Dynamic effects of a foot-and-mouth disease outbreak: introducing farm bankruptcy risk

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3èmes journées de recherches en sciences sociales

INRA SFER CIRAD

09, 10 & 11 décembre 2009 –Montpellier, France

Abstract:

In FMD free countries, the occurrence of a FMD outbreak is a rare event with potentially large economic losses. In this paper we explore the dynamic effects of a FMD outbreak taking into account the largely neglected issue of farm bankruptcy. We find complex dynamic effects when the farm credit market suffers from information imperfections leading to farm closure. Welfare effects are also dramatically altered when these farm credit imperfections are acknowledged. Domestic consumers loose in the long run from a FMD outbreak because domestic supply contracts. Finally we show the crucial role of price expectations in presence of a potentially catastrophic risk.

Keywords: Animal disease, catastrophic risks, credit markets.

1. Introduction

The recent resurgence of animal disease outbreaks is a growing concern around the world. The highly contagious Foot-and-Mouth Disease (FMD) is one of the most feared animal diseases. Affecting any cloven-hoofed animal the FMD reduces animal productivity and may even cause animal death. In addition to these productivity effects, a FMD outbreak also leads to market effects because importing countries usually react with imposing import bans on any country experiencing such disease. Thus a FMD outbreak can have large economic costs for affected farmers and the whole food chain as well. The amount of these direct and indirect costs partly depends on the public measures taken to eradicate the disease. In fact public authorities have two main ex post alternative strategies to cope with FMD. One consists of culling infected herds as well preventing stamping out of animals located around the infectious zone. This first strategy may involve massive slaughtering of animals if the virus rapidly spreads. The other strategy consists also in the culling of infected herds plus the vaccination of animals located in a ring vaccination zone. This second vaccination strategy imposes a priori less mandatory culling of animals but larger international trade restrictions compared to the stamping out strategy. To date economic evaluations show that these trade induced costs indeed represent the bulk of total FMD cost, leading to the proposition of delaying the implementation of a vaccination strategy (Mahul and Gohin, 1999).

In addition to choose between ex post alternative strategies, public authority may also implement preventive actions to limit the occurrence and extent of FMD effects (like periodic animal testing, maintenance of veterinary laboratories). Farmers themselves also have some ex ante flexibility (albeit small in the short run) to cope with a potential FMD outbreak (like choice of production type, the location of the farm, the sanitary and feed practices). In theory we can determine the optimal levels of private and public, preventive and curative measures, including the adoption of risk managing instruments like insurance, such that expected marginal benefits equal expected marginal costs (see Elbakidze and McCarl, 2006). In practice one first major issue is that FMD outbreaks are characterised by a low probability of occurrence with considerable potential economic losses. In other words, the FMD potentially is a catastrophic risk and thus may not be privately insurable (Skees and Barnett, 1999; Duncan and Myers, 2000). Above all assessing the costs of FMD and optimal levels of decision variables is challenging because there are lasting impacts due to the animal population dynamics.

Cost-benefit analyses of FMD outbreaks have long used static economic models. Recent works introduce dynamic elements (Conrad, 2004; Rich and Winter-Nelson, 2007; Paarlberg and al., 2008). Although the animal inventories rightly evolve over time, farmer optimal decisions were not derived from a well-behaved profit maximisation behaviour. The exception is Zhao and al. (2006) who build on Jarvis

(1974) and Rosen (1987) modelling framework: farmer periodic breeding, feeding and culling decisions maximise a linear profit function discounted over several years subject to a linear biological reproduction process. These authors specify a quadratic inventory adjustment cost function such as to obtain price-increasing supply curve in the steady state. With this consistent framework they show that the impacts of FMD changes from year to year before returning to a new steady state, which is typical when studying animal supply responses (Aadland and Von Bailey, 2001).

Our main objective in this paper is to provide new dynamic estimates of FMD impacts by introducing the possibility that some farmers fall into bankruptcy. Indeed a FMD outbreak may induce a temporary price drop due to trade restrictions. Even if only one farm among all farms in a given country is affected by the FMD, all farmers in this country suffer from this price drop. In order to smooth this negative income loss over time, farmers may contract new debts and/or delay investments or even disinvest. Lenders, more generally the functioning of the farm credit market, have clearly a great role here by supplying or not new debts to farmers. For instance, if they supply new debts at a standard interest rate without side conditions, then farmers may be effectively able to deal with the immediate negative consequences of the FMD outbreak over several years. On the other hand, if lenders use a standard insolvency rule for determining farm bankruptcy, some highly debt farms may be forced to exit the market in the next period (Vercammen, 2007). This may create a new type of dynamic effects on the market in addition to the one induced by the animal reproduction process.

Accordingly we generalise previous works in two main directions. First we add physical capital investment/disinvestment decisions and equity financing decisions in the farmer dynamic behaviour. In addition to animal herds and animal feeds, we introduce physical capital and labour in an annual constant return to scale production function. This annual production function is specified with a dual quadratic cost function. Farm labour is supposed to be fixed in the short run, hence a positive slope of the supply curve in the steady state. Farmers maximise their discounted expected profit subject to three dynamic constraints: the standard animal reproduction process, the accumulation of physical capital and finally the accumulation of debts. Second we specify two alternative farm credit supply functions. In the first case, we assume that the lending sector operates in a competitive environment with full information on farms characteristics and markets and no transaction costs. In this first case, the lending sector always provides loans to farmers at a fixed interest rate and they never force farm bankruptcy. In the more realistic second case rooted on financial models, we assume that the farm credit market suffers from information asymmetries and transaction costs. In this case, farms with higher net debt face a higher effective interest rate. The competitive lending sector may even force farmers into bankruptcy when current net equity falls to a critical level.

We implement our model on a stylised agricultural economy with farms differentiated according to their initial feeding costs and initial net equities. These farms initially produce one animal product and initial export represents a non trivial outlet. We then simulate the dynamic consequences of a hypothetical FMD outbreak limited to only one farm and one period. Exports are banned during this period but borders are reopened afterwards. As expected, the output price significantly drops during the outbreak period and induces a serious decrease of residual labour incomes. In the first setting where farmers are able to write new debts at constant costs in order to maintain their labour incomes, then the dynamic impacts of this FMD outbreak are minimal on output markets. It mainly increases debt levels in the steady state. In the second setting where farmers may fall into bankruptcy, then the dynamic impacts of the same FMD outbreak are complex. Domestic supply contracts, then output price recovers at higher level than initial levels. Farmers who are able to stay on the market finally may even gain in the long run thanks to higher output price. Despite border reopening, the stylised agricultural economy becomes a net importer rather a net exporter. In this second setting where full information is not the rule, we also examine the issue of price expectations formulated by farmers and lenders. We show that this may exacerbate the decline of the domestic production. Finally we show that the total negative welfare effects are more much significant in this second setting. Contrary to a widespread result obtained from static analysis (for instance, Mangen and Burrell, 2003), we also show that consumers loose over the years from a FMD outbreak due to the reduction of domestic supply.

2. Modelling framework

We consider an agricultural economy where there are initially N farmers producing only one product which is sold domestically and on the international market. We first describe the dynamic behaviour of farmers when farm credit is not a limiting factor, then move on the alternative specification for the farm credit supply function and finally close the model description with the specifications of the demand side.

2.1. The dynamic behaviour of farmers with a "perfect" farm credit market

We assume that each farm maximises each period the sum of the present value of all future profits by choosing the culling rates of animal, the "feed" cost level, the physical capital stocks and finally the level of debts. Each farm is constrained by an annual constant return to scale production function resumed in a (quadratic) feed cost function, by the dynamics of animal herds, capital and debt accumulations. At each period, each farmer is endowed with initial levels of animal herd, capital stock and debt. Formally, the program of each farm in each period is given by:

$$\max \quad \sum_{t=0}^{\infty} \beta^t E_0(\pi_t) = \sum_{t=0}^{\infty} \beta^t E_0\left(p_t.Y_t - C_t(w_t, H_t, K_t, l) - R_t\right)$$

subject to the constraints:

$$\begin{aligned}
&H_{t+1} \le (1+g)H_t - Y_t && t = 0,\ldots,\infty \quad ; \quad H_0 = \overline{H_0} \\
&K_{t+1} \le (1-\delta)K_t + I_t - DI_t && t = 0,\ldots,\infty \quad ; \quad K_0 = \overline{K_0} \\
&D_{t+1} \ge (1+r)D_t + pi_t.I_t - pi_t.(1-\gamma).DI_t - R_t && t = 0,\ldots,\infty \quad ; \quad D_0 = \overline{D_0}
\end{aligned}$$

Where β is the farmer discounting factor, p_t the output price, Y_t the output supply, w_t the feed price, H_t the animal herd, K_t the stock of physical capital, l the fixed level of farmer labour allocated to farming, $C_t(.)$ is the variable cost function of feeding, more generally taking care of the animal herd, R_t the level of debt repayment, I_t the level of investment and DI_t the level of disinvestment, pi_t the purchasing and installation cost of physical capital, g is the animal reproduction rate, δ is the depreciation rate of physical capital, γ is the difference between purchasing and selling price of physical capital and finally r is the interest rate charged by lenders.

The periodic profit is the difference between market receipts and “feeding” costs and debt repayments. This profit rewards farmer labour allocated to farming. The first constraint is a simplified representation of the animal reproduction process taken from Rosen (1987). It stipulates that the next period animal herd equals the initial animal herd plus net birth ($g.H$) less animal supply. The second constraint is the standard physical capital accumulation process where we allow for both new investments to increase the capital stocks and disinvestments as well. Finally the last constraint describes the evolution of farmer debt. The next period debt increases with the initial debt augmented by the interest charge and the new investment. On the other hand, it decreases with farm disinvestment and debt repayment. Accordingly we assume following Barry and Robinson (2002) that farmers finance their capital only with debts and not by issuing equity. We also assume that farmers are able to reduce their debt level by selling part of their capital stocks but at a price much lower than the purchasing price. This is intended to reflect the fact that they are huge transaction and installation costs of physical capital.

In this first setting, we assume that the interest rate is fixed and independent of the farm net debt. The optimal level of farmer decisions variables are determined by the following set of first order necessary conditions (NC):

NC1: $\beta^t \hat{p}_t - \lambda h_t \leq 0 \quad \perp \quad Y_t \geq 0 \quad t = 0,...,\infty$

NC2: $-\beta^t \dfrac{\partial C_t(.)}{\partial H_t} + \lambda h_t (1+g) - \lambda h_{t-1} \leq 0 \quad \perp \quad H_t \geq 0 \quad t = 1,...,\infty$

NC3: $H_{t+1} - (1+g)H_t + Y_t \leq 0 \quad \perp \quad \lambda h_t \geq 0 \quad t = 0,...,\infty$

NC4: $\lambda k_t - \lambda d_t.\hat{p}i_t \leq 0 \qquad \perp \quad I_t \geq 0 \quad t = 0,...,\infty$

NC5: $-\lambda k_t + \lambda d_t.\hat{p}i_t.(1-\gamma) \leq 0 \quad \perp \quad DI_t \geq 0 \quad t = 0,...,\infty$

NC6: $-\beta^t \dfrac{\partial C_t(.)}{\partial K_t} + \lambda k_t (1-\delta) - \lambda k_{t-1} \leq 0 \quad \perp \quad K_t \geq 0 \quad t = 1,...,\infty$

NC7: $K_{t+1} - (1-\delta)K_t - I_t + DI_t \leq 0 \quad \perp \quad \lambda k_t \geq 0 \quad t = 0,...,\infty$

NC8: $-\beta^t + \lambda d_t \leq 0 \quad \perp \quad R_t \geq 0 \quad t = 0,...,\infty$

NC9: $-\lambda d_t (1+r) + \lambda d_{t-1} \leq 0 \quad \perp \quad D_t \geq 0 \quad t = 1,...,\infty$

NC10: $-D_{t+1} + (1+r)D_t + pi_t.I_t - pi_t.(1-\gamma).I_t - R_t \leq 0 \quad \perp \quad \lambda d_t \geq 0 \quad t = 0,...,\infty$

Where $\lambda h_t, \lambda k_t, \lambda d_t$ are the Lagrangian multipliers associated with the three dynamic constraints and the notation $\hat{p}$ stands for expected price. Second order conditions for an optimal solution are satisfied if the feed cost function is increasing with the animal herd and decreasing with the capital stock. In the empirical application, we ensure that these conditions are always satisfied by the choice of a globally regular quadratic cost function.

Assuming an interior solution, the first three NC determine the optimal levels of output supply and animal herds for given levels of capital stocks. In particular, by plugging NC1 into NC2, we find the optimal level of animal herd is such that the cost of keeping one additional animal (which is the sum of feeding this animal and the opportunity cost by not selling it in the present period) equals its expected profit (which is the expected price of output in the next period for this animal and its progeny). In a similar way, the next four NC determine the optimal levels of investment, disinvestment and capital stocks for given levels of animal herds. These conditions also depend on the debt-related Lagrangian multipliers. It must be noted that investment and disinvestment are not possible in the same period due to the difference between purchasing and selling price. Finally the last three NC determine the levels of debt repayments and debt stocks for given levels of investment/disinvestment. Combining NC8 and NC9, we find that the farmer discounting factor is directly related to the interest rate. This makes sense because this first setting assumes that farmers are allowed to save / borrow at this fixed interest rate. We also find that we are not able to determine the absolute amount of both debt repayment and debt stocks. Again this makes sense because there are no transaction costs on debts and this result echoes the Modigliani-Miller's theorem. We can also check this by characterizing the steady state in this first setting. Farmer decision variables in the steady state are given by:

ST1: $\frac{\partial C_t(.)}{\partial H_t} = \hat{p}_t.g$

ST2: $Y_t = gH_t$

ST3: $\frac{\partial C_t(.)}{\partial K_t} = -\delta.\hat{p}i_t$

ST4: $I_t = \delta K_t$

ST5: $R_t = rD_t + \hat{p}i_t.I_t$

In this first setting, let's consider analytically the impact of a temporary unexpected price drop due to a FMD outbreak in the country affecting another farm. Production and investment plans were made with previous expected prices and farm have not the possibility in the short run to modify these plans. Accordingly the residual labour income at the end of the outbreak period falls below expected level, may be even negative and this farmer may be unable to make expected debt repayment. If this farmer wants to maintain his residual labour income to pre-FMD levels, he has the possibility to contract a new debt. Hence in the period following the FMD outbreak, this farmer starts with an increased debt level. From steady state conditions 1 to 4, we observe that this has absolutely no impact on his production and investment plans if farmer price expectations remain the same. On the contrary periodic debt repayments are now greater due to the fact that initial debts are greater (see ST5). This implies that if this farmer still wants to maintain pre-FMD labour income, he will again contract new debt to deal with this increased debt repayments. Accordingly debts will accumulate over the years but this is not an issue because lenders always provide loans in this first setting. This is clearly not a realistic outcome because this implies that farmers will be able to perpetually continue farm operations even with growing net debt.

2.2. Introducing farm credit imperfections

In most countries, livestock farms are quite heterogeneous for a variety of reasons (sol quality, managerial capacities, age of the farm, feeding systems, etc.). Understanding this heterogeneity by gathering all these information is extremely costly for lenders. Hence the farm credit market is characterized by informational asymmetries about the farm profitability as well by incentive issues because lenders can not control the diligence of farmers. The main consequence of this information asymmetry is that lenders charge higher interest rates to cope with potential repayment default of farmers. We assume here that the farm interest rate is an increasing function of its debt to asset ratio. We still assume that there is perfect competition between lenders and thus that farmers are able to learn about lender behaviour. Accordingly they can take into account of this supply curve of farm credit in their dynamic behaviour, such as there is a farm optimal debt to assets ratio. Formally this implies that the interest rate is no longer an exogenous variable; it is given by:

$$r_t = r(D_t, A_t) = r(D_t, \hat{p}_t.H_t + \hat{p}i.(1-\gamma).K_t)$$

This interest rate function is increasing with debts and decreasing with assets. This function may even reach infinity at some critical level of the farm debt to asset ratio, in which case it may be optimal (or they are forced) to exit the sector. Finally we introduce expected price in the valuation of the assets to allow the possibility that lenders may have price expectations different from the farmer ones. In the derivation below we simplify the analysis by assuming that these expectations about price (and market) developments are the same.

In this second setting, the following first order necessary conditions differ from previous ones as follows:

NC2': $$-\beta^t \frac{\partial C_t(.)}{\partial H_t} + \lambda h_t(1+g) - \lambda h_{t-1} - \lambda d_t.D_t.\hat{p}_t.\frac{\partial r_t(.)}{\partial A_t} \leq 0 \quad \perp \quad H_t \geq 0 \quad t = 1,\dots,\infty$$

NC6': $$-\beta^t \frac{\partial C_t(.)}{\partial K_t} + \lambda k_t(1-\delta) - \lambda k_{t-1} - \lambda d_t.D_t.\hat{p}i_t.(1-\gamma)\frac{\partial r_t(.)}{\partial A_t} \leq 0 \quad \perp \quad K_t \geq 0 \quad t = 1,\dots,\infty$$

NC9': $$-\lambda d_t\left(1 + r + D_t.\frac{\partial r_t(.)}{\partial D_t}\right) + \lambda d_{t-1} \leq 0 \quad \perp \quad D_t \geq 0 \quad t = 1,\dots,\infty$$

The optimal levels of animal production and animal herd are no longer completely independent of the farm capital structure (debts and assets). More precisely, the last term of the NC2' condition makes clear that there is an additional benefit of keeping one animal in the herd because it increases the farm total asset and thus reduces the marginal interest rate. Accordingly an unexpected temporary price drop due a FMD outbreak in the country will affect the optimal farm production and investment if the temporary shortfall of labour residual income leads farmer to contract new debts in order to maintain labour income. That is, the fact the farmer starts the next period with a higher debt and interest rate temporary modifies his new production plans compared to previous ones (the last term of NC2' condition is higher). Hence in the short run farmers are encouraged to keep animals in their breeding stock such as to increase their assets and decrease interest rates. Characterizing the steady state allows to assess the effects in the long run. The new steady state equations are:

ST1': $$\frac{\partial C_t(.)}{\partial H_t} = \hat{p}_t.g - D_t.\frac{\partial r_t(.)}{\partial A_t}$$

ST3': $$\frac{\partial C_t(.)}{\partial K_t} = -\left(\delta + (1-\gamma).D_t.\frac{\partial r_t(.)}{\partial A_t}\right).\hat{p}i_t$$

ST6: $$\beta^{-1} = 1 + r_t(.) + D_t\frac{\partial r_t(.)}{\partial D_t}$$

The optimal breeding stock level in the steady state (and optimal production) is such that the marginal "feeding" cost equals the expected price times the progeny rate minus the effects of the marginal herd unit on the interest rate (condition ST1'). A new steady state equation determines the optimal level of debt (ST6). These steady state solutions are obviously different from the ones without farm credit imperfections. But the ST6 condition shows that in the long run, farmers want to reach an optimal debt structure which is independent of the consequences of a FMD outbreak. This optimal debt is related to his discounting factor.

To resume, with an imperfect farm credit market due to asymmetric information, a FMD outbreak will have short run effects on production levels if the temporary unexpected price drop leads farmer to contract new debts in order to maintain their labour residual income. This has no effects on the long run if farmer price expectations stay the same. If they form these expectations on past realisations, then production at the individual farm level may change. Production at the macro-economic levels may also change if some farms exit the market. Some farms may decide to exit if the increased interest rate is prohibitive. Formally this is not reflected in previous optimal conditions. This will be the case when the total expected profit falls below a critical level, a condition that we will implement in the empirical section. The FMD outbreak may also place some farmers at a critical debt to asset ratio such that the lender can force the farm into bankruptcy by seizing and selling the farm's capital assets (animal herd and physical capital). Again this is not presented formally in previous equations but this is implemented in our empirical model.

2.3. Specifications of the demand side and the market equilibrium

So far we present the domestic supply of each farm on the market. Total domestic production is obviously the sum over all active farmers of individual production. This production is sold on the domestic market and can be exported as well. These two demands are inversely related to the domestic price. We also introduce the possibility of imports if their price is lower than the domestic price. We consider only one foreign zone and that the animal product is a homogenous good. So imports and exports can not coexist. In fact we model a net trade function. Formally this implies that we have:

$$\sum_i Y_t^i = D_t(p_t) + X_t(p_t)$$

We assume that the domestic consumption derives from a well behaved utility maximization program and depends on the realised market price (not an expected one). We also make this accommodating assumption for the net trade function. In the empirical section, we will assume that a FMD outbreak leads to a banning of exports to the foreign zone during the outbreak period. We will also assume the destruction of animals for the infected farm. Then this farm perceives subsidies to rebuild the breeding stock from imports.

3. Parameterization and resolution of the model

We analyse the dynamic impacts of a FMD outbreak on a stylised agricultural economy (intended to grossly represent some characteristics of the French cattle production). We suppose that there are initially 100 farms endowed with the same level of breeding stocks ($H0 = 100$) and labour force ($l = 1$) and facing the same output price ($p = 1000$), capital purchasing price ($pi = 1000$) and feed unit price ($w = 1$). The progeny rate, capital depreciation rate and difference between purchasing and selling price of physical capital are also common across all farms ($g = 1, \delta = 0.1, \gamma = 0.25$). These farms differ in terms of feed costs and debt to asset ratios. These feed costs are uniformly distributed and represent between 40% and 60% of sale values. Debt-to-asset ratios are also uniformly distributed and span the 20% to 80% interval. Most of these data can usually be retrieved from farm accounting data.

The interest rate is fixed at 5% in the perfect farm credit setting. On the other hand, when there are farm credit imperfections, we suppose like Monge-Arino and Gonzalez-Vega (2007) that the supply curve of farm credit is given by:

$$r_t(D_t, A_t) = r0 + \chi . \left(\frac{D_t}{A_t} \right)^2$$

With $r0$ is the minimum interest rate (fixed at 5%) and χ is a reduced form parameter capturing the issues of information asymmetries. We assume that this parameter equals 5% as well, such as the total interest rate equals 10% when farm debts equal farm total assets.

We suppose that these generated data represent a steady state and that farmers correctly anticipate market prices, so we are able to consistently determine initial values of other variables (like debt repayments, debt levels, capital stocks, investment, farm discounting rate). These last variables are usually not easily observable in farm accounting data. It finally remains to determine the cost function to fully specify farmer behaviour. We specify a quadratic cost function:

$$C_t\left(w_t, H_t, K_t, l\right) = w_t.\begin{pmatrix} \alpha_H.H_t + \alpha_K.K_t + \alpha_l.l + \\ 0.5.\alpha_{HH}.H_t^2 + 0.5.\alpha_{KK}.K_t^2 + 0.5.\alpha_{ll}.l^2 + \\ \alpha_{HK}.H_t.K_t + \alpha_{Hl}.H_t.l + \alpha_{Kl}.K_t.l \end{pmatrix}$$

Parameters of this cost function are calibrated using initial values of variables as well by providing three substitution elasticities between labour, physical capital and feeds. Following an OECD literature review, we assume the following Allen substitution elasticities:

$$\sigma_{FEED,K} = 0.1$$
$$\sigma_{FEED,l} = 0.1$$
$$\sigma_{K,l} = 0.3$$

In order to assess the calibration of the model, we compute supply price elasticities by simulating the model.[1] We suppose a long run increase of expected output price by 1%. In the first setting, the price elasticity of aggregate supply equals 0.59 and at the farm level, elasticities vary between 0.19 and 1.95.[2] When we introduce farm credit imperfections, these figures are 0.73, 0.21 and 3.40 respectively. As expected supply responses are greater with these farm credit imperfections because a price increase allows farmer to contract new debts (see ST6).

Turning to the demand side of our stylised agricultural economy, we suppose that 90% of domestic production is sold on the domestic market. The remaining 10% are initially exported to the international market. Domestic demand is price inelastic (-0.25) while the export demand is price elastic (-20). Both demands are specified using a simple linear form.

This model is solved sequentially. For each period, we first solve the farmer program with given price expectations. In this respect we will formulate different expectation schemes below. We implicitly assume that future markets are unavailable for all periods upon which farmers optimize or, if they are

[1] When one wants to simulate a dynamic program, the specification of terminal conditions can be critical (Lau et al., 2002). In other words, the issue is to determine when we reach infinity in the farmer dynamic behaviour. We solve this issue by implementing the steady state terminal conditions ST2, ST4 and ST5. We assume that the steady state solution is reached after 5 periods at the individual farm level. Results are unchanged if we extend to 6 periods, proving the robustness to this assumption.

[2] These figures are long run supply elasticities. In the first period, supply decreases because farmers want to increase their breeding stocks.

available, that basis risk is so important that farmers do not use the information from these future markets. If total expected profit of one farm is negative (for instance due to pessimistic price expectations), then we assume that this farm prefers to exit and sells all animals on the market. On other words, the reservation wage level equals zero. This farm also sells the physical capital and reimburses debts.

We thus first determine aggregate supply with given price expectations for different periods. Then we determine current prices by equating the current aggregate supply with domestic and international demands. The latter may be zero if there is a FMD outbreak during the period. Once current prices are determined, we compute realized farm profits. If they are lower than initial expected profits, then farmers may contract new debts in order to sustain their residual labour income. In the first setting with perfect farm credit market, we assume that farmers will contract new debts such as to maintain their labour income at pre-FMD levels because they never face the risk of bankruptcy. Then farmers optimize their program in the following period with a higher initial debt and with animal herds and capital stocks as determined in the previous period. This will determine aggregate supply in the second period given new price expectations by farmers and so on.

In the second setting with imperfect farm credit market, we also have to determine the level of new debts. We again assume that they equal the difference between initial expected profit and realized profit. In this instance we assume that farmers are unable to smooth their consumptions by other means (like other income). If farmers contract new debts, they also start the following period with higher initial debt and also with higher interest rates. Furthermore they face the risks of bankruptcy. Lenders will provide them these new debts if they believe that they are solvent. If their new debt-to-asset ratios reach a critical level, then lenders force these farms to exit the market. All animals in the herds are sold on the market. In this second setting, there may be few farms on the markets. Moreover farms face higher debt interest rates, leading them to adjust their optimal production plans. Accordingly the evolution of aggregate supply and by way of consequences of market prices is more complex in this second setting.

4. Results

We simulate a FMD outbreak occurring in the first period on only one farm. In both setting, farmers have been unable to anticipate this outbreak; the level of aggregate supply is fixed in this period. So the drop of market price in the first period due to the loss of export market is independent of the assumptions on farm credits. So the market price decreases by 40% such as to simulate domestic demand up to domestic production. We now examine the dynamic effects of this FMD outbreak over the 10 following periods.

4.1. With a "perfect" farm credit market

As derived from the analytical section, the dynamic effects of the FMD outbreak are very simple in this setting. Optimal production plans by farmers are unchanged if they view the FMD outbreak as a temporary outcome and hence maintain their initial price expectations. So equilibrium price and demand are also unchanged. The only dynamic effect is the accumulation of debts. Figure 1 below presents the debt-to-asset ratios for the 100 farms of our stylised agricultural economy. This figure provides the pre-FMD debt-to-asset ratios, then the level one period after the FMD outbreak and finally the level 10 years after. As expected we observe a significant increase in the first period. Then debts smoothly increase because farms have always higher debts to repay and they contract new debts every year so as to maintain their labour income. Debt-to-asset ratios reach one for some farms ten years after.

Insert figure 1 here

In this setting, the welfare effects of the FMD outbreak are first computed during the outbreak period. Farmers lose 40% of their price and hence individual producer welfare/profit decrease by 40 000 euros. Aggregate producer surplus decreases by 4 millions euros in the first period. On the other hand, domestic consumers enjoy this price decrease. The consumer welfare increases by 3.78 millions euros. Hence total welfare decreases by 220 000 euros in the first period. In fact farmers contract new debts such as to maintain their labour income. The new debts in turn generate new debt repayments in the following years. Aggregate farm debts increases by 6.25 billions euros 10 years after the outbreak. On the other hand, consumers no longer benefit from price decreases. They consume exactly like the pre-FMD period. If we simply sum over all years (the outbreak period and the 10 years after) we find that total domestic welfare decreases by 2.47 million euros.

4.2. With an imperfect farm credit market

We now introduce farm credit imperfections. Even if farmers and lenders anticipate that the domestic price will return to pre-FMD levels after the outbreak, it appears that 8 farmers are forced to exit the market at the 85% debt-to-asset critical ratio (see table 1). Accordingly these farms are forced to sell their capital and animal herds. So the total domestic production one period after the outbreak equals pre-FMD levels (due to our assumptions of progeny rates). On the other hand, this production is 8% lower after two periods. In the second period, we also observe new exit (3 farms) because the increased debts induce larger repayments. If these farms want to maintain their labour income, they must borrow more funds and lenders no longer supply credit to them. Again we observe 3 new exits in period 3 for the same reason.

Insert table 1 here.

Afters these first three periods, all farms are able to stay in business. This is so because market prices are going up thanks to the reduced domestic supply. Market prices are 6.3% higher than pre-FMD steady state levels at the end of our simulated period. Domestic demand is lower (by 1.6%) and our stylised agricultural economy becomes a net importer. Imports represent 3% of total domestic demand.

One striking result is that optimal productions are unchanged for farms staying in the market. They always produce 100 animals and their breeding stocks also stay at 100 units. This is so because 1) we assume so far that price expectations are unchanged and 2) the particular form of the credit supply function. In fact, in the steady state, farmers target the same level of debt (see steady state condition ST6'). This level is related to their constant discounted rate. Accordingly their optimal production plan is also constant (see steady state condition ST2'). This means that, after the FMD outbreak, farmers reduce their debt levels to initial levels with higher debt repayment. This may lead them at the end of the period to low residual farm income. In that case, they will contract new debts at the end of the period and so on. In other words, farmers try to return to their pre-FMD conditions because their price expectations remain the same. Figures do change when other price expectations are specified (see below).

Finally the welfare effects are now different. At the initial period we still observe losses for producers and benefits for consumers. But for subsequent period, consumers loose due to reduced supply and greater domestic prices. Over the 10 years following the FMD outbreak, we find that the consumer welfare decreases by 0.92 million euros (compared to the gain of 3.8 million euros in the previous simulation). On the other hand, producer welfare decreases less. Again this is mainly due to the price increases. Aggregate producer welfare still decreases by 3.74 million euros because some farms exit the market. After 10 years, total welfare effect decreases by 4.66 million euros (to be compared to the previous 2.47 million euros).

4.3. The issue of price expectations

So far we assume that farmers and lenders have stable price expectations. This assumption is not realistic in the second setting because the long run prices are higher than pre-FMD levels. The big issue here is to formulate price expectations just after the outbreak. Even if all stakeholders know that the loss of exports is temporary, farmers and lenders don't know the capacity of each farmer to cope with the price drop. Again we simplify the analysis by assuming that future markets are absent or not available for all periods. In this section we explore one alternative price expectation scheme. We assume that both farmers and lenders have simple adaptative expectations (Chavas, 1999 for instance). More precisely they anticipate that the prices of animals in all future periods will be an average of past 5 periods.

Market results are provided in table 2 and more even more complex. In the first period following the FMD outbreak, 14 farms exit the market compared to 8 in the previous section. Two reasons justify this difference. First price expectations are less optimistic for the first periods and hence farmer assets are lower. Accordingly more farms (11) are declared bankrupt. Second some farms also prefer stopping their activity because they don’t foresee profit in future periods with these lower expected prices (3 farms in the first period). Despite lower expected prices, we observe that the domestic production increases in the first period to 10331. This is a standard short run effect in the supply of animals where the supply function is price decreasing in the first period and price increasing afterwards when shocks are permanent (Rose, 1987, Aadland, 2001). Accordingly market price did not recover to pre-FMD periods (985).

In the second period after the outbreak, we observe that 2 new farms decide to exit the market. They were not forced by lenders but price expectations are again too low to anticipate positive profits. So we end up with 84 rather 86 farms. Domestic production in the second period dramatically falls because some farms already exit at the beginning of the first period. Moreover, continuing farms reduce their breeding stocks in the previous period because they did expect lower prices. This lower domestic production induces higher market price at this period.

It appears that the most significant impacts occur in the third period. Domestic production is 20% lower than pre-FMD levels, the market price is 9% higher and imports represent 9% of domestic demand. From this third period to the last one, we observe a gradual recovery of production because price expectations become greater than pre-FMD periods. In our last simulated period, we are quite close to results from the previous section. The main difference is that we have here a more stable solution because price expectations are closer to realized market prices.

5. Conclusion

In FMD free countries, the occurrence of a FMD outbreak is a rare event with potentially large economic losses. In this paper we explore the dynamic effects of a FMD outbreak taking into account the largely neglected issue of farm bankruptcy. We find complex dynamic effects when the farm credit market suffers from information imperfections leading to farm closure. Welfare effects are also dramatically altered when these farm credit imperfections are acknowledged. Domestic consumers loose in the long run from a FMD outbreak because domestic supply contracts. Finally we show the crucial role of price expectations in presence of a potentially catastrophic risk.

This paper must be viewed as a first step only in the analysis of the optimal role of public intervention to manage the consequences of a FMD outbreak. In this paper we deliberately exclude policy instruments in order to know if a FMD is really a catastrophic risk. So we compute the dynamic effects of such disease to reveal the loss potential. As expected we find that this depends on the functioning of private markets. If the farm credit market suffers from asymmetry information issues, then there is a potential role for public intervention. The next step will be to consider what can be the optimal articulation of public and private risk instruments (such as public and private stocks). The economic framework developed in this paper, once applied to realistic figures, will be relevant to investigate this long standing issue (Koontz et al., 2006).

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Figure 1. Evolution of farm debt-to-asset ratios following the FMD outbreak (with perfect farm credit market).

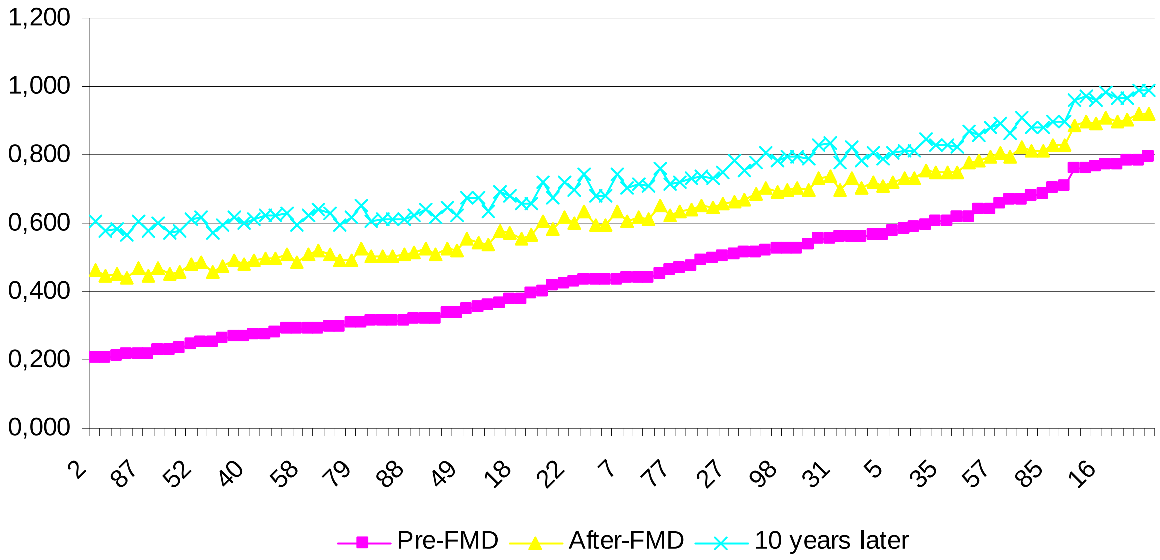

Table 1. Dynamic market effects of a FMD outbreak with farm bankruptcy risk

Period	Price	Production	Demand	Net Trade	Final herd	Number farms
Outbreak	600	9900	9900	0	10000	100
1	1000	10000	9000	1000	9200	92
2	1036	9200	8919	281	8900	89
3	1049	8900	8889	11	8600	86
4	1063	8600	8858	-258	8600	86
5	1063	8600	8858	-258	8600	86
6	1063	8600	8858	-258	8600	86
7	1063	8600	8858	-258	8600	86
8	1063	8600	8858	-258	8600	86
9	1063	8600	8858	-258	8600	86
10	1063	8600	8858	-258	8600	86

Table 2. Dynamic market effects of a FMD outbreak with farm bankruptcy risk and moving price expectations

Period	Price	Production	Demand	Net Trade	Final herd	Number farms
Outbreak	600	9900	9900	0	10000	100
1	985	10331	9033	1297	8600	86
2	1080	8223	8820	-598	8084	84
3	1089	8013	8799	-786	8131	84
4	1083	8147	8813	-666	8249	84
5	1078	8274	8825	-551	8351	84
6	1073	8371	8835	-464	8428	84
7	1070	8442	8842	-400	8484	84
8	1068	8495	8848	-352	8526	84
9	1066	8534	8852	-317	8557	84
10	1065	8563	8855	-291	8580	84