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How Many Times Could You Replicate Polyface Farm? A Schematic Model of Ecosystem Services in Agriculture

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DISCLAIMER

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How Many Times Could You Replicate Polyface Farm?

A Schematic Model of Ecosystem Services in Agriculture

ABSTRACT

There has been considerable recent interest in the idea that farms can produce both food and a variety of ecosystem services. One particularly intriguing notion is that farmers might find it in their own interest to adopt an "ecosystem services" approach to production in preference to a "conventional" approach. In the conventional approach farmers devote substantially all of their land directly to production and purchase a variety of fertilizers, pesticides, and other inputs. In contrast, if farmers preserve a substantial fraction of their land in a more-or-less "natural" condition, or restore it to such a state, the ecosystem services provided by preserved natural systems may obviate the purchase of many inputs. While private adoption of the ecosystem services approach would not result in the optimal provision of ecosystem services, given that some such services generate positive benefits on a broader scale than an individual farmer can appropriate, it is reasonable to regard the conversion of farms from a conventional to an ecosystem services approach to production as a step in the right direction toward more ecologically benign land use. In this paper I develop a simple and schematic model of land use in agriculture. I motivate the model by reference to Polyface Farm, a farm described in Michael Pollan's 2006 bestseller *The Omnivore's Dilemma*. Polyface Farm has adopted an ecosystem service approach: its owner restored more than fourth-fifths of the land he controls to a natural state. In contrast, his neighbors actively farm the great majority of their holdings. I develop a simple model that duplicates the stylized fact that farmers choose between very different production approaches. The model also predicts, however, that farmers who adopt an ecosystem services approach would reduce their production in the same proportion as they reduce the area of land they employ directly in production. This finding has an important implication for policy. While manipulation of agricultural prices or subsidies might induce some farmers to adopt an ecosystem services approach, such a strategy would be self-limiting. When one farmer adopts an ecosystem services approach in preference to the conventional approach she will reduce her output. Prices would rise in response, and the incentive for others to emulate her choice would be reduced.

Keywords: ecosystem services; conventional agriculture; perfect substitutes; purchased inputs; subsidy.

JEL classifications: Q24; Q57; R14

1. Introduction

Readers of Michael Pollan's bestseller *The Ominvore's Dilemma* (2006) will remember Joel Salatin. The effusive and opinionated Mr. Salatin owns and operates the 550 acre Polyface Farm near the Blue Ridge Mountains in western Virginia. Describing himself as a "Christian, libertarian, capitalist environmentalist" (Salatin, nd), Salatin runs his farm according to a set of environmental and ethical principles that sharply differentiate his operations from those of many of his neighbors.

Mr. Salatin's farm both generates and benefits from many ecosystem services. Less than 20% of his land is used directly in production (Pollan 2006). Since his father acquired the property in 1961, the majority of the farm's land has been replanted in trees. Mr. Salatin describes the land his father purchased, and which the family transformed into Polyface Farm, as "the most worn-out, eroded, abused farm in the area . . . Using nature as a pattern . . . [and] [D]isregarding conventional wisdom, the Salatins planted trees, built huge compost piles, [and] dug ponds . . ." In summary, the family "believe that the Creator's design is still the best pattern for the biological world," and restructured their holdings so that nature could provide a host of services for which other farmers pay to acquire artificial substitutes (Salatin, nd).

While some of the forest land is harvested for lumber, fuel wood and woodchips (which are used in composting operations), the plan is to retain most of the current forest area. Mr. Salatin credits the forest with providing a host of services to his farm. It moderates climate, protects plants and animals, promotes soil regeneration, shelters small predators that eat agricultural pests while acting as a buffer between farm animals and the larger predators that might otherwise threaten them, moderates the flow of water, and facilitates its retention (Pollan 2006, pp. 222 – 225). Mr. Salatin's practices of managing his land to retain its natural hydrology, recycling organic material to obviate the need for manufactured fertilizers, retaining natural habitats to protect birds and insects that provide pest control and pollination, and other low-impact management allow him to substitute ecosystem services for fertilizers, irrigation equipment, pesticides, animal feed, and other inputs he might otherwise have to purchase. From all indications Polyface Farm is a financially as well as an ecologically sustainable enterprise.

Polyface Farm provides a particularly interesting example, as it might be a template for the enhanced provision of ecosystem services. There has been considerable recent interest in this topic (see, e. g., NRC 2004, MA 2005,). While "ecosystem services" have not yet been given a concise and universally agreed upon definition (see Fisher, *et al*. 2008 for several candidate definitions of the term), we might define them for present purposes as goods and services provided by "natural"[1] ecosystems. Lists of such services have been provided by several authors (see, e. g., Daily 1997; MA 2005). Ecosystem services might be both important byproducts of, and valuable contributors to, agricultural production (Ricketts, *et al.*, 2004; Polasky 2008).

The ecosystem services provided by preserved natural areas integrated with agricultural landscapes might also confer substantial benefits on off-farm beneficiaries. Several authors have documented the classic dichotomy between socially beneficial but privately costly land use choices. They note that off-farm benefits would motivate conservation that purely private returns would not, absent payments for services such as carbon sequestration, biodiversity protection, and downstream water protection (see, e. g., Kremen *et al*., 2000; Naidoo and Ricketts 2006).

While ideally farmers would be compensated for all of the services they provide to society, for a variety of reasons they may not be. Be that as it may, if farmers are, in fact, generating ecosystem services that help their neighbors as well as more distant beneficiaries it would certainly be a step in the right direction if more farmers were to adopt more ecologically benign practices. Thus some authors suggest that a more complete appreciation of the on-farm benefits of ecosystem service provision might motivate farmers to adopt more ecologically benign practices in their own self-interest (see, e. g., Ricketts, et al., 2004). Moreover, to the extent that current land use practices may be motivated in part by subsidies either on prices received on farm outputs or paid on farm inputs (see, e. g., Pollan 2006, p. 38), there is an efficiency argument for reducing such "perverse" subsidies (Myers and Kent 2001)

In this paper I ask under what circumstances a farmer would adopt an "ecosystem services" approach to production rather than a "conventional" approach. In the

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[1] It seems prudent to enclose the term "natural" in quotes, as defining what is "natural" in a world that has long been subject to human influences (see, e. g. Mann 2005) is itself a very challenging task.

conventional approach farmers are assumed to cultivate all the land available to them (in the interest of brevity, I will use the term "cultivate land" to mean "use land directly in the production of agricultural output"). They make up for the lack of natural fertilizers, pest control agents, water retention, etc. that preserved natural ecosystems would afford by purchasing inputs. In contrast, farmers adopting an ecosystem services approach preserve land in a more-or-less natural state so as to obviate the need to purchase artificial substitutes (in the interest of brevity I will use the term "preserve land" to mean "preserve natural cover on land or restore degraded land").

I explore this issue with a very simple and schematic model. I have introduced this paper with the example of Polyface Farm to underscore a basic feature of that model. I adopt extreme assumptions to duplicate a striking outcome: Mr. Salatin's farm is very different from those of his neighbors. Mr. Salatin does not purchase any chemical pesticides, manufactured fertilizers, or feed from other sources (Pollan 2006, Salatin, nd). His neighbors in Augusta County, Virginia, devote almost half of their total production expenses to such purchases (USDA 2007). More than four-fifths of the 550 acres of land on Polyface Farm is retained in forest (Pollan 2006). Less than one fifth of the other 286,000 acres designated as farmland in Augusta County is forested (USDA 2007).

There is a big difference between the practices of the handful of practitioners of more ecologically benign agriculture such as Mr. Salatin and those of other farmers, even within the same region. A model describing the choice between approaches should generate sharply different results depending on relatively small differences in underlying factors. I do this by taking at face value the assertion that ecosystem services are very good – in the limit, perfect – substitutes for purchased inputs.

Given this assumption, the model does what it is constructed to do: it predicts that farmers will adopt a discontinuous strategy. The decision to adopt an ecosystem service approach in preference to the conventional approach is essentially a choice to substitute less expensive for more expensive inputs. If the cost of purchased inputs is relatively high in comparison to the price of output and/or preserved land is very effective in generating the services that could be obtained from purchased inputs, farmers will adopt the ecosystem services approach of preserving land. This would obviate the purchase of certain inputs. Under the opposite conditions, farmers will adopt the conventional approach, using essentially all land available and purchasing other inputs.

This process of conversion may be self-limiting, however. A farmer may find conversion to an ecosystem services approach profitable not so much because her productivity is enhanced as because her costs of production are slashed. Her costs go down, in large measure, because she produces less. If enough farmers switch to an ecosystem services approach, then, the aggregate reduction in output will trigger an increase in food prices and, with it, erosion in the advantages of the ecosystem services approach.

The remainder of this paper consists of three elements. First, I develop and solve the model I have introduced above. Next, I consider how a farmer's choice to adopt a different production approach affects the amount of output he supplies. The model I have constructed is very schematic. I do not consider a host of complicating factors. The third element of the paper is, then, a discussion of what even so simple a model as this may say about more complicated problems.

2. The model

Suppose that agricultural production is described by a quadratic function

$$q = y - \gamma y^2, \tag{1}$$

where q is output *per hectare of land*, and y is a composite input, also measured per hectare of land. Let us assume that land used in production is homogenous, and that the composite input is given by

$$y = \frac{x + \phi(1 - A)}{A}, \tag{2}$$

where x is the *total* quantity of a purchased input employed, A is the total amount of land used in production, and ϕ is a constant. Normalize total land area to one for convenience, and thus suppose that $1 - A$ represents the area of land preserved to provide ecosystem services. The constant ϕ measures the rate at which ecosystem services provided by natural systems can be traded off against purchased inputs. I will say that ϕ measures the *effectiveness* of preserved land in providing ecosystem services: the higher is ϕ, the less need there is to purchase inputs.

Total production when an area $A \leq 1$ is cultivated is the product of output per unit of land and the amount of land used directly in production:

$$Q \;=\; qA \;=\; x + \phi(1-A) - \gamma\frac{[x + \phi(1-A)]^2}{A}. \tag{3}$$

Farm profits are derived by multiplying farm output, from equation (3), by price, *p* and subtracting the costs of inputs purchased at price *w*. Thus profit is

$$\pi \;=\; p[x + \phi(1-A)] - p\gamma\frac{[x + \phi(1-A)]^2}{A} - wx. \tag{4}$$

First-order conditions for the maximization of profit are

$$\frac{\partial\pi}{\partial x} \;=\; p - w - 2p\gamma\frac{x + \phi(1-A)}{A} \;\leq\; 0 \tag{5}$$

and

$$\frac{\partial\pi}{\partial A} \;=\; -\phi p + p\gamma\frac{(x + \phi)^2 - \phi^2 A^2}{A^2} \;\geq\; 0. \tag{6}$$

Note that both expressions (5) and (6) are stated as weak inequalities. As we shall see momentarily, there may be a corner solution in which all land is devoted to production, or another in which the purchase of inputs is obviated by the ecosystem services provided by preserved land.

As the latter of the two potential corner solutions is extreme and rather implausible if taken literally, a word of explanation might be offered. We might suppose that the "price" of output, *p*, is really a net price, consisting of the price received per unit of output less costs incurred in planting, harvesting, transporting, etc., each unit of output. These costs, in contrast to those of the purchased inputs, *x*, would be incurred whether or not certain services are provided by natural ecosystems rather than manufactured inputs. Whether corn is treated with chemical pesticides or protected by pest-eating animals from adjoining forests, for example, the cost to truck a ton of it to market is the same.

Solving (5) for *x*, we have

$$x \;\geq\; A\frac{p-w}{2p\gamma} - \phi(1-A). \tag{7}$$

Using (7) in (6) and taking account of the possible inequalities, we find that

$$x \geq 0,\ 0 < A \leq 1, \quad x \quad \begin{matrix} A = 1,\ x > 0 \\ = \\ 0 < A < 1,\ x = 0 \end{matrix} \quad A\frac{p-w}{2p\gamma} - \phi(1-A). \tag{8}$$

as

$$\frac{(p-w)^2}{4pw} \begin{matrix} > \\ = \\ < \end{matrix} \phi\gamma\,. \tag{9}$$

Other things being equal, when the price of output is high all land will be devoted to production; when the price of inputs is high, land will be preserved to provide ecosystem services; and when ϕ, the effectiveness of preserved land in generating ecosystem services is high, land will be preserved to provide ecosystem services.[2]

The "conventional" approach

It will be useful to have results for the case A =1, $x > 0$ for subsequent comparisons. I will refer to this as the "conventional" case, as it corresponds to what is, in much of the developed world, at least, now the most common approach to agriculture: cultivate substantially all available land and purchase inputs instead of relying on ecosystem services.

If the left-hand side of (9) is greater than the right, then $A = 1$ and

$$x_0 = \frac{p-w}{2p\gamma}. \tag{10}$$

I will use a subscript zero to designate results under the conventional approach. Mnemonically, "zero" land is set aside to provide ecosystem services. Substituting from (10) into (3), the expression for output,

$$Q_0 = \frac{p^2-w^2}{4p^2\gamma}, \tag{11}$$

[2] The effectiveness parameter will generally enter into the expressions below in the product $\phi\gamma$. The parameter γ indexes the rapidity with which diminishing returns set in. The larger is γ the lower is the production generated for any given quantity of the composite input $y = [x + \phi(1 - A)]/A$. Heuristically, both ϕ and γ index the degree to which additional quantities of ecosystem services come to be in excess supply as more are provided. In the interest of brevity and simplicity, I choose to focus on the effectiveness parameter ϕ.

and substituting from (10) into (4), the expression for profit,

$$\pi_0 \;=\; \frac{(p-w)^2}{4p\gamma}. \tag{12}$$

The decision to switch approaches with no subsidies

Let us consider next a situation in which a small farm's production possibilities are described by equation (1), and its optimal choices of cultivated land and purchased inputs are summarized by expressions (8) and (9). If we suppose that the farmer takes the prices of input and output as fixed, then expression (9) describes a knife-edge condition. It is unlikely to be an exact equality for any particular farmer. If

$$\frac{(p-w)^2}{4pw} \;<\; \phi\gamma \tag{13}$$

the farmer will preserve some of her land to provide ecosystem services in lieu of purchasing inputs. Inequality (13) is saying that preserved land must be sufficiently effective – the parameter ϕ must be "large enough" – to justify withholding some land from production so as to provide ecosystem services.

The first-order condition with respect to A, expression (6), when it holds as an equality and no inputs are purchased, requires that

$$A^2 \;=\; \frac{\phi\gamma}{1+\phi\gamma}. \tag{14}$$

We just saw in expression (13) that preserved land must be "effective enough" in providing ecosystem services to justify withholding it from cultivation. However, the *more* effective is preserved land in providing ecosystem services that enhance agricultural productivity, the *less* land will be withheld from production to provide ecosystem services. For values of the effectiveness parameter, ϕ, large enough that inequality (13) is satisfied, the farmer will switch to the ecosystem services approach, which will involve a discontinuous reduction in the amount of land cultivated. For values of ϕ larger than this critical effectiveness, however, the area of land cultivated will increase again. If "a little goes a long way" in providing required services, the farmer will cultivate more land to take advantage of the ecosystem services provided, rather than preserve still more land to provide services that are already available in abundance. This relationship is illustrated in Figure 1.

[Figure 1 here]

Let us next consider some further characterizations of the land allocation decision. Substituting from (13) into (14), and simplifying the resulting expression,

$$A \;\geq\; \frac{p-w}{p+w}. \tag{15}$$

While one should not make excessive claims for such a simple and schematic model as this, expression (15) has an interesting empirical implication. Consider a farmer who is just indifferent between adopting the conventional approach, in which she purchases inputs and cultivates all her land, and the ecosystem services approach, in which she preserves some of her land and, by doing so, obviates the need to purchase inputs. To be indifferent would mean that profit is equal under either the conventional or the ecosystem services approach. Recall from expression (12) that earnings from the conventional approach would be $\pi_0 = (p - w)^2/4p\gamma$, while multiplying output, Q_0 from expression (11), by the price of output,

$$pQ_0 \;=\; \pi_0 + wx_0 \;=\; \frac{p^2-w^2}{4p\gamma}. \tag{16}$$

The quotient $\pi_0/(\pi_0 + wx_0)$ is equal to $(p - w)/(p + w)$, and so if the indifferent farmer were to switch to the ecosystem services approach, she would choose to cultivate a fraction

$$A \;=\; \frac{\pi_0}{\pi_0 + wx_0}, \tag{17}$$

or equivalently, to preserve a fraction

$$1-A \;=\; \frac{wx_0}{\pi_0 + wx_0} \tag{18}$$

of her land. The amount of land preserved by a farmer adopting the ecosystem services approach would be no greater than the ratio of expenditures on purchased inputs to expenditures on purchased inputs and land rent under the conventional approach.

It is prudent to repeat the caveats both that this is a *very* simple and schematic model, and that imprecision in interpreting the available data precludes any very exact comparisons. Bearing those warnings in mind, however, we might consider the following data. Mr. Salatin's farm produces mostly meat and eggs, and hence the land he uses in production is largely pasture. In Augusta County, Virginia, where Polyface farm is located, pasture land commanded a rent of $25.50 per acre in 2008 (USDA 2008). There are about 286,000 acres of farmland in Augusta County. Total production expenses of about $166 million were incurred there, an average of about $580 an acre (USDA 2007). Only about $25 per acre of such expense was accounted for by inputs that are clearly obviated by Mr. Salatin's approach: synthetic fertilizers and pesticides. However, close to half of the average Augusta County farmer's expenses were incurred to purchase feed. This is another expense that has been largely been obviated in Mr. Salatin's approach, where natural grass replaces purchased feed. It is difficult to say exactly how much of the feed Mr. Salatin's animals consume can be described as arising from an "on-farm ecosystem service". However, from equation (18), Mr. Salatin could justify cultivating only 20% of his land if

$$0.80 \leq \frac{wx_0}{25.50 + wx_0}, \tag{19}$$

or

$$\$102 \leq wx_0 . \tag{20}$$

Again, total production expenses for Augusta County were about $580 per acre; Mr. Salatin would only have to avoid less than a fifth of those expenses to justify his approach. While the many imprecisions of the data make it a weak result, we can, at the very least, say that Mr. Salatin's choice to preserve so much of his land is not obviously inconsistent with this simple model.

Quantity effects

While Mr. Salatin's land preservation choices are not demonstrably profit-reducing, and the citizens of rural Virginia (as well as occasional urban passers-through, such as myself) might thank him for preserving the character of the natural landscape, his choices beg another question: what would happen if large numbers of Mr. Salatin's neighbors were to follow his example?

The answer is that they would likely reverse the circumstances that have motivated a handful of farmers like Mr. Salatin to adopt the ecosystem services approach. The model suggests that the advantage of the ecosystem services approach for those farmers who adopt it is not so much that it increases their productivity as that it slashes their costs. Their costs are lower because they use much less land to produce much less output.

To see how much output declines relative to the conventional approach when a farmer adopts the ecosystem services approach, evaluate equation (3), which specifies output, when $x = 0$ and $A < 1$ is set optimally, and designate the result as Q^*. Since no inputs are purchased when a farmer adopts the ecosystem services approach, the corresponding profit is

$$\pi^* \;=\; pQ^*. \tag{19}$$

Dividing both sides of (19) by $Q_0 = (p^2 - w^2)/4p^2\gamma$, production when the conventional approach is adopted and all land is cultivated,

$$\frac{Q^*}{Q_0} \;=\; \frac{\pi^*}{p\left(\dfrac{p^2 - w^2}{4p^2\gamma}\right)} \;=\; \frac{p-w}{p+w}\frac{\pi^*}{\pi_0}. \tag{20}$$

For a farmer who is just indifferent between adopting the conventional approach or switching to the ecosystem services approach, $\pi^* = \pi_0$, and so expression (20) implies that

$$Q^* \;=\; A^*Q_0 \tag{21}$$

A farmer who cultivates 100 $(1 - A^*)$% less land will grow 100 $(1 - A^*)$% less food.

It is worth noting in passing that expression (21) results when a farmer is indifferent between adopting conventional and ecosystem services approaches. If adoption of the ecosystem services approach would prove considerably more profitable than the conventional approach, the consequent reduction in output would not be as drastic as depicted in expression (21). Of course, if profits were considerably higher under the ecosystem services that the conventional approach, it would mean that farmers were ignoring the opportunity for a profitable change in practices, which seems unlikely.[3]

The specific result that food production declines in direct proportion to the area of land cultivated is an artifact of the many assumptions I have made to simplify and streamline an analysis intended to be illustrative rather than precise. Inasmuch as none of the simplifying assumptions introduces any obvious bias, however, it seems reasonable to suppose that the principle that output declines dramatically if the area cultivated declines dramatically is more general.

3. Discussion and extensions

In this section I will first briefly defend the simplifying assumptions I have adopted in order to produce a tractable model. I then discuss some other considerations in a farmer's choice between conventional and ecosystem services approaches. The section concludes with a discussion of how the simple model of individual farmer choice I develop here might be embedded in a more general model.

Modeling assumptions

I have adopted a number of simplifying assumptions. In the real world ecosystem services and purchased inputs are not perfect substitutes. Farmers cannot indefinitely replicate operations, as is implied by my assumption of constant returns to scale in land and the aggregate input. Agricultural land is not available in absolutely fixed supply. Agricultural production possibilities cannot be described with much precision by a quadratic function.

While each of the above statements is unobjectionable, each also admits a rejoinder that suggests that the assumptions are adequate for the purposes of illustrative modeling. Ecosystem services and purchased inputs are not perfect substitutes, but much of the literature on ecosystem services in agriculture is premised on the suggestion that ecosystem services can greatly reduce, if not entirely eliminate, the need to employ purchased (and, often, less ecologically benign) inputs.

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[3] One possibility is that farmers would treat the choice to switch approaches as a costly and irreversible investment made under uncertainty. See the discussion in the following section.

A scarcity of favored locations prevents the replication of the most efficient farms. Moreover, some ecosystem services will be provided by lands preserved by default, as it were, given that they are unsuitable for farming. More generally, however, there is an opportunity cost to preserving potentially productive farmland. The essential feature captured in the model is not that all potential farmland is the same, but rather that there is a tradeoff between farming and preserving at least some land.

I presume that agricultural land is available in fixed supply. In reality, of course, farmers compete with residential developers, businesses, and public works for available land. Inasmuch as the other categories of land use typically take up small fractions of the rural landscape, however, it is not too unreasonable to ignore them for the purposes of such an illustrative model. While some land may remain submarginal even today, the real issue is whether farmers would preserve land with positive opportunity costs, and it is this choice that the model addresses.

I have modeled agricultural production as a quadratic function because this specification yields particularly neat solutions. The functional form I have chosen may be regarded as a second-order approximation to any function in which land and the composite input are essential to production, however. As such, it can be defended as a canonical form, and results derived from it may be presumed to be reasonably general.

The farmer's choice

In the model I have developed I present the farmer's choice between approaches to production as a one-time decision made on the basis of prevailing prices and technology. Mr. Salatin's family restored land they found "worn-out, eroded, [and] abused" by doing a great deal of work and waiting a long time to realize the fruits of their labors. Similarly, a farmer who wished to abandon an ecosystem services approach in favor of using more land under a conventional approach would be making an expensive and, in the short run, irreversible investment. The theory of real options should be applied if one wanted to model farmers' choices more realistically. This embellishment would not change one basic prediction of the model, that relative prices (or, more generally, trends in relative prices) determine the choice of approach.

One of the model's more striking results might be revisited if we consider the investments required to adopt a different approach to farming. It could take considerable time to reestablish the natural assets required to operate a farm by substituting ecosystem services for purchased inputs. Such a transition might only be justified if operating profits were considerably higher after the change to a new approach than under the conventional *status quo*. Perhaps, then, output would not decline by as much as predicted in expression (21), if we are comparing steady state production under the conventional status quo vis a vis the ecosystem services approach. In a way, however, this underscores the point suggested by expression (21). Production may decline substantially during the period of transition, even if it subsequently recovers.

I have also not explicitly considered certain idiosyncrasies that would likely enter into a farmer's choice between approaches. It is obvious on reading Mr. Salatin's own account of his motivations that he operates his farm the way he does not only because he finds it profitable, but also because he finds it personally satisfying. Inasmuch as many of the benefits Mr. Salatin perceives in operating his farm as he does are external to him (Pollan 2006), one must admire his altruism. The fact that different farmers may perceive or respond to the external benefits of their actions differently does not contradict the model, however. Given a farmer's perception of and interest in providing external benefits, she will be more likely to adopt the ecosystem service approach if relative prices are favorable and less likely to if they are not.

The reader may already have objected that my simple model ignores an important determinant of the choice of approaches. Polyface Farm produces sharply differentiated products from those of its more conventional competitors, and it charges considerably higher prices for its meat and eggs (Pollan 2006). Polyface Farms products are differentiated from those of conventional farms along four dimensions: health benefits; taste (meat and eggs have different flavors depending on animal feed and growing conditions); the welfare of the animals; and the ecological consequences of production.

A large price differential would, then, make it more attractive to adopt an ecosystem service approach and to underscore the differences of both product and process in marketing. The more general principle that the incentives to adopt the ecosystem service approach would be eroded the more farmers who adopt it would be borne out, however.[4]

Market equilibrium

The observation that when one farmer adopts the ecosystem services approach in preference to the conventional approach his output declines considerably begs the question of how agricultural supply in total would respond. One should approach this question through a model of market supply and demand equilibrium or, better yet, a full-fledged general equilibrium model. For expositional reasons I have not done this here[5], contenting myself instead with a demonstration that an individual farmer's choice to adopt an ecosystem service approach may have the effect of dissuading other farmers from doing the same.

We can describe the follow-on effects of one farmer's decision to switch from the conventional to the ecosystem services approach in qualitative terms, however. The switcher will reduce her own production. This will result in an increase in prices, which will, in turn induce other farmers to increase their purchases of inputs and increase production.[6] In short, the ecological benefits resulting from one farmer's choice to switch to the ecosystem services approach will be partially offset by the reactions of others.

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[4] I might also note that Mr. Salatin has established an enviable niche in the organic/alternative food industry. In addition to marketing his farm products, Mr. Salatin has become something of a celebrity farmer. During a recent stroll through the charming town of Staunton, Virginia, a poster caught my eye. It was advertising "An Evening with Joel Salatin," for which tickets were offered at $20 each. Further research revealed that for a speaking fee of $4000 for academic and nonprofit organizations, or $7000 for corporations (plus expenses, in both instances), one can engage Mr. Salatin to give a presentation. He also markets his six books, DVDs, tours of Polyface Farm, tee shirts, note cards, and gift certificates through his website. One doubts that the market could bear many imitators of Polyface Farm – a sentiment which might, if too widely held, substantially depress sales of Mr. Salatin's book *You Can Farm: The Entrepreneur's Guide to Start and Succeed in a Farming Enterprise*.

[5] In an earlier draft of this paper I integrated the analysis I now present here with a market of the agricultural market as a whole. I found, however, that the expositional dissonance introduced by speaking in one section of the decisions of one farmer while considering in another those of all collectively argued for splitting the analyses between different papers.

[6] While I have generally phrased arguments in terms of reductions in the amount of land cultivated leading to an increase in output prices, there could also be a similar transmission mechanism through a decrease in input prices. If more farmers adopted an ecosystem services approach there would be less demand for fertilizers, pesticides, etc. Their prices would fall, making their use under the conventional approach relatively more attractive. I am grateful to Heather Klemick for suggesting this point.

This chain of effects might be borne in mind particularly in the context of prospective policies to encourage such switches. Switches might be encouraged by reducing the price received on farm products (by taxes, for example, or perhaps by reducing existing production subsidies); increasing the cost of purchased inputs (again, by taxes, particularly if such could be justified as Pigovian responses to externalities from pesticides or nutrients, or the elimination of subsidies); apprising farmers who might not have been aware of the benefits of an ecosystem services approach (in my notation, informing them that ϕ is greater than they thought it was); or, most directly, establishing or increasing a subsidy paid for land conservation. In each case, however, policy makers should be careful not to confuse the dramatic reduction in land use by individual farmers switching approaches with the much more modest aggregate effects that will occur after some farmers reduce their output while others increase theirs.

4. Conclusion

A number of authors and commentators have suggested that farms should provide both food and an array of ecosystem services. This is, in many ways, an attractive vision: natural landscapes confer many benefits on society for which farmers are not currently compensated. They should be. Payment of such compensation, at least in modest amounts, is unlikely to turn the dominant agricultural paradigm to that of Polyface Farm, however. As some farmers switch to a more ecologically benign mode of operations their effect on the market will be, through price increases, to reduce the incentives for others to emulate them.

Moreover, if subsidies were large enough to induce large-scale conversion to farms adopting the ecosystem services approach, we could see both a great reduction in the area of land cultivated and in the quantity of production realized on that land. There are good arguments to be made that people should eat less, waste less, and eat different things than they do.[7] These arguments should be made explicitly when public policy toward agriculture and ecosystems is discussed The simple model I have developed

[7] In particular, reduced consumption of meat would greatly reduce the demand for agricultural land. Animals eat many times the calories embodied in their meat when they are raised.

suggests that a transition to an ecosystem service approach to agriculture would not alleviate tradeoffs between food production and conservation.

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Figure 1:

Amount of land cultivated as a function of the effectiveness of preserved land

$w = P/2$; $\phi\gamma$ varies from 0 to 0.625