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Impact of Modern Ways of Farming on Agricultural Production: A Review

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Abstract:
The study of innovation has a long standing tradition in the field of agricultural economics.Particularly, the determinants of the adoption and diffusion of innovations go back a longwhile. In his seminal study on the adoption of hybrid corn in Iowa, Griliches (1957)developed an economic version of the S-shaped diffusion curve and confirmed thatprofitability gains positively affect adoption. Feder*et al.* (1985) review a large body ofempirical studies that originated in the work of Griliches. In a recent paper, Sundung andZilberman (2000) provide the most comprehensive overview of this literature to date.Studying the determinants of innovation usually involves studying its impact, sinceinnovation only occurs when the impact for the farmer is positive. However, in recent years,studies focusing solely on the impact of innovations have emerged.The aim of this paper is to discuss the impact of new technologies using two case studies ofagricultural innovation, agricultural biotechnology and automatic milking. As this paperdraws from two different research projects, not only the focus is different, also themethodology is.

Introduction:
Agricultural research is conducted in the context of other economic and agricultural policies,but research is only one instrument of social policy, and most non-efficiency-relatedobjectives are more effectively pursued using other policy instruments. Thus public-sectorresearch should be treated as one of several available instruments for attaining agriculturalsectorgoals, and decisions on research resources should reflect the reasons behind publicsectorinvolvement in research. In many places, stated objectives for the agricultural researchsystem include (1) economic growth, (2) income distribution, and (3) food security.Environmental objectives are frequently voiced as well but can be thought of as falling undergrowth, distributional, and security objectives. For example, environmental concerns oftenarise when measures of growth fail to include the external costs associated withenvironmental damage or when the distribution of benefits to future generations may bejeopardized (Alston, Norton, and Pardey, 1995).

Agricultural Biotechnology in Arable Farming Distributional Issues:
A central question in stimulating agricultural biotechnology research is the distribution of thebenefits from this technology among all actors in the technology diffusion chain: inputsuppliers, farmers, processors, consumers, and government. Who gains and who (potentially)looses from these innovations? A popular argument used by the opponents of agriculturalbiotechnology is the idea of an input industry extracting all benefits generated by theseinnovations. Are life science firms able to appropriate all benefits or is there a limit to theirmonopoly power? The impact estimates can come from five sources, ranked according byincreasing representatively and reliability: (1) laboratory trials, (2) field trials,(3) on-farm

partialadoption trials, (4) on-farm field-level surveys, and (5) whole-farm surveys. the range of the estimates for Bt cotton, herbicide tolerant (HT) cotton, and HT soybeans, provided by Lin, Price,and Fernandez-Cornejo (2001). The estimates vary strongly according to the region, the dataset,and the methodology. In general, the distribution of the estimates tends to be skewed toward apositive yield increase and a negative pest control cost increase, especially for Bt cotton. For HTsoybeans, some studies advance the evidence of a yield drag (Benbrook, 1999). However, themeasured yield difference can be biased by the choice of varieties to be compared. In the case ofa currently used conventional variety, which is compared to a transgenic variety, the latter is oftenpenalised by the fact that it is not necessarily as well adapted to the biophysical and climaticconditions of the area as is the case with the conventional variety. Varieties are agro climaticallyspecific, and thus varieties initially released by seed companies may not have been appropriatefor all regions, especially the lower adopting regions (Falck-Zepeda, Traxler,and Nelson, 2000b).This will undoubtedly change as traits are genetically inserted in a larger set of varieties. A moreaccurate method is to compare yields in properly conducted side-byside trials carried out withnear-isogenic lines4 that differ only in the possession of the inserted gene. Such trials are the mostreliable way to isolate the consequences of genetic differences,all other things being equal(Benbrook, 1999).Again, the near-isogenic conventional parent of the transgenic variety hasgenerally not been among the set of conventional varieties farmers have chosen to grow in thearea. So, although these trials give a direct measure of the genetic yield potential (the change inyield owing to the transgene only), they may result in an over-estimation of the farm-levelimpactof adopting the transgenic variety.

Environmental and Human Health Externalities:

There are many types of external effects in agriculture. An externality arises when there is aspillover effect of one person's actions on another person's economic opportunities and wherethat effect is not fully compensated through a market transaction (Alston, Norton, and Pardey,1995). Many people are concerned that the capacity of agricultural systems (globally orlocally) is being depreciated too rapidly by excessive exploitation of the natural resource base.Underlying this concern is an implicit belief that agricultural decision makers are discountingthe future too heavily, that they find it optimal to consume the natural resource base tooquickly,compared with some standard. Two possible rationales are that (1) private discountrates are greater than social discount rates and (2) some individuals attach too little weight tothe welfare of future generations. Thus, the costs of environmental externalities, perceived bysociety, are inseparably linked to the definition of a discount rate, which is representative forthe society as a whole. The lower (higher) the discount rate, the more society attaches weightto the welfare of future (present) generations.The decision-making rule for GMO's can be described as comparing – explicitly or implicitly– the expected costs of their release with the expected benefits. The release of the transgeniccrop will be approved if the expected discounted sum of benefits exceeds the sum of theexpected discounted costs. Traditional cost-benefit-analysis could result in socially nonoptimalallocation of resources because the value of delaying a decision and waiting foradditional information is neglected. Generally, the decision can be seen as one undertemporal uncertainty and irreversibility. Real option pricing theory has shown that under suchcircumstances, the benefits have to exceed the costs by a factor significantly greater than oneto account for the option to delay the decision. This factor is commonly called the *hurdle rate*(Wesseler, 2000).In order to assess the total social costs of agricultural biotechnology

innovations, reliable data about the potential positive (declining pesticide use, declining toxicityof pesticides) and negative externalities (gene flow risks, loss of biodiversity) of thesetechnologies are needed, as well as – and this part is often neglected – data about the externalitiesof conventional and alternative technologies. Conventional agricultural systems rely often ontoxic pesticides, which leach into groundwater. Even systems based on mechanical weeding relyon heavy machines compacting soils, enhancing soil erosion, consuming fuel and emittingexhausts in the atmosphere. Since conventional agricultural techniques are already associatedwith some externalities, the correct evaluation of the total social costs and benefits of agricultural

biotechnology has to take them into account by computing the change in these costs whenagriculture moves progressively from conventional to agricultural biotechnology techniques.If agricultural biotechnology applications in the EU are more environment-saving thanconventional techniques, as they seem to promise, this would mean that the marginal socialcost shift would be even greater than the rightward marginal private cost shift presented inand that net benefits (reduction of externality costs) are flowing to an important actor of theagricultural biotechnology diffusion chain: the environment. The major challenges in the comingyears will be the (1) aggregation and (2) valorisation of the environmental benefits and costsassociated with the introduction of genetically modified crops. Once an acceptable hurdle rateand social discount factor are defined, policy makers can make rational decisions on theregulatory approval of GM crops. However, much research still has to be done in the aggregationand valorisation of all potential private and social (environmental) benefits and costs involved insuch decisions.The potential human health and environmental externalities of the two currentlymajor GM traits, i.e. insect resistance and herbicide tolerance, are summarized via a case study on BT maize and HT soybeans (Nelson and De Pinto, 2001). Positive externalities appear in fat,while a regular font is used for the negative ones. A direct human health impact of biotechnologyhas been reported by Pray *et al.* (2000). The latter show that only 5 % of Chinese farmers in theirsample report poisonings due to the application of insecticides on Bt cotton, while this figure is22 % for the case of conventional non-transgenic cotton. Since this health impact is limited onlyto the farm operation, it is not an externality but a private (indirect or ‘non-pecuniary’) benefit ofadopting transgenic Btcotton.Crawley*et al.* (2001) monitor four different GM crops (HT oilseed rape, BT potato, HT maize and HT sugar beets) in 12 different habitats over a period of 10 years.The purpose is to find out if these crops would become weeds of agriculture or invasive of naturalhabitats, and that the introduced genes would be transferred by pollen to wild relatives.Gura(2001) reviews some environmental studies being undertaken in the UK, shedding light on somemixed effects of agricultural biotechnology. The purpose of the studies is comparing biodiversity(nontarget effects in Table 4:) in fields of HT beet, maize and oilseed rape with that incomparable plots of equivalent non-GM varieties. The central question is: “Will the large-scalegrowing of these crops be damaging to wildlife?" A British researcher, for example, alarminglyobserves that HT sugar beet and the associated application of glyphosate could almost eradicatethe wild herb *Chenopodium album*, fat hen or lamb's quarters, and severely diminish skylarkpopulations. On the other hand, the use of broad-spectrum herbicides in conjuncture with HTmcrops should mean that many fewer sprayings are needed.Fewer sprays should also slow theemergence of herbicide resistance in weed species.Moreover, the GM technology will allowfarmers to avoid tilling the soil at the beginning of every season, a practice that is meant todestroy weeds, but which is also thought to diminish biodiversity by reducing soil moisture andnutrients, and increasing the risk of erosion.In contrast, Elmegaard and Pedersen (2001) observe that the implementation of HT fodderbeets may increase biodiversity in beet fields. In general, the weed flora and arthropod faunain HT plots contain more individuals and species than the conventional plots. They believethat this difference would benefit the avi-fauna during a period of time where food availabilityis critical to farmland birds. The use of Roundup as a weed-controlling agent is morepowerful and efficient compared to conventional herbicide regimes in beet fields. WhenRoundup can be used in beet fields more weeds can be accepted for a period of time becausecontrol can be obtained in more developed weed vegetation. However, this improvement ofconditions for flora and fauna relies on a delayed weed control. A dense and diverse weedflora is believed to benefit the fauna in several ways. Firstly, occurrence and density of thehost affect herbivorous insect species thriving on specific weed species. Secondly, themicroclimate and habitat structure of weedy spots attracts a number of arthropod species ofdifferent feeding guilds. Thirdly, the aggregation of arthropods for the aforementionedreasons may benefit predators including birds.The concern about potential development ofresistance of insects (like e.g. European Corn Borer) against the toxins produced by Bt crops isjustified. Therefore, industry and entomologists have focused attention on refuge managementplans to combat resistance. Refuge zones are planted with the conventional non-GM varieties,allowing susceptible pests to mate with resistant pests slowing the proliferation of resistance. Aspart of the US Environmental Protection Agency's (EPA) conditional registration, a mandatory20 % pesticide treated or 4 % untreated refuge is required for transgenic cotton. Differentresearchers have analysed refuge management plans in order to limit the development ofresistance (Hurley, Babcock, and Hellmich, 1998, Babcock and Secchi, 1999, Hurley, Secchi,and Hellmich, 1999, Hyde *et al.*, 1999, Onstad and Guse, 1999, Secchi and Babcock, 1999,Mitchell, Hurley, and Hellmich, 2000, Livingstone, Carlson, and Fackler, 2000, Hyde *et al.*,2000, Secchi and Babcock, 2001, Secchi*et al.*, 2001). These studies more or less agree thatthe EPA recommendations will be sufficient in order to prevent a catastrophic accelerateddevelopment of resistance. compounds of pesticides (Heimlich *et al.*, 2000), or some combinationof these four elements.

The Triple Bottom of Automatic Milking

Changes in farm management:

The milking robot has been introduced on a commercial farm for the first time in 1992. Themilking robot is developed to make the physical assistance of the farmer during the milking ofeach cow unnecessary. This is however only the smallest change on the farm

(Kuipers andVan Scheppingen, 1992). For optimal benefit, a whole Automatic Milking System (AMsystem)is built around the robot, not just as a replacement for a milking parlour, but as amanagement appliance. Hence, the AM-system differs from other agricultural technologies inthat it not only takes over a process previously executed by men, but it implies a whole newway of managing a dairy farm. It not only changes the way the milking is carried out, but alsothe farmer's schedule, the feeding and the housing management.The AM-system integrates three management functions: milking frequency, individualconcentrates allocation and cow traffic. The use of these three functions makes it possible toimplement a planned regime in the milking robot dairy and to control it. Additional importantfunctions of the system are the monitoring of milk quality, of cow and udder health and ofcow fertility. A Management Information System (MIS), integrated in the system, analysesperformance data for each cow and executes management decisions through expert systems.By incorporating milking frequency, concentrates allocation and cow traffic on an individualbasis into the system's management functions, the full production potential of each cow canbe utilised. This can result in a good utilisation and a high efficiency of the technologicalfacilities (Devir*et al.*, 1997). By using the data provided through the MIS for the observationof the cows, health and welfare problems may be detected earlier.

Economic aspects:

The costs of the above-mentioned factors are difficult to predict. Their contribution to thechange in farm profits is determined by the specific situation on the farm and by themanagement capacities of the farmer. Especially the extent to which the farmer reallyexploits the positive effects that the AM-system can generate is important (Arendzen and VanScheppingen, 2000). This will depend on the farmer's knowledge about and experience withthe system. To be cost-effective, cows will need to be motivated to use the AM-system asmany hours as possible (Parsons and Mottram, 2000). In general, the hypothesis is putforward that automatic milking increases fixed costs, but decreases variable costs.7 However,considering the amount of factors playing a role, it is clear that there is a considerablevariation possible in the effect of an AM-system introduction on profits for similar sizedfarms, and that it is very difficult to draw conclusions on the optimal number of milking boxesto use from herd size alone.Most studies about the profitability of the AM system expect that dairy farmers renovating afarm building or building a new stable are the main group for whom the decision for theintroduction of the AM-system arises (Parsons and Mottram, 2000; Arendzen and VanScheppingen, 2000; Dijkhuizen*et al.*, 1997; Kuipers and Van Scheppingen, 1992). Theycompare AM-adoption with the purchase of a traditional system, as they assume that theproducer is at a point where the existing milking system needs replacing or requiresmodernisation. However, a survey among 32 German and Dutch robot users learned that only22% of them needed a new stable at the time of the AM-system introduction (Decuyper inLandbouwleven, 2000a). In addition, these studies always apply to a very specific set ofassumptions and farm characteristics, such that it is difficult to generalise their results.According to Parsons and Mottram (2000), the robot is competitive with the conventionalmilking parlour for zero grazing systems, if the price of quota is low and assuming that therobot shows the same reliability as the conventional milking system.

They used a simulationmodel to test the costs and benefits of different management regimes for the AM-system.Another study, Dijkhuizen*et al.* (1997) estimated the break-even level of AM-system adoptionon a 125-dairy cow farm in the Netherlands and the USA. The break-even level, defined asthe equivalent level of investment to make the AM-system as profitable as a conventionalmilking parlour, was found to be nearly double that of the herringbone parlour system. Asensitivity analysis showed that the break-even level was particularly sensitive to changes inwage rates.The profitability of the automatic milking system can also be expressed in the *maximumacquisition value* (MAV), i.e. the amount of capital that may be invested in the system toachieve the same net farm result as with a traditional milking parlour. If the investment
exceeds the MAV, net farm results will be smaller (Kuipers and Van Scheppingen, 1992). Inthat case, farmers who base adoption solely on the perception of how the new technology orequipment will increase the profitability of the dairy farm will not invest in the robot(Armstrong and Daugherty, 1997). Farmers looking for labour savings, more freedom,increased cow welfare etc. will only invest if they expect the lower profitability to becompensated by a desired fulfilment of their expectations. The MAV highly depends on thedesired alternative for automatic milking. Capital which would normally be invested inrenovation or replacement of a traditional milking parlour can be invested in an AM-system(Kuipers and Van Scheppingen, 1992). In practice, it can be expected that farmersconsidering buying an AM-system would also prefer a high degree of automation for thelayout of a traditional milking parlour. The difference in investment with an AM-system willtherefore be smaller. For farmers who would decide in favour of a cheaper and lower-techalternative milking parlour, the step towards an AM-system is bigger.The AM-system will have the highest efficiency on farms with herd sizes that fit to the robot(Kuipers and Van Scheppingen, 1992) or, conversely, on farms where the farmer is willing,
and able, to adjust the herd size to the AM-system. It is obvious that the milk yield per cowand the desired milking frequency are important factors in determining the number of cowsthat can be milked with an AM-system. The system’s capacity (if expressed as number ofcows per milking unit) also depends on whether the equipment is used efficiently (Devir*etal.*, 1997). In practice the milking frequency on commercial farms is 2.6 to 2.7 milkings percow per day on average. The number of cows milked per hour mostly depends on the steadyvoluntary cow traffic throughout the day (Spahr and Maltz, 1997). According to themanufacturers, the capacity of a 1-box robot is 60 cows when the average daily milkingfrequency is assumed to be 2.8 to 3.0 milkings per cow. With a second box, they assert it tobe 90 or 120 cows, depending on the system (differences are possible in the method of teatcleaning, system cleaning, teat cup attachment etc.) (Schoonhoven, 2000).Kingmans (1999)described how the available quotum influences the exploitation of the robot capacity asfollows: “Having a quotum above approximately 450,000 litres, a 1-box system will beoverloaded, while a second box will be under-utilised and thus used inefficiently. Farmershaving a quotum that can be milked efficiently by a 1-box, but who want to expand themilking activity in the coming years, will also be confronted with a capacity problem. Onlyfor a large growth, a second box becomes economically interesting”.

It should be noted thatin practice, there is a large variation in number of cows and litres of milk that are milked witha similar AM-system.8 Milk yield per cow and number of milkings per day are importantdeterminants of the system's capacity. Furthermore, farmers can gain in capacity by selectionof faster milking cows and by a more efficient use of the system when becoming moreexperienced.A dairy farmer may aim for a higher milk production per cow. The reason for thiscan be either to keep down the variable costs of the herd in the long term by milking the quotawith a smaller number of cows, or to enlarge herd size and production per cow to profit fromincreasing scale. According to Bart Sonck (personal communication), most farmers do nothave the intention to cut down their herd size because they see this as a step back. Theyusually think in terms of growth and enlargement. For example, a survey showed that only20 % of the 32 interviewed robot milkers considered the higher production rates as anargument (Decuyper in Landbouwleven, 2000a). The production increase with the AMsystemis reached through increased milking frequency and by combining individual milkingand feeding strategies (Kuipers and Van Scheppingen, 1992; Devir*et al.*, 1997). Kuipers andVan Scheppingen (1992) assumed a 10 to 15 % higher milk yield per cow to be possible.These values have been reached on experimental farms, but on commercial farms productionincreases are generally lower (with 5% as the estimated average) (Bart Sonck, personalcommunication). Moreover, the production increase has a fair amount of variance(Dijkhuizen*et al.*, 1997) and the advantage of a higher yield by increase of the milkingfrequency is gradually diminishing due to genetic progress (Landbouwleven, 2000a). If amilk production increase occurs due to the AM-system use, quota can be milked with fewercows. In that case, the European robotic milker has to choose between the purchase ofadditional milk quota and a reduction of herd size. If all the new milk produced requires alease of quota to cover it, an AM-system becomes much more unprofitable (Cooper andParsons, 1999). According to Dijkhuizen*et al.* (1997) reducing herd size is economically themost interesting option when milk quota are at a high price level (e.g., 2.04 Euro in theNetherlands). As a consequence of the higher milking frequency or an enhanced freezingpoint caused by a slightly larger percentage of water in the milk or a combination of these twofactors, a reduction in fat content (approximately 0.15%) may occur when milkingautomatically. There may also be an effect on protein content, but less apparent (a decline of0.05% on average) (Dijkhuizen*et al.*, 1997). Lower fat and protein levels imply a slightdecrease in the milk price for the farmer. Some farms have problems with milk quality afteradoption, which can be due to an increase in the somatic cell count, a raised free fatty acidcontent or an increase in total bacterial count. It should however be stressed that themanagement of the farmer plays a determinant role in keeping up the milk quality level, incase of traditional as well as for automatic milking.

Social aspects:

Traditional farmers are generally risk-averse. They may seek security in using the sametraditional methods their parents used and in avoiding borrowing money, even forinvestments. However, farmers may be interested in the milking robot, because of theattraction of something new and revolutionary. The AM-system may become a new kind ofstatus symbol in dairy farming or it may be considered in the future as a necessity for afarmer's quality of life and pleasure at work. The conflict between looking for security andtrying something new will influence the decision for or against adoption of the AM-system.In an interview with Hoefman (1998a), Van Scheppingen distinguished between three groupsof dairy farmers:

1. farmers who choose for the robot despite an expected decrease in farm profits, because oftheir high appreciation of the expected labour reduction or the expected increase inflexibility, in milk production , in cow health, etc.;
2. farmers who only choose for the robot if they expect farm profitability to stay equal or toincrease;
3. farmers who do not want to work with an AM-system because they prefer a strict dailyplanning and want to control the milking process themselves, or for other reasons.

Obviously, the introduction of an AM-system is not a good choice for every farmer. Itssuccess largely depends on the specific farm situation (Kingmans, 1999). Particularly in theearly days, farmers returned to the traditional way of milking after disappointing experienceswith the AM-system. The reasons they gave were: disappointing labour reductions, problemswith milk quality, the fact that one was not able to relax carrying a beeper that can give analarm at any time of the day, disorders cows suffered from, high maintenance and electricitycosts, high prices for quota reducing the possibility to increase capacity or difficulties to dealwith the financial aspect (Hoefman, 1998b). The unfulfilled expectations or undesiredimplications may have been due to the 'child diseases' of the system or to the fact thatinformation on the consequences of adoption was still scarce.A reason why a dairy farmer may be interested in robotic milking is the expectation of areduction in labour. The change in labour time after adoption is however difficult to estimate.

It is very different from farm to farm and largely dependent on the chosen managementfunctions, namely the system of cow traffic and the feeding system (from limited grazing tosummer feeding) (Devir*et al.*, 1997). Also the reliability of the technology, the level of useof the technology, the position of the AM-system in the stable, the herd size and the portion ofthe herd that cannot be milked automatically play a role. For example, Artmann and Bohlsen(2000) found that the labour time required on four farms with the AM-system ranged from127% to 54% in comparison to conventional milking in herringbone parlours. Although thisstudy was done on a very limited sample, it may give an indication of the largely varyingresults of labour time on AM-farms. Roovers (1999) stated that especially on one-personfarms, the labour time gained for work outdoors or for other farm activities will be limited.According to Artmann and Bohlsen (2000), an AM-system with a fully-functioning facilityand with consideration of a higher level of animal monitoring can create the possibility tosave about two-thirds of the time needed in conventional milking practices. According to astudy by Sonck (1995), the AM-system with human-controlled cow traffic applied during thewhole year and with an average milking frequency of three times a day results in physicallabour savings for milking of maximum 38% (or 470 hours/year). With computer-controlledcow traffic and cows kept indoor the whole year, a maximum reduction of 66% (or 821.3hours/year) is reached. These percentages exclude time needed for repair or unexpectedtrouble shootings. Other studies mention potential labour savings of 300 up to 950 hours ayear or as much as 2.6 hours a day for a herd size of 125 (Landbouwleven, 2000b; Dijkhuizen*et al.*, 1997). It is generally accepted that the physical workload will decrease after adoptionof an AM-system. Milking is classified in the category of light to moderately heavy labour(Belt, 1984). Health complaints a milker may have with back, neck and shoulders will bereduced by the introduction of an AM-system (Hildebrandt, 1989; Rossing*et al.*, 1997). Theamount of repetitive monotonous tasks strongly diminishes. This can be the main reason foran older farmer with physical problems to choose for the AM-system, namely to be able tocontinue farming in an easier way.

The farmer’s vision on labour organization is an important factor in the decision in favour oragainst an AM-system. Some farmers prefer to work in peak moments, whilst others prefer alighter, but more continuous load (Bart Sonck, personal communication). When milking inthe traditional way, a farmer is tied to fixed milking hours 7 days a week. Moreover, thetraditional milking hours are considered to be socially unfavourable. With an AM-system, thefarmer is relieved from the fixed daily milking times. The farmer has more freedom of timeplanning during the day, more flexibility and the opportunity to have a life-style more in linewith that of people working in other sectors. This may make an important difference for thefarmer’s social life. On the other hand, a robot user must be available 24 hours a day to solvepossible disturbances. Unpredictable interventions can be necessary when the system breaksdown or when abnormal cow behaviour blocks the activities of the AM-system. Theseinterventions will disturb the daily labour planning and even social activities of the farmer andhis family. This may cause stress to the farmer, especially when work of a high priority has tobe interrupted, and to the family life. The reliability of the AM-system will play an importantrole in this. The fact that one can get alarmed at any time of the day can be experienced asworse than the usual milking process (Sonck, 1995; Sonck, 1996). Some farmers only feelcomfortable working with a strict planning: to milk in the morning and in the evening and toexecute the other work in between the milking sessions (Hoefman, 1998a).In case of automatic milking, the contact with the cows is expected to be less intensive(Sonck, 1995). This idea can be one of the reasons not to buy a robot. Some farmers considerthe contact with their animals of major importance for their pleasure at work and see it as theloss of a major element in their stockmanship to give away the milking task to a robot. Withan AM-system, however, a good contact with and control of the cows remains very importantfor the health of the herd and consequently for a good technical result (Roovers, 1999). Onlygood care makes it possible to realise high productions in a justified way. A survey amongBelgian robot milkers showed that most farmers did not feel to have less contact with theircows. On the contrary, thanks to the robot they had more time to observe their cows and towalk between their cows (MML, 2000). Furthermore, the robot farmer can do his routinechecking at a moment of the day he chooses himself without having to milk at the same time.Physical environmental elements such as light, noise and climate are rather unfavorable in aconventional milking parlour. As the AM-farmer will spend less time in this unfavorableenvironment, the system can contribute to the health of the farmer (Sonck, 1996). In addition,milking conventionally is not without any risks according to statistics on accidents. Positiveeffects can be expected with the AM-system as there will be less direct contact with animals:the incidence of labour unfitness caused by milking activities will be rare.

Conclusions:

The aim of this paper is to discuss the impact of modran ways of farming on agriculturalproduction. Agricultural production cannot be isolated from the institutional, socio-economic andpolitical scene in which they are embedded. Both innovations are entirely coherent within theparadigm of the *second agricultural revolution of Modern Times*, since they consist in arefinement of the already existing techniques. The first studies show that both technologies offerpotential pecuniary benefits to farmers via increasing yields, and savings in management costsand input use. Moreover, the innovations also introduce some non-pecuniary benefits in the farmoperation due to their convenience in use and the increased flexibility in agricultural tasksthey provide.

On the other hand, both technologies entail new aspects complicating any assessment of theirassociated benefits and costs. The increasing involvement of the private sector in plantbreeding research implies that the traditional flow of public-funded research benefits fromfarmers to consumers does not hold any longer. Increased concentration in the seed marketallows the latter to take part in the rent creation process during the diffusion of agriculturalinnovations. Moreover, agricultural biotechnology and automatic milking innovations cannotbe studied without taking into account the influence they exert on the environment and animalwelfare. Finally, both technologies have shown to be prone for consumer opposition. Theobserved divergence of attitudes of different stakeholders in the technology diffusion chain ismaybe the result of a narrow view on technological innovations in the past. For a long time,agricultural technologies have been evaluated, solely based on its private benefit-cost ratio.Much emphasis was put on farm profitability and commodity price declines. In reality, theintroduction of new technologies has impacts far beyond the farm or the consumer alone.Some stakeholders are already absorbing externalities of technologies. The negative effectsor 'costs' of pesticides are currently 'paid' by the environment. This means that the marketoptimum of agricultural technological innovations does not include any guarantee for'sustainability' yet, since we may be excessively exploiting our natural resource base.Therefore, we might want to reconsider the conventional 'private' welfare framework ofagricultural innovations by including 'social values', like environment, society, consumerviews, and animal welfare, transforming it into a 'social' welfare framework.

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