13 Introducing Legumes into European Cropping Systems: Farm-level Economic Effects

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Abstract

Legume cultivation in Europe has declined in recent decades due to decreased farm-level economic competitiveness compared with cereal and oil crop production. The increase in soybean prices in recent years and the public benefits expected from diversified production systems are reasons to reconsider legumes in Europe. Farm-level economic assessments, based on gross margin analysis of individual crops, often underestimate the contribution that legumes make to the farm business. We addressed this deficit using assessments made at the crop rotation level. We explored the possibilities resulting from: (i) the consideration of the management and yield of subsequent crops; (ii) systematic cropping system design; and (iii) changed price relations for legume feed grain. We identified several situations where legume-supported crop rotations are competitive and can create economic and environmental win–win situations to support a sustainable intensification of European cropping systems.

Introduction

Legume production can protect and enhance public goods, including through reduced greenhouse gas and nutrient emissions, increased crop and associated biodiversity, and reduced resource requirements of cropping and animal feeding systems. In spite of these, the area cultivated with legumes has declined in recent decades (Bues *et al.*, 2013). A combination of drivers, including yield developments, public policy decisions and economic under-evaluation of the farm-level economic effects, has led European farming to specialize in cereal and oil crop production (Zander *et al.*, 2016).

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The current situation of legumes in Europe – main drivers

In Europe, the relative and absolute difference in grain yield between legumes and cereals is high (Bues *et al.*, 2013). Consequently, European farmers specialize in cereal production. Soy is imported to supplement these cereals in livestock feeds.

Furthermore, grain legume yields fluctuate more than most cereals (Cernay *et al.*, 2015). The gross margins of pea and faba bean were more volatile than those of other crop types in three out of five case study sites across Europe (LMC International, 2009). Consequently, cereals occupy on average 54% of arable land in the European Union (EU) (average 2005–2011) compared with 35% in the USA and Canada (FAOSTAT, 2014).

Legumes also compete with other broadleaved crops, especially oilseeds, even though many oil crops have similarly low and unstable yields. The high demand for these oilseed crops is partly attributable to European bioenergy policy, which has strongly favoured the production of rapeseed in particular (Robles, 2011; Peri and Baldi, 2013). Rapeseed production expanded partly at the expense of legumes (Brisson *et al.*, 2010). Since oil is a higher value component than starch (De Visser *et al.*, 2014) and the residues of oil extraction also provide a protein-rich feedstuff, expanding rapeseed production reduces the demand for legumes on the feed market as well as the amount of land available for legumes.

Underestimation of the on-farm economic impacts of diversification in cropping

Simplified farm management, maximized utilization of machinery and established value chains enable higher financial gains from cereal-based systems. However, the resulting specialization comes at the cost of increased fertilizer and pesticide requirements. Crop diversification through legumes reduces the dependency on these external inputs and often increases the yield and cost-efficiency of subsequent crops (Kirkegaard *et al.*, 2008; Peoples *et al.*, 2009a). These 'pre-crop effects' include the provision of nitrogen derived from biological nitrogen fixation to the subsequent crops (see e.g. Peoples *et al.*, 2009b, or Reckling *et al.*, 2014a) and the phytosanitary impact of breaking a sequence of similar crops (typically cereals) reduce disease, weed and pest risks (Robson *et al.*, 2002). Longer and more diverse rotations prevent the build-up of pathogens, particularly soil-borne root diseases such as take-all in cereals and clubroot in rapeseed. Legumes also have the potential to improve the structure and other quality parameters of soils (Leithold *et al.*, 1997; Jensen and Hauggaard-Nielsen, 2003; Peoples *et al.*, 2009b; Jensen *et al.*, 2011).

Approach

A combination of agroeconomic drivers (yield developments) and public policy has thus led to a focus on cereal and oil crop production in Europe. However, as the price of soy imports and the relevance of diversification increase, the economic drivers behind specialization weaken. Our analysis is focused at the farm level, where decisions about growing legumes are taken. We therefore discuss the relevance of different economic indicators using literature and case studies, and illustrate trade-offs between economic and environmental performance and the potential to raise the on-farm economic value of legume grain through on-farm use or niche marketing.

Limitations of economic indicators

A classical and simple indicator of the economic competitiveness of a certain crop is the gross margin, calculated by deducting all variable costs from the revenues received. It is suitable for comparing crops that have similar fixed cost frameworks, such as machinery, buildings and management. It can be useful for comparing wheat and barley, for example, to help farmers decide which is the more profitable cereal to grow. In contrast, comparing cereals with tomatoes using gross margins would not be a good decision basis, because tomatoes require a completely different fixed cost base. In the case of legumes, a realistic assessment of the competitiveness of legumes requires consideration of the economic value of pre-crop effects. Hence the level of comparison needs to be raised to the level of the cropping sequence or even to the farm level to capture effects on fixed costs. A good compromise would be to include labour and fixed machinery costs into the analysis. However, to allow comparison with literature data, we limit our analysis to gross margins and their extension through the inclusion of pre-crop values or whole rotations.

Methods

We compiled yield and economic assessment data from the literature and conducted case studies in five geographic regions of the Legume Futures project. The literature included data from 29 experiments carried out in Europe that enabled the yield of cereals and rapeseed preceded by different pre-crops to be compared. Furthermore, the analysis included six studies comparing simple gross margins of legumes and non-legume crops and six studies comparing gross margins across similar rotations including and excluding legumes.

In the five case study regions, we conducted a structured expert survey in 2012/2013 to obtain crop production data on pre-crop and site-specific crop management and crop rotation rules using expert knowledge supplemented by statistical data. Emphasis was placed on pre-crop effects. The survey also specified several sub-sites for each region, such as different soil grades or lowland and highland, which determine yield levels and the range of suitable crops. The data were fed into a rotation generator to identify the full range of agronomically feasible rotations for each region and sub-site and to evaluate each rotation for economic and environmental performance.

Economic Evaluation from Crop to Rotation Level

To illustrate and address the economic value of legumes, we present, step by step, first the simple gross margin comparisons, then a review of the size and value of legume effects on subsequent crops, and lastly systematic economic evaluations for the case studies in a rotational context.

Crop-level profitability

Data from the Legume Futures survey revealed that legume gross margins ranged from −€322/ha in Brandenburg (faba bean) to +€574/ha in Sud-Muntenia (soybean) (Table 13.1). In Eastern Scotland, Västra Götaland and Sud-Muntenia, grain legumes had positive gross margins (i.e. they covered the direct costs of production). However, by comparing with data in Table 13.3, it is evident that they were competitive with wheat only in Sud-Muntenia. In contrast, gross margins were negative in Brandenburg and the Calabrian lowlands. Prices for grain legumes were comparable or slightly higher than those of cereals. In Germany for example, prices for grain legumes ranged between €102/t for faba bean and €182/t for pea, whereas prices for wheat were €165/t; in Calabria, legume prices of €250–260/t compared with a wheat price of €250/t. These price differences do not compensate for the lower yields.

A compilation of six studies (Preissel *et al.*, 2015) shows a similar picture: low and unstable yields and comparably low prices resulted in a considerable gross margin deficit of grain legumes compared with alternative crops in 12 European

Table 13.1. Economic evaluation of legumes across the case study regions in selected site classes. (From survey data from the Legume Futures project.)

Country, region	Site class	Crop	Yield (t/ha)	Price (€/t)	Revenue (€/ha)	Variable costs (€/ha)	Gross margin (€/ha)
Germany –	Loam[a]	Faba bean	4.0	102	408	730	–322
Brandenburg	Loam[a]	Narrow-leafed lupin	2.5	150	375	679	–304
	Loam[a]	Pea	3.0	182	545	749	–204
Italy –	Lowland[b]	Faba bean	1.6	250	400	560	–160
Calabria	Lowland[b]	Pea	1.2	260	312	487	–175
UK –	Grade 3	Faba bean	5.0	197	986	701	285
Eastern Scotland	Grade 3	Pea	4.0	240	960	714	246
Sweden –	Clay soil	Faba bean	3.1	168	521	397	124
Västra Götaland	Clay soil	Pea	3.0	207	621	455	166
Romania –	Chernozem	Pea	3.5	325	1138	828	310
Sud-Muntenia	Chernozem	Soybean	2.5	440	1100	526	574

[a]Local site class 2.
[b]Rain-fed systems.

sites ranging from €70/ha to several hundred euros per hectare at eight sites; they were competitive with cereals at only four out of the 12 sites.

Pre-crop value of legumes

These crop-level gross margins do not take into account the pre-crop effects of the legumes. A meta-analysis of 29 experiments in Europe (Preissel *et al.*, 2015) showed that, where the yield of cereals following grain legumes was compared to that of cereals after cereals, a consistent yield difference of 0.5–1.6 t/ha was observed at both moderate and high fertilization levels. However, when cereals following grain legumes were compared to those following other broadleaved pre-crops, small yield increases of 0.1–0.4 t/ha were observed at moderate fertilization levels (up to 90 kg N/ha), but not at high fertilization levels (100–200 kg N/ha). Thus, the pre-crop effect of legumes on subsequent crop yield is similar to that of other broad-leaved crops in intensive production systems. In Mediterranean water-limited sites, overall yield levels as well as legume effects are smaller (López-Bellido *et al.*, 2012). Mediterranean cereals often yielded 0.2–1.5 t/ha more after grain legumes than after cereals or sunflower. This yield increase in the subsequent cereal is worth between €20/ha and €300/ha compared with cereals in temperate sites (assuming a moderate wheat price of € 200/t). Prices play a crucial role in the overall evaluation.

Reduced costs in subsequent crops have a smaller effect on economic performance compared with increased revenue. In Europe, nitrogen fertilization of subsequent crops can be reduced by an average of 23–31 kg/ha without any yield losses (compiled in Reckling *et al.*, 2014a and in Preissel *et al.*, 2015). This would amount to cost savings of €18–24/ha at 2012 prices (for urea averaged over several countries; Eurostat, 2015a). Where nitrogen fertilizer use is restricted, nitrogen fertilization to subsequent crops can be reduced further by 62 kg/ha on average across estimates while maintaining adequate yields (i.e. the same yield as if the crop was grown following a cereal) (compiled in Preissel *et al.*, 2015). The ability of legumes to reduce weeds and diseases in subsequent crops has the potential to reduce costs by up to €50/ha (Luetke-Entrup *et al.*, 2003; von Richthofen *et al.*, 2006; Jensen *et al.*, 2010). Most break crops have the potential to improve soil structure, creating better establishment conditions for subsequent crops with less tillage and potentially saving about €20–60/ha in fuel costs (Luetke-Entrup *et al.*, 2003; Alpmann *et al.*, 2013a). The highest cost reductions can be achieved where legumes are grown in combination with reduced tillage, leading to potential cost reductions of €70–125/ha when reductions of fixed costs for machinery endowment and labour costs are included (Luetke-Entrup *et al.*, 2003). Table 13.2 summarizes these different potential effects.

As Table 13.2 shows, the impact of break crops is very variable depending on the situation and on the willingness and ability of farmers to diversify their cropping system. Whether these rotation-level effects fully compensate for the frequently lower gross margins of legumes depends on the environmental conditions, prices and crop management. Notably, legume rotational crop effects are similar to other break crops, so competition between legumes and these other break crops is a significant factor in determining farmers' cropping choices.

Table 13.2. Potential economic effects of grain legumes on subsequent winter wheat in temperate sites.[a]

	Compared with cereal pre-crops		Compared with other break crops	
Effects on subsequent crops	Quantities per ha	Monetary value (€/ha)	Quantities per ha	Monetary value (€/ha)
Yield effects in subsequent cereals	+100 to +1500 kg	20–300	Up to +300 kg	< 60
Reduced N fertilization	By 23–31 kg N	18–24	By 23–31 kg N	18–24
Savings in weed and disease management	One to two treatments	< 50	No extra increase	–
Savings from better machinability		20–60		20–60
Savings from reduced tillage		70–125		70–125
Total range		130–560		38–209
Comparison: Legume futures Case studies		106–296		No effect

[a]Prices are moderate assumptions based on 2012 data: wheat €200/t, N fertilizer €1.27/kg.

In the Legume Futures case studies, gross margins that take into account the pre-crop effect were calculated for all crops, confirming the pre-crop value based on literature estimates. Gross margins of winter wheat grown after grain legumes or rapeseed ranged from €322/ha to €689/ha (Table 13.3), and were €106–188/ha higher than after a cereal crop (€296/ha in Sud-Muntenia). Winter wheat grown after forage legumes generated additional gross margins of €116–301/ha.

Rotation-level profitability

A reliable estimate of legume profitability should compare the gross margins of full rotations. To represent the range of possibilities for sites, we generated a large number of feasible crop rotations using a crop rotation generator that takes rotational restrictions into account (see Reckling *et al.*, 2016a; Table 13.4). For a small number of sites we were unable to generate systems without legumes due to agronomic restrictions and a lack of crop combinations. For Romania, we excluded the most profitable rotations as these included common bean, a specialized food crop that only a few farmers could grow with specific marketing contracts.

Environmental and agronomic factors had a strong effect at all sites. Legume-supported rotations performed best compared with non-legume rotations in Romania, with an average advantage of €22/ha/year. They also had an advantage in the UK, with €6/ha/year and €10/ha/year on two soils suited to arable cropping. We found even greater advantages for a small number of Romanian

Table 13.3. Gross margins (GM) of winter wheat grown after cereals and legume pre-crops across the case study regions in selected site classes.

Country, region	Site class	Pre-crop type	Yield (t/ha)[a]	Price (€/t)[b]	Revenue (€/ha)	Variable costs (€/ha)	GM (€/ha)	Additional GM (€/ha)
Germany –	Loam[c]	Cereal	5.7	165	942	779	162	0
Brandenburg	Loam[c]	Grain legume	6.8	165	1123	801	322	160
	Loam[c]	Forage legume	6.8	165	1123	801	322	160
Italy –	Lowland[d]	Cereal	3.2	250	800	626	175	0
Calabria	Lowland[d]	Grain legume	3.5	250	875	530	345	171
	Lowland[d]	Forage legume	3.6	250	900	530	370	196
UK –	Grade 3	Cereal	7.5	186	1395	986	409	0
Eastern Scotland	Grade 3	Grain legume	8.0	186	1488	973	515	106
	Grade 3	Forage legume	8.0	186	1488	963	525	116
Sweden –	Clay soil	Cereal	6.1	188	1147	645	501	0
Västra Götaland	Clay soil	Grain legume	7.1	188	1335	645	689	188
	Clay soil	Forage legume	7.7	188	1448	645	802	301
Romania –	Chernozem	Cereal	3.6	232	835	688	147	0
Sud-Muntenia	Chernozem	Grain legume	5.0	232	1160	717	443	296

[a]Yields are assessments by regional experts.
[b]Prices of wheat are farm-level prices as given by the regional surveys.
[c]Local site class 2.
[d]Rain-fed systems.

rotations including common bean as a food crop and a small number of rotations under irrigation in Calabria (not shown). In Västra Götaland and Brandenburg, legume-supported rotations had €20–40/ha/year lower gross margins. In rain-fed sites in Italy, gross margins were up to €108/ha/year lower. Gross margins of arable systems were lowest in the German cases and highest in the UK cases for both legume-supported systems and systems without legumes. In Brandenburg, arable cropping systems on sandy soils had, on average, negative gross margins because of poor site productivity.

In forage systems, legume-supported rotations had an average advantage over rotations without legumes in all three regions where this comparison was possible (Table 13.4). Differences between regions were lower than in arable systems. The regional averages of the gross margins in forage legume rotation were €4–103/ha/year higher than those of the non-legume rotations.

Six other studies used rotation gross margin analysis to evaluate cropping systems (Table 13.5). Their results align with ours. Legumes were especially competitive in three Spanish case studies due to the low profitability of alternative crops, and in three French case studies. In Denmark and Switzerland, the studies identified no competitive grain legume rotations, as did our research for Sweden. For the UK, comparing the studies with our research (Table 13.4) yields a mixed result. In Germany, they identified competitive legume production in one organic and several conservation tillage systems, but only one competitive

Table 13.4. Generated rotations and the ranges of their gross margins across the case study regions and site classes.

Country, region	Sub-site	With/without legume	No. of rotations	Gross margin (€/ha/year) Min	Max	Av.[a]	Average difference
Arable crop rotations							
Germany – Brandenburg	Loam[b]	– Legume	28	69	315	131	
		+ Legume	65	–3	214	76	–40
	Sand[c]	– Legume	18	–175	68	–3	
		+ Legume	35	–194	55	–24	–20
Italy – Calabria	Lowland[d]	– Legume	6	171	267	225	
		+ Legume	281	–15	233	116	–108
Sweden – Västra Götaland	Clay soil	– Legume	3,191	343	644	451	
		+ Legume	19,077	320	593	415	–36
UK – Eastern Scotland	Grade 1–2	– Legume	3,938	426	1,455	985	
		+ Legume	16,079	425	1,544	995	10
	Grade 3	– Legume	2,135	181	872	603	
		+ Legume	8,802	194	910	609	6
Romania – Sud-Muntenia	Chernozem	– Legume	20	272	432	369	
		+ Legume[e]	156	238	518	391	22
Forage-oriented rotations							
Germany – Brandenburg	Loam[b]	– Legume	374	59	429	185	
		+ Legume	792	92	462	217	22
	Sand[c]	– Legume	89	–35	262	80	
		+ Legume	343	–69	365	176	103
Italy – Calabria	Lowland[d]	– Legume	–	–	–	–	
		+ Legume	136	75	287	177	–
UK – Eastern Scotland	Grade 3	– Legume	23	638	922	737	
		+ Legume	20	660	874	746	9
	Grade 4	– Legume	8	372	502	423	
		+ Legume	10	389	572	465	42
Sweden – Västra Götaland	Clay soil	– Legume	136	430	590	481	
		+ Legume	132	311	614	485	4

[a]Average over all rotations with and without legumes, respectively, generated for a specific sub-site.
[b]Local site classes 1–2.
[c]Local site classes 3–5.
[d]Rain-fed systems.
[e]Excluding common bean.

legume rotation in conventional production systems. These results partly align with observed production trends in these countries (FAOSTAT, 2014): grain legume production areas reduced slightly in Romania and Spain (17% reduction in 2000–2012), moderately in the UK, Italy, France and Germany (20–50% reduction) and substantially in Sweden and Denmark (50–80% reduction). The 40% increase in grain legume areas in Switzerland is not explained by these results, and the assessments do not adequately represent countries where production areas have increased since 2000 (mostly Eastern European countries).

Table 13.5. Competitiveness of legume-supported crop rotations with those not containing legumes according to modelled rotation gross margins. (From literature review by Preissel *et al*., 2015.)

Region	Number of grain legume rotations compared: Total	Competitive[a]	Not competitive[b]	Reference
Germany: Bavaria (organic farming, food soy)	2	2	–	Weitbrecht and Pahl (2000)[c]
Denmark: Fyn	2	–	2	von Richthofen *et al.* (2006)[d]
France: Barrois, Picardie	2	2	–	von Richthofen *et al.* (2006)[d]
Germany: Saxony-Anhalt, Lower Bavaria	3	1	2	von Richthofen *et al.* (2006)[d]
Spain: Castilla y Leon, Navarra	3	3	–	von Richthofen *et al.* (2006)[d]
Switzerland: Vaud	1	–	1	von Richthofen *et al.* (2006)[d]
France: Burgundy, Moselle, Beauce	14	11	3	Hayer *et al.* (2012)[d]
France: Eure et Loir, Seine Maritime	2	2	–	LMC International (2009)[e]
Germany: Lower Saxony	2	–	2	LMC International (2009)[e]
Spain: Castilla-La Mancha	1	1	–	LMC International (2009)[e]
UK: East Anglia	2	–	2	LMC International (2009)[e]
Germany: Bavaria, Westphalia, Mecklenburg (plough and reduced tillage)	8	5	3	Luetke-Entrup *et al.* (2006)[c,d]
Spain: central (plough and reduced tillage)	3	3	–	Sánchez-Girón *et al.* (2004)[c,d]
Total	45	30	15	

[a]Average annual gross margin of grain legume rotation is higher or less than €10/ha lower than that of non-legume rotation.
[b]Average annual gross margin of grain legume rotation is more than €10/ha lower than that of non-legume rotation.
[c]Based on experimental results.
[d]Optimistic estimates of pre-crop effects: yield effect on first subsequent crop, N fertilizer saving, further cost savings due to reduced tillage.
[e]Conservative estimates of pre-crop effects: yield effect on first subsequent crop, some N fertilizer saving.

The comparison of the crop- and rotation-level profitability measures illustrates that crop-level comparisons neglect a sizeable share of the profitability of legumes and rarely find them competitive with other crops. The following section shows how crop choice can be fine-tuned for local conditions and the likely environmental impacts of competitive crop rotations with legumes.

Environmental Impact of Profitable Legume Rotations

Legume-supported cropping sequences are more economically viable than conventional gross margin analysis indicates. This leads to questions about the environmental impact of choosing economically competitive legume-supported cropping systems. Table 13.6 provides a comparison between the most economically viable rotations with and without legumes for their impact on nitrate leaching and nitrous oxide (N_2O) emissions (methods are described in Reckling *et al.*, 2014b).

The results show economic–environmental win–win situations for legumes in Eastern Scotland; while minor trade-offs compared with the most profitable non-legume cropping systems occur in Brandenburg and Sud-Muntenia. In Scotland, the legume rotation with faba bean substantially improves income and environmental impacts compared with the optimum without legumes. In Brandenburg, the legume rotation achieved only marginally lower income while substantially reducing emissions by 21% for nitrate and by 25% for nitrous oxide. In Sud-Muntenia, a legume rotation with soybean increases income and reduces nitrous oxide emissions, with a slight negative effect on leaching.

In contrast, in Västra Götaland and Calabria, even the most profitable legume rotations are economically poorer than rotations without legumes, while they lead to divergent environmental impacts. In Västra Götaland, the rotation with faba bean brings a sizeable loss of income compared with a rotation with linseed and no reduction in nitrate leaching, although nitrous oxide emissions are lower. In the Calabrian lowlands, the legume rotation would mean a sizeable income loss, while increasing leaching but substantially reducing nitrous oxide emissions.

When economic–environmental optimum rotations with legumes were compared with current farming (without legumes), these performed economically and environmentally better in Västra Götaland, Sud-Muntenia and Eastern Scotland (Reckling *et al.*, 2016b). Overall, the impact of the most profitable legume rotations on nitrate-N leaching was very site-specific and determined by the crop management, while nitrous oxide (N_2O) emissions were reduced by 12–35% in all selected legume-supported rotations compared with cropping systems without legumes. Our case studies showed highly positive environmental impacts for forage systems with legumes, but their economic assessment is highly complex and beyond the scope of this chapter. Reckling *et al.* (2016b) concluded from their analysis that legumes provide benefits to both the economic and the environmental performance of forage systems.

This assessment highlights that systematic cropping system design can be used to identify cropping systems with minor trade-offs or even win–win situations for improving the environmental performance of cropping. The assessment approach can also be used to identify and select those generated rotations that perform best in relation to specific indicators, such as rotations with the lowest emissions or highest N efficiencies, to provide a range of options for sustainable intensification of cropping systems in the case study regions.

Table 13.6. Comparison of most profitable legume and non-legume rotations, respectively, for arable production across the case study regions in selected sub-sites.

Country, region (sub-site)	Non-legume rotation	Gross margin (€/ha/year)	Legume rotation	Gross margin (€/ha/year)	Difference of legume to non-legume rotations[a]: Gross margin (€/ha/year)	Nitrate-N leaching (%)	Emission of N_2O (%)
Germany – Brandenburg (loam[b])	Rapeseed, wheat, winter barley	128	Rapeseed, wheat, rye, rye, pea	111	–17	–21	–25
Italy – Calabria (lowland, rain-fed)	Rapeseed, wheat, rapeseed, wheat	267	Rapeseed, wheat, rapeseed, wheat, faba bean	233	–34	+16	–20
UK – Eastern Scotland (grade 3)	Rapeseed, winter barley, winter barley, winter barley, winter oat	509	Rapeseed, winter barley, winter oat, faba bean, winter barley	547	+38	–14	–8
Sweden – Västra Götaland (clay soil)	Rapeseed, wheat, linseed, wheat, spring barley	644	Rapeseed, wheat, faba bean, wheat, spring barley	593	–51	±0	–35
Romania – Sud-Muntenia (Chernozem)	Rapeseed, maize, wheat	432	Rapeseed, soybean, maize, wheat	518	+86	+7	–20

[a]Positive values signify a higher impact of the legume-supported rotation.
[b]Local site class 2.

Potential for Increasing the Economic Value of Legume Grain

Although the competitiveness of legumes as crops is better than often estimated, the relatively low market value of the grain still discourages their production. There is an increasing potential for obtaining higher prices for legume grain by exploiting local feed markets. European-grown legume grain is under-valued in feed markets. A mix of locally grown legume grains and cereals is often cheaper than an equivalent mix of soybean and cereals. This gap has been explained by compounders' preference for the larger and more homogenous quantities offered by international traders (Sauermann, 2009; LLH, 2012; Alpmann *et al.*, 2013b). The purchase price for soybean meal almost doubled between 2006 and 2012 while the purchase prices for feed wheat increased at a lower rate (Fig. 13.1). Aramyan *et al.* (2009) predicted further increases in the prices of soy in markets that require genetically modified (GM)-free produce. Although changes in pea prices reflect changes in the price of soybean and wheat (LMC International, 2009), European pea and faba bean producer prices did not fully follow the price increases of soy-based feed ingredients. Consequently, the incentive for using pea or beans as locally grown feedstuff has increased. This is shown using a German feed calculator for pork feed ingredients (LLH, 2012). For given wheat and soybean purchase prices, this feed calculator computes the equivalent economic value of other products such as pea and faba bean on the basis of their most important contribution to pig feeds, namely the essential amino acid lysine and metabolizable energy.

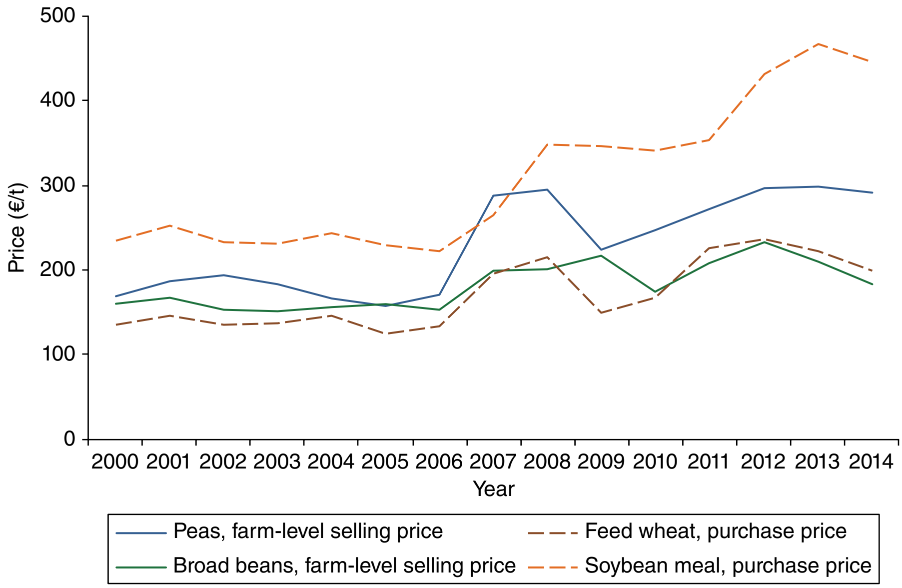

Fig. 13.1. Changes in the purchase prices of soy- and wheat-based feed and farm-level selling prices of major feed grain legumes in Europe. (From Eurostat, 2015a, b.)

Introducing the purchase prices for feed wheat and soybean meal into the calculator shows that, since around 2010, the equivalent economic value of pea and faba bean for pig production is considerably higher than the prices that the farmer would receive for selling those products (Fig. 13.2). In 2014, the difference between the value based on feed characteristics and the market price was more than €100/t (+55%) for pea and €28/t (+10%) for faba bean. In the German case study example, this surplus would raise pea gross margins to a positive value (see

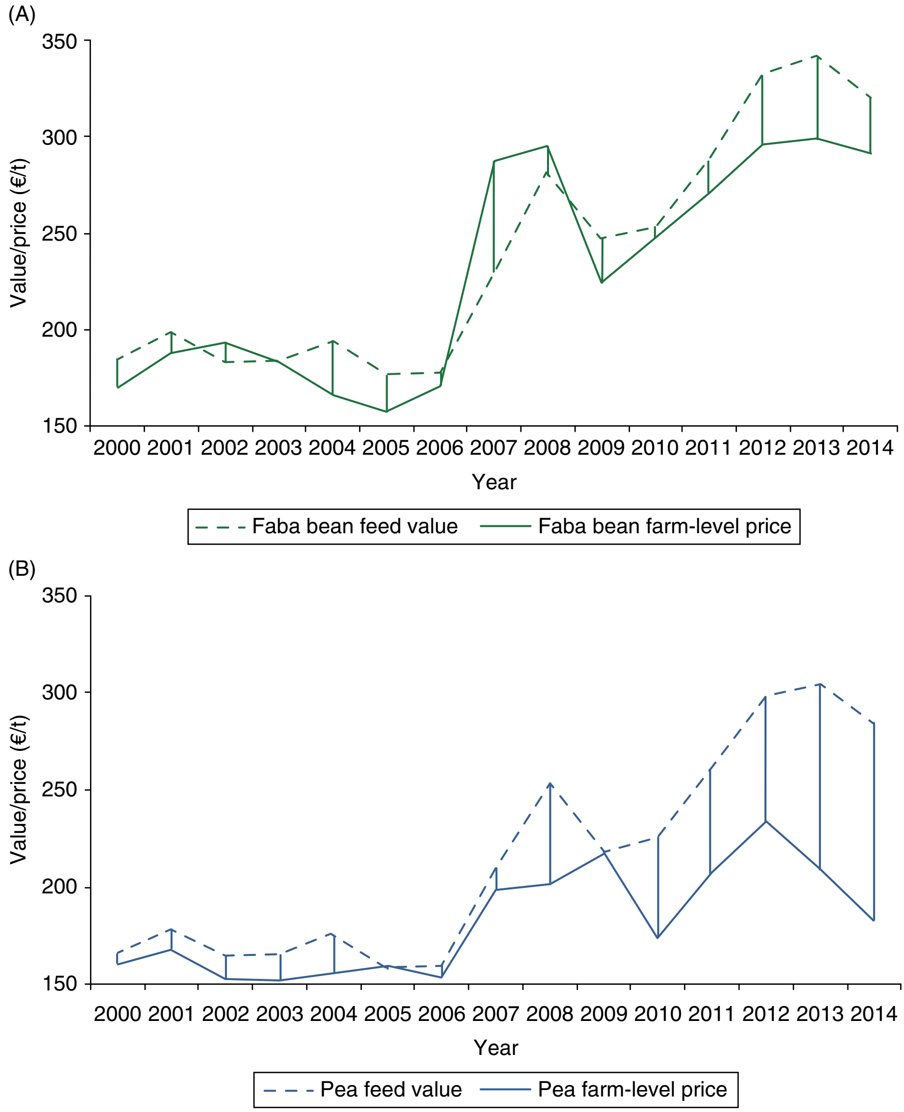

Fig. 13.2. Changes in farm-level (crop selling) prices and calculated feed value based on farm purchase prices for alternative feed ingredients (according to LLH, 2012) for faba bean (A) and pea (B), based on prices from Eurostat (2015a, b).

Table 13.1). Marketing legumes outside the feed sector holds further potential for improving their crop-level economic value. There are high-quality and high-price niches for legumes. Examples include the use of lupin in a number of new food products, such as PlantsProFood (Pro Lupin, 2014), or the non-food sector, including renewable resources for biorefineries (Papendiek *et al.*, 2012; Papendiek and Venus, 2014).

Conclusions

There is an economic under-valuation of legumes due to the lack of consideration of their wider effects in cropping systems. European-grown pea and faba bean are often under-valued in markets in relation to their feeding value. Thus, our calculations show that the economic value of legumes is substantially higher than commonly perceived. Legume-supported systems performed economically well where:

- the use of nitrogen fertilizers is restricted (e.g. organic farming, water protection areas);
- legume grain has a high value (e.g. soybean, grains for food uses, grain for local or on-farm feeding);
- other broadleaved crops are not particularly profitable (e.g. in parts of Spain); and
- grain legumes support effective reduced-tillage systems.

Through systematic cropping system design and economic evaluations at rotation level, we identified a number of cropping systems with the potential to improve both economic and environmental performance compared with standard rotations, which would not be identified using standard gross margin analysis.

Beyond these farm-economic (private) implications of legumes, we identified environmental (public) benefits of legumes that are not always recognized. A comprehensive assessment of entire supply chains could help to identify further levers for developing legume cropping and use. Increasing prices of nitrogen fertilizers and of soy imports will slightly improve the competitive situation of legumes, but this alone will not tip the balance to more diversified production systems throughout Europe. As the competitive advantage of cereals and oil crops is a result of technical and policy efforts in recent decades, we expect that similar efforts could raise the competitiveness of legumes to a similar level.

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