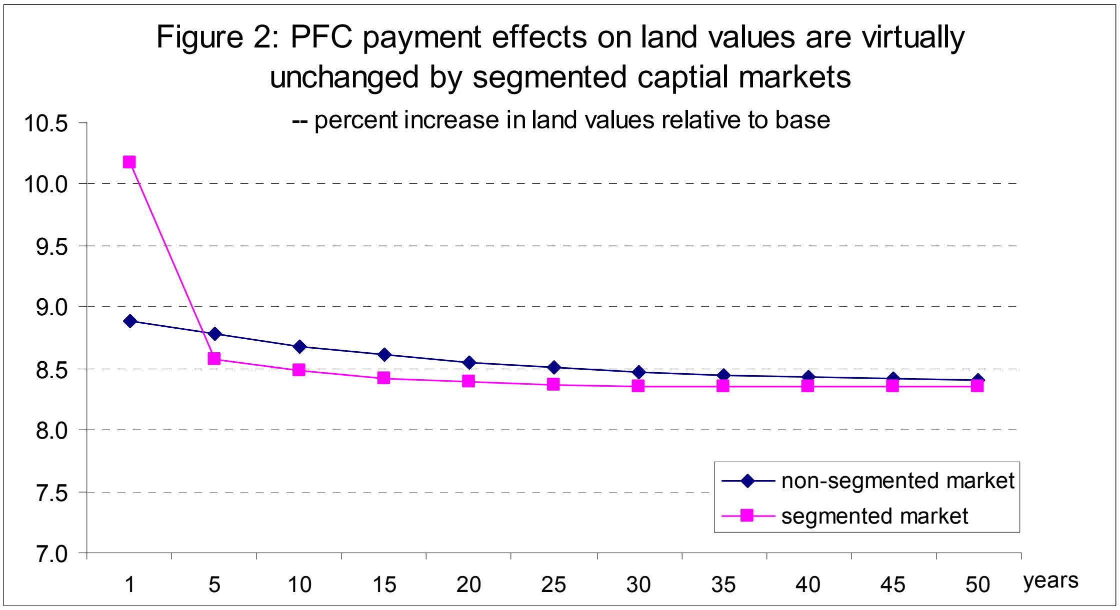

Figure 2: PFC payment effects on land values are virtually unchanged by segmented captial markets
-- percent increase in land values relative to base
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
1
5
10
15
20
25
30
35
40
45
50
years
non-segmented market
segmented market

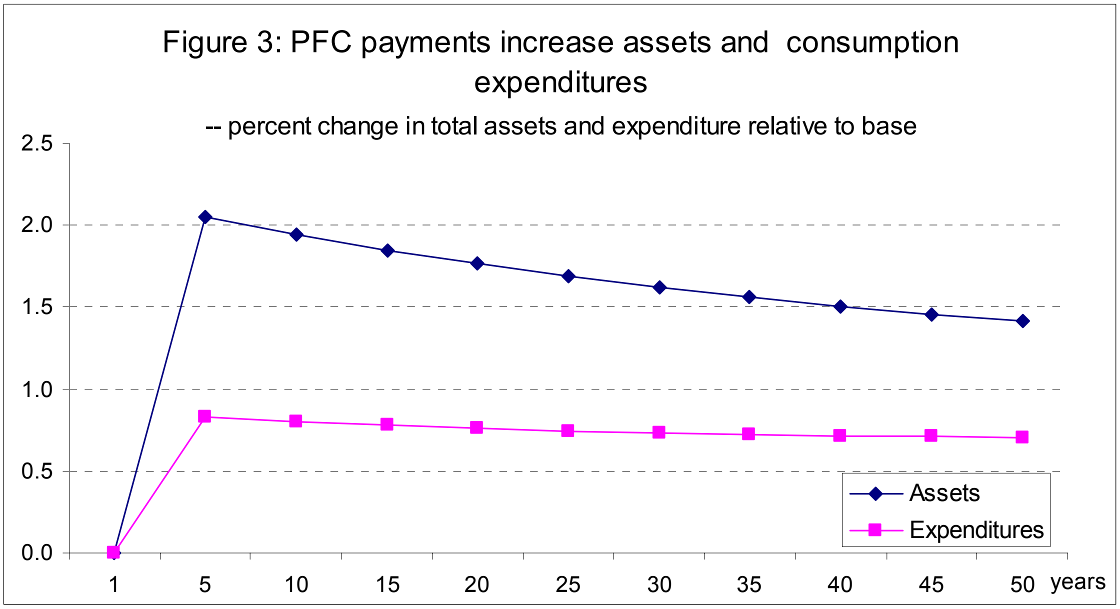
Figure 3: PFC payments increase assets and consumption expenditures
-- percent change in total assets and expenditure relative to base
2.5
2.0
1.5
1.0
0.5
0.0
1
5
10
15
20
25
30
35
40
45
50
years
Assets
Expenditures

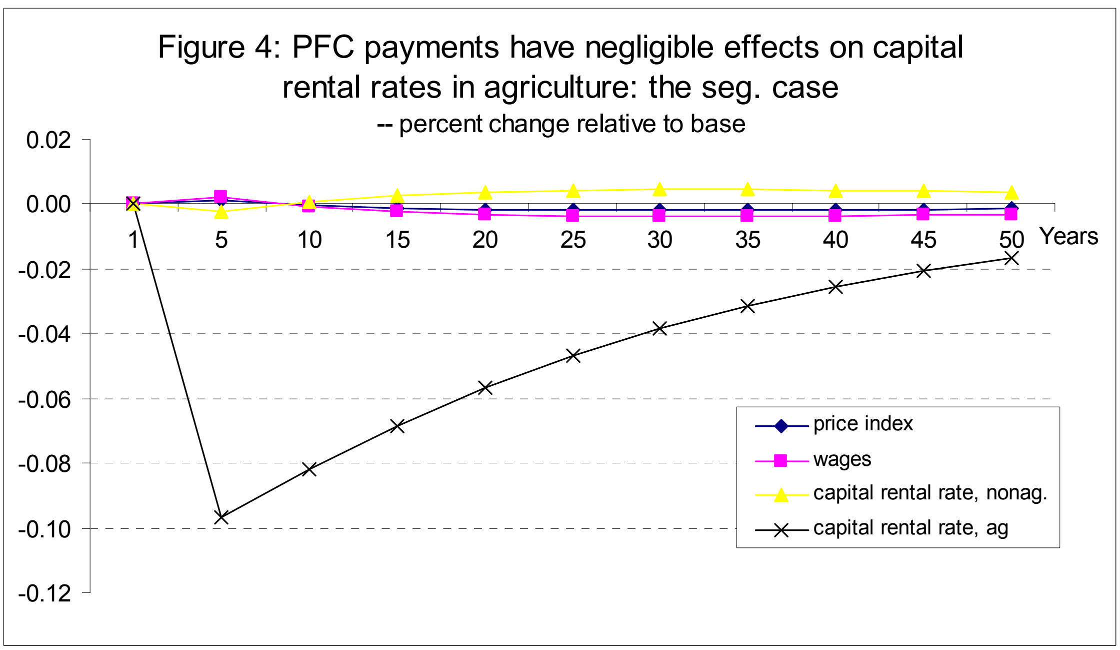
Figure 4: PFC payments have negligible effects on capital rental rates in agriculture: the seg. case
-- percent change relative to base
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
1
5
10
15
20
25
30
35
40
45
50
Years
price index
wages
capital rental rate, nonag.
capital rental rate, ag

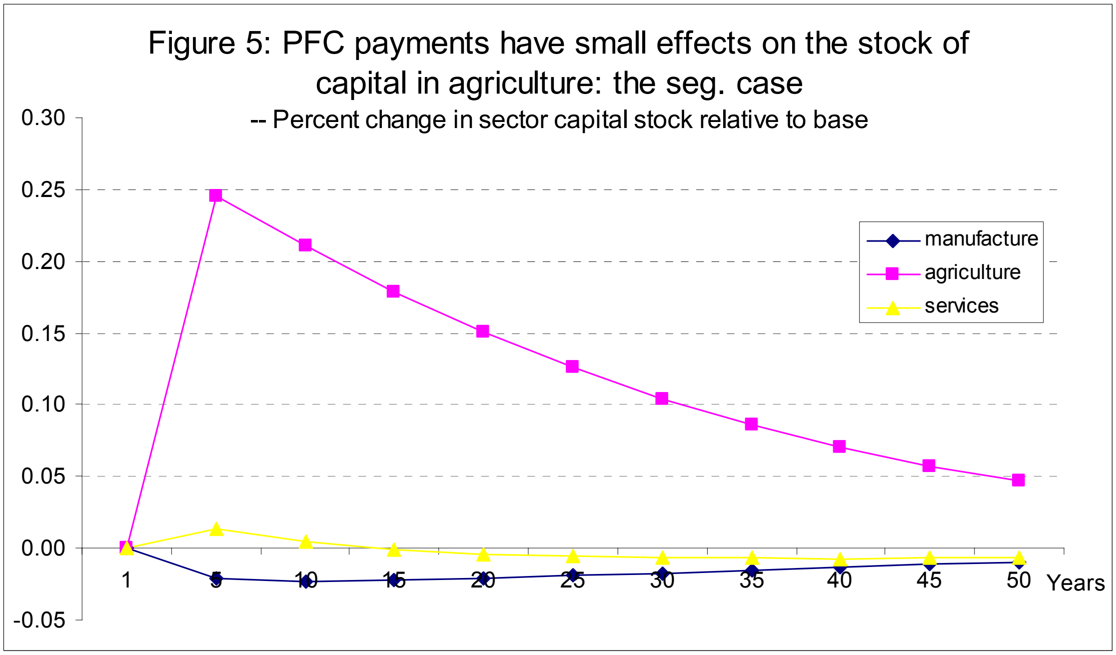
Figure 5: PFC payments have small effects on the stock of capital in agriculture: the seg. case
-- Percent change in sector capital stock relative to base
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
1
5
10
15
20
25
30
35
40
45
50
Years
manufacture
agriculture
services

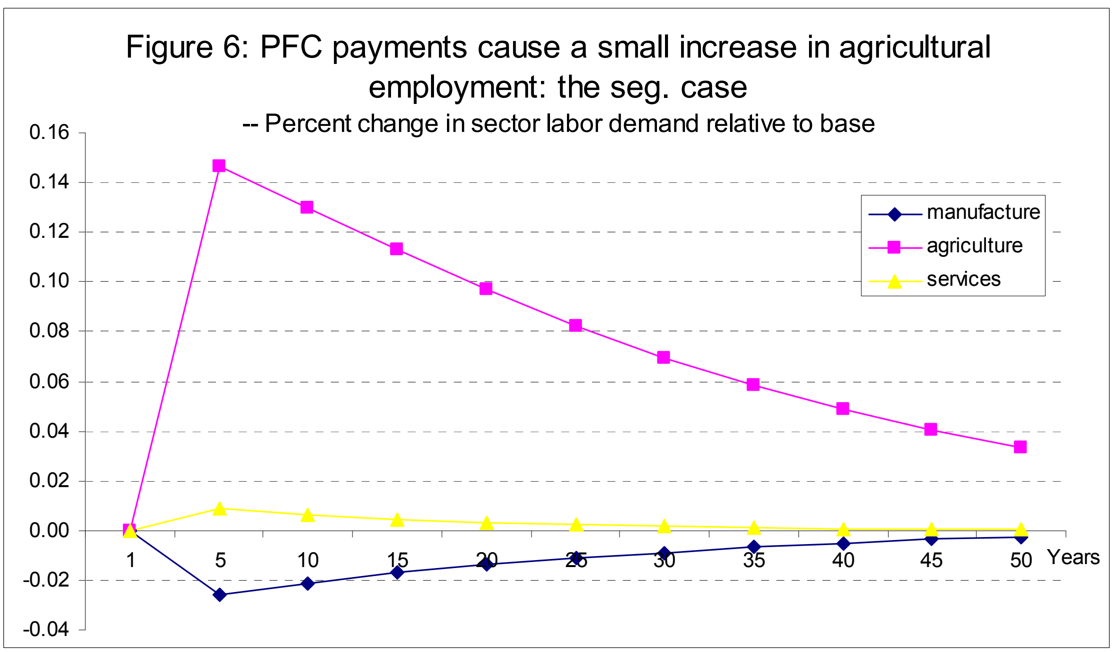
Figure 6: PFC payments cause a small increase in agricultural employment: the seg. case
-- Percent change in sector labor demand relative to base
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
1
5
10
15
20
25
30
35
40
45
50
Years
manufacture
agriculture
services

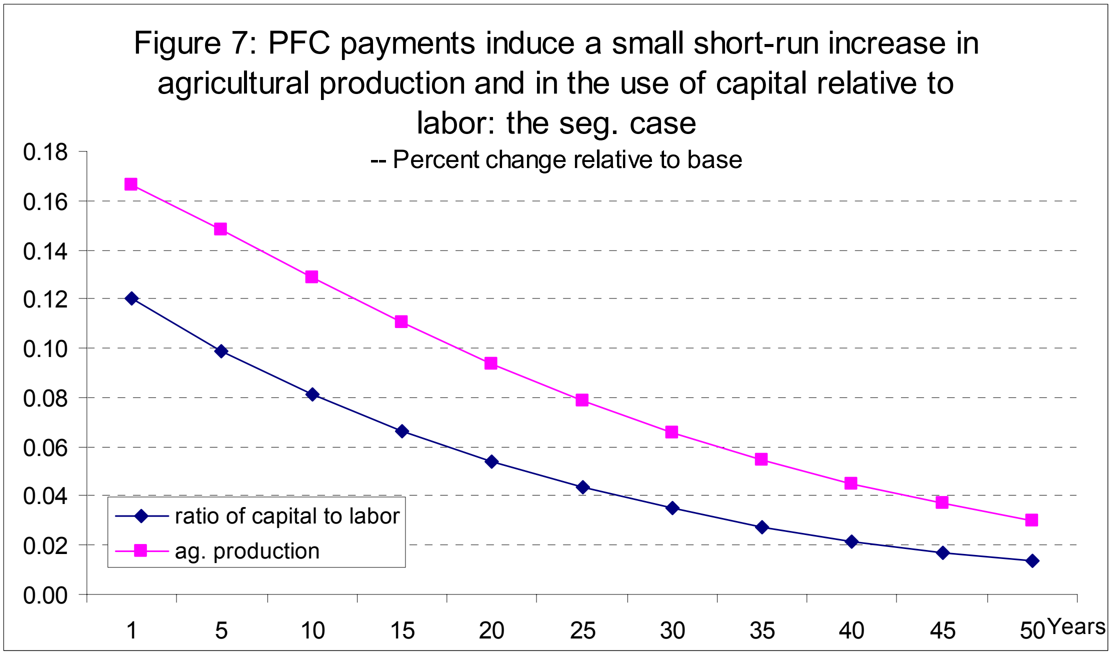
Figure 7: PFC payments induce a small short-run increase in agricultural production and in the use of capital relative to labor: the seg. case
-- Percent change relative to base
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
ratio of capital to labor
ag. production
1
5
10
15
20
25
30
35
40
45
50
Years

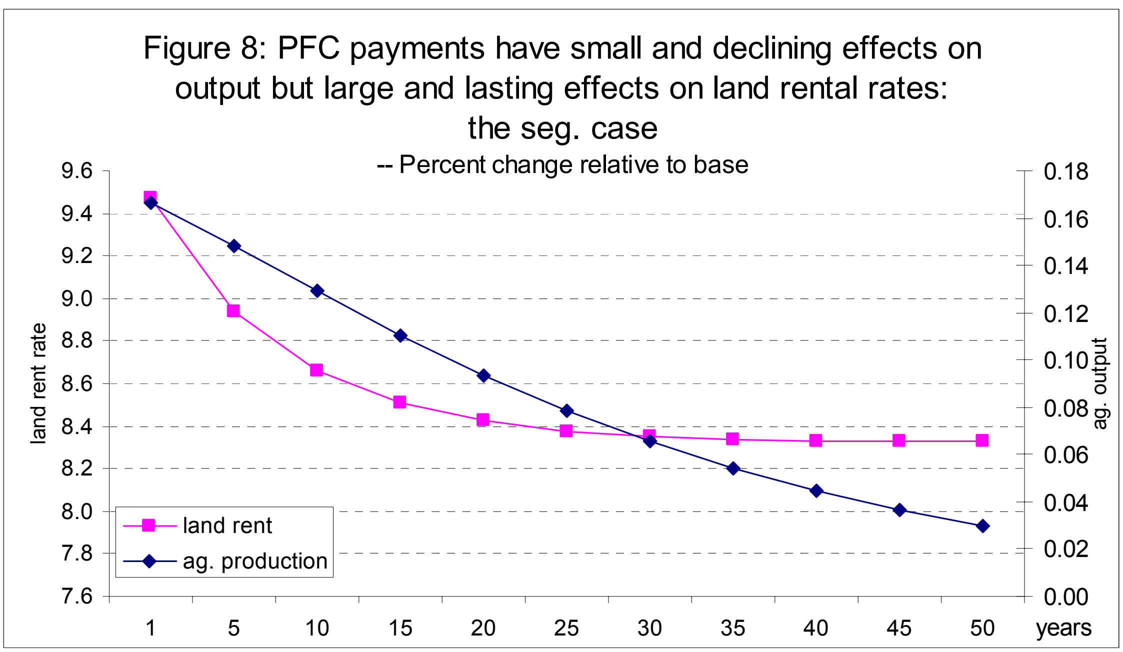
Figure 8: PFC payments have small and declining effects on output but large and lasting effects on land rental rates: the seg. case
-- Percent change relative to base
land rent rate
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
ag. output
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
land rent
ag. production
1
5
10
15
20
25
30
35
40
45
50
years

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