Chapter 6

The Metabolism of Spanish Agriculture

In the previous chapters, we studied the evolution of each fund element. We will now try to examine them in an integrated fashion to understand the metabolic dynamic and its drivers. First, however, it is necessary to know the biomass demands of the Spanish economy and society as well as how the agrarian sector fulfilled them. This requires an analysis of domestic consumption and of the role played by foreign trade in its evolution. In a country with a long export tradition like Spain, this is essential. The objective is to characterize the structure, functioning, and dynamics of Agrarian Metabolism (AM), taking into account its place in the metabolism of the Spanish economy as a whole, based on its main indicators and its behavior in relation to domestic consumption. Next, we will try to analyze the biggest drivers of the agricultural sector's metabolic activity, both on the supply side and demand side. The analysis reveals at least four differentiated periods in the biophysical evolution of Spanish agriculture.

6.1 The Agrarian Sector in the Metabolism of the Spanish Economy

What happened in Spanish agriculture cannot be disassociated from the economy as a whole and, therefore, from the final uses of the animal and vegetable biomass that society has demanded. In two recent studies, we analyzed the metabolism of materials in the Spanish economy between 1860 and 2008 (Infante-Amate et al. 2015) and examined the role played by biomass throughout the twentieth century (Soto et al. 2016). As has happened with developed countries, Spanish industrialization was accompanied by an accelerated increase in the consumption of materials, both in absolute terms and per capita, thanks mainly to the growing extraction of abiotic materials. On a global scale, it was at the end of the 1950s when the extraction of abiotic exceeded the extraction of biomass, according to the data composed with the EW-MFA methodology (Kraussman et al. 2009). In Spain, the growth of the

consumption of materials was equally important but also experienced a certain lag in time. The great transformation of the country did not take place until the 1960s, both in terms of extraction and consumption of resources (Infante-Amate 2015). The per capita direct consumption of materials in Spain was almost 20% lower than the world average in 1960. In 1970, it was similar and in the year 2000, the consumption of Spanish materials already doubled the global average (Krausmann et al. 2009; Infante-Amate et al. 2015). The transition was not, as happened in England or the USA (Schandl and Schulz 2002; Gierlinger and Krausmann 2012), an unhurried process but a swift one. Its patterns match well with countries called latecomers, which went through industrialization in a much faster way than firstcomers did, also in biophysical terms (Krausmann et al. 2009). In this sense, the first phase of the metabolic transition was a “weak transition”, characterized by significant qualitative changes, though without any notable transformation in quantitative terms.

From the point of view of the Domestic Extraction (DE) of materials, it went from 58.9 million tons (Mt) in 1860 to 422.6 Mt in 2010, multiplying by 7.2 (Graph 6.1). The DE was multiplied by 1.4 between 1860 and 1950, while between 1950 and 2008 it did so by 5, mainly due to the growing weight of abiotic materials. The biomass remained relatively stable, with extreme values of 49.5 Mt (1900) and 68.5 Mt (2008), while the inorganic materials grew significantly: in 1860, the DE of these materials barely amounted to 1.2 Mt, in 1950 to 23.7 and in 2000, the year in which the historical maximum was reached, it was 425.7 Mt. From the middle of the XIX century and until the first decades of the XX century most of the extraction of abiotic products was due to metallic materials, mainly to iron ore that was exported to industrialized countries, especially to England. Still in 1910, the iron exported to that country accounted for almost 50% of the national extraction. Until Franco’s autarky, when there was a blackout of international trade in the country, Spain was, therefore, a net exporter of resources, mainly minerals destined for the industrialized countries. Since 1920, energy products replaced metallic minerals in extractive importance. Its extraction continued to increase until 1990 when the peak was reached with 38.6 Mt. Since then it has continuously decreased to 8.3 Mt in 2010, a figure lower than that of 1940. From the sixties, the prominence has corresponded to the quarry products that have grown continuously until now accounting for almost 90% of the total DE of the country. They passed between 1860 and 2010 from 0.06 Mt to 342.1 Mt. These materials reflect the strong growth experienced in the last decades of the twentieth century, and until the economic-financial crisis, by the Spanish real estate sector, and that these goods were used in construction and to a lesser extent in the country’s own industrialization (Graph 6.1).

In any case, until the beginning of the sixties the extraction of abiotic materials did not surpass the biotic ones. Until that time, the metabolism of the Spanish economy remained essentially “organic”, although the relative share of biomass in the overall metabolism of the Spanish economy declined steadily throughout the twentieth century. In 1860, 97.9% of the extraction was biomass, while in 2008 it only represents 16%, a pattern shared with the developed countries. Paradoxically, the biomass DE has not stopped growing, as we have seen in Chap. 2, stimulated by a growing and

Graph 6.1 DE in millions of tons (a), DE in percentage (b), Imports (positive), exports (negative) and total PTB (c) and PTB per inhabitant of biotic, abiotic and total, in tons per inhabitant and year (d).
Source Infante-Amate et al. 2015

specialized demand. This evolution is coincident with the evolution of the DE on a planetary scale (Krausmann et al. 2009).

On the other hand, the integration of the Spanish economy in international markets has also gone through two periods that should be retained. A first period comprises from mid-nineteenth century to mid-twentieth, when trade flows were little significant but growing (with stoppages due to historical junctures such as the First World War and the Great Depression) to suffer a kind of widespread commercial blackout during the First Francoism. This was due to the autarkic policy that cut the incipient economic dynamism of the country. The second begins in the sixties and is characterized by the progressive integration of the Spanish economy in international circuits of materials, both biotic and abiotic, to a large extent depending on them. Total exports went from 0.5 Mt in 1860 to 132.6 Mt in 2010, and imports from 0.4 to 245.9 Mt. Here also there was a significant change in the composition of trade flows: in 1860 a 20% of both exports, and imports were biotic and the remaining 80% were abiotic. Although DE was then concentrated in agricultural products, the country's trade was focused on metals, energy products, and other minerals. In recent years, both exports and imports of biomass represent only between 8–14% of total sales.

The Physical Balance of Trade (PTB) shows the changing behavior of the Spanish economy. As we have said, Spain was a net exporter of materials until 1950 and, since then, it has been a net importer in increasing magnitudes. During the second half of the nineteenth century and much of the first half of the twentieth century, we saw that most of the national production of iron was sold to other countries. The trend changed in the second half of the twentieth century. Exports grew substantially, but imports did so at a much higher rate, both biotic and abiotic. The transition to a globalized economy became, rather quickly: in 1950 the PTB was 0.2 Mt, while in the year 2000 it was 126.5 Mt, going from 0.01 to 3.1 t/inhab/year. (Graph 6.3, Table 6.1).

The changes in the DE and in the PTB explain the behavior of the domestic consumption of materials of the Spanish society (Graph 6.2), which like all of the developed West has experienced a very significant increase, especially in the second half of the twentieth century. This pattern corresponds to the so-called Great Acceleration of the consumption of energy and materials (Constanza et al. 2007). Between 1860 and 1950 the DC grew moderately, going from 58.7 to 85.5 Mt. The population increase made that there was even a fall in consumption by inhabitant: the DMC per capita went from 3.8 to 3.1 t/inhab/year. During this period, most of the materials mobilized were logically of biotic origin. But during the second half of the twentieth century, consumption multiplied, putting pressure on the DE and causing resources from other countries to flow into Spain, that is, the PTB became more and more positive. In this way, the DC went from 85.5 Mt in 1950 to 619.8 Mt in 2000 and from 3.1 t/inhab/year to 15.2. Due to the economic crisis, consumption fell to 11.6 t/inhab/year in 2008 (Table 6.1, Graph 6.3).

Table 6.1 Indicators of the metabolic profile in Spain

		1860	1950	2000
Population	Millions	15.6	28.0	40.7
GPD/capita	000\$ 1990	1.2	2.3	171.5
DEpc	t/capita	3.8	3.0	12.1
<i>Biotic</i>		3.7	2.2	1.7
<i>Abiotic</i>		0.1	0.8	10.5
PTB	t/capita	−0.0	0.0	3.1
<i>Biotic</i>		−0.0	0.0	0.4
<i>Abiotic</i>		−0.0	0.0	2.7
DMC	t/capita	3.8	3.1	15.2
<i>Biotic</i>		3.7	2.2	2.1
<i>Abiotic</i>		0.1	0.9	13.1
Biomass/total DMC	%	98.1	72.1	13.6

Source Infante-Amate et al. 2015

6.2 Foreign Trade and Domestic Consumption of Biomass

What role has the agricultural sector played in the dynamics that we have just seen? As we have seen, the growth of consumption has been based on abiotic materials, relegating biomass to a secondary place. The consumption of biomass per capita has decreased in line with this, but this has not meant a reduction of the biomass consumed in absolute terms, as we have seen, but quite the opposite. The demand for biomass has also grown throughout the twentieth century for various reasons that we will have occasion to analyze with particular intensity in its second part. Next, we will focus on the evolution and composition of the biomass DC and to what extent the supply came from the DE or foreign trade.

Against the traditional belief, Spain has not been an agro-exporting country if viewed from the biophysical point of view since it has received more biotic products than it has exported. To a large extent, this is due to the fact that the main exports of Spain were composed of fruit and vegetable products, with a high water content and therefore with a much lower dry weight than abiotic materials or imported biomass. Even so, the percentage of biomass traded in international markets was quite small compared to the total biomass ED. Despite this, the importance of foreign trade in biomass has increased significantly. Total imports went from 0.8 to 31.9 Mt between 1900 and 2008. Exports from 0.5 to 12.7 Mt. However, this growth has not been continuous throughout the century. Until the 1960s the weight of foreign trade was low, even contracted after 1933, but from 1970 there was an accelerated growth that has not yet stopped. There has also been a significant change in its composition: until the 1960s most of the biomass exports were concentrated in the category of human food and tended to diversify as of that date. In 2008, the main export categories were wood and firewood (especially wood), followed by human food and animal feed.

Graph 6.2 Total consumption, millions of tons (a) and consumption per inhabitant, in tons per inhabitant and year (b)

With regard to imports until 1933, about half were wood, while the main category between 1940 and 1960 was that of human food. Since 1970, imports of animal feed increased to almost half of the total imported biomass (42%) (Table 6.2).

The PTB shows that effectively and contrary to what the monetary values say, Spain has been a net importer of biomass throughout the period of our study. Only in some years between 1900 and 1970 has it exported more than it has imported into the food category with human destiny. Likewise, the weight of the PTB has been very insignificant until the 1960s, in such a way that the DC evolved in parallel with the DE between 1900 and 1960 (Graph 6.1b). The percentage of PTB on the DC oscillated between 0.9 and 2.4% during those years (with an extreme value of 0.1% in 1950). However, since 1970, the role of foreign trade in biomass DC has had an increasing importance, from 6.2% in that date to 22.2% in 2008. The greatest commercial integration of Spain in the last 40 years explains that the DC of biomass has grown at a higher rate (74%) than the DE (38%) between 1900 and 2008, from

Graph 6.3 Biomass trade and consumption. **(a)** PTB, Mt of dry matter **(b)** DMC, Mt of dry matter **(c)** Consumption per capita, Mt of dry matter **(d)** Net food balance, kilocalories per inhabitant per year.
Source Soto et al. (2016)

Table 6.2 Physical trade balance, Kt dry matter

	1900	1910	1922	1933	1940	1950	1960	1970	1980	1990	2000	2008
<i>Imports</i>												
Food	100	100	200	100	500	200	700	600	1100	2800	4400	6300
Feed	100	200	300	100	200	100	600	3000	6900	5600	10,400	13,300
Seeds	0	0	0	0	100	0	100	0	100	100	400	600
Wood and fuel wood	400	400	300	500	100	100	500	1300	1900	5200	9600	9800
Raw materials	200	200	300	300	100	100	300	300	500	600	1400	2000
Total	800	800	1200	1000	900	500	2200	5300	10,500	14,300	26,200	31,900
<i>Exports</i>												
Food	100	200	200	300	100	400	500	900	1100	1900	3700	4000
Feed	0	0	100	0	0	0	100	200	300	1400	1400	1900
Seeds	0	0	0	0	0	0	0	0	0	100	100	100
Wood and fuel Wood	100	100	100	100	0	0	100	300	1100	1800	4400	6200
Raw materials	100	100	100	0	0	0	0	100	300	300	400	500
Total	300	400	500	400	200	500	600	1500	2800	5400	9900	12,700
<i>Physical trade balance</i>												
Total	500	500	700	600	700	0	1600	3800	7600	8900	16,300	19,300

Source Soto et al. (2016)

50.0 to 86.7 Mt of dry matter. In other words, biomass consumption in Spain depended on the DE until the late 1960s. From that moment, it began to depend increasingly on imports. The Spanish consumption of biomass today represents a considerable percentage, 27.6%, of the NPP, seven points more than in 1900, but a part is actually extracted in other countries, given that the DE is a 21.8% of NPP produced by Spanish agroecosystems. The difference between the DE and the DC, which did not exist in 1900, stood at 18.3 Mt of dry matter in 2008, the highest of the period. This gap means that international trade contributes a fifth of domestic consumption, as we have seen (Graph 6.3).

6.3 The Main Indicators of Agrarian Metabolism

How did the agricultural sector respond to the consumption increase described in the section above? Despite international trade's increasing role, the bulk of the required biomass continued to be supplied by Spanish agroecosystems. To meet growing demand, it was necessary to expand Spanish agricultural metabolism by almost 50% (see Table 6.3). This was achieved not only by increasing net primary productivity but also by raising the share appropriated by society as seen in Chap. 2, as well as net biomass imports. Maximum relative extraction took place in the 1950s, coinciding with the end of traditional agriculture when production difficulties favored by Francoism encouraged maximum appropriation of biomass, in a context of falling yields. However, in absolute terms, the maximum volume of extracted biomass was reached in the year 2000, when almost seventy million tons of dry matter was obtained mostly from crops. Therefore, greater production efforts essentially concentrated in cultivated lands and in certain crops or livestock specialties. Indeed, DE growth was driven by cultivated land intensifications, increasing by 236% with respect to 1900. In contrast, the abandoning of pastures or their underusage, together with conservation and reforestation, with scarce biomass energy use, explain DE drops, respectively, by 46 and 17% in these lands since 1900. The NPP_{act} showed an opposite trend concerning the three major land uses from the perspective of human biomass appropriation: DE decreased by 17% per hectare in forests and by 81% in pastures, while it increased for crops. Such a remarkable growth in agricultural production can be explained not only by cultivated lands' productivity growth, but also by changes in biomass use patterns extracted from cropland, as seen in Chap. 2: productivity multiplied threefold for the main crops, but only grew by 40% relating to residues.

There has also been significant changes in the final use of DE. Biomass aimed at human food consumption increased from 9 to 14%, biomass aimed at raw materials went from 1 to 4% and biomass aimed at animal feed went from 56 to 57.5%, reaching two-thirds in the 1960s. Since that decade, around 40 million tons of dry matter per year have been used to feed livestock, despite the fact that animal traction is no longer used. This development can be explained by the Spanish agricultural sector's increasing orientations towards livestock and was especially visible in the case of cereals. The role of cereals as feed is heavier today than in 1900 when it

Table 6.3 Evolution of the indicators of Spanish agriculture metabolism, 1900–2008 in Mt of dry matter

	1900	1933	1950	1970	1990	2008
Imports (input)	0.03	0.3	0.4	2.8	4.3	4.7
Actual NPP	244.6	255.8	257.9	283.3	292.6	314.2
Unharvested biomass	183.4	184.3	184.2	203.5	202.9	222.1
Accumulated biomass	11.7	10.8	12	21.7	23.4	23.7
Domestic extraction (DE)	49.5	60.7	61.7	58.1	66.3	68.5
Reused biomass	28.4	37.6	39.9	35.8	41.3	41.9
Recycled biomass (Unharvested biomass + Reused biomass)	211.7	221.8	224.1	239.4	244.2	263.9
Socialized biomass (export)	21.5	23.7	22.4	23.7	27.7	30.6
Socialized vegetal Biomass	21.2	23.1	21.8	22.2	24.9	26.6
Socialized animal Biomass	0.4	0.6	0.6	1.4	2.8	4
Domestic Consumption (DC) (DE + Import-Export)	28.4	37.9	40.3	38.7	45.6	46.6
TMR (DE + I)	49.6	61	62.1	60.9	70.6	73.2
Metabolic profile (per capita)	1.5	1.5	1.4	1.1	1.2	1
TMR/per capita	1.1	1.3	1.3	1.3	1.5	1.6
1900 = 100						
Imports (input)	100	974	1168	8279	12.674	13.832
NPPreal	100	105	105	116	120	128
Unharvested biomass	100	100	100	111	111	121
Accumulated biomass	100	93	103	186	201	202
Domestic extraction (DE)	100	123	125	117	134	138
Reused biomass	100	132	140	126	146	148
Recycled biomass (Unharvested biomass + Reused biomass)	100	105	106	113	115	125
Socialized biomass (export)	100	110	104	110	129	142
Socialized vegetal Biomass	100	109	103	105	118	126
Socialized animal Biomass	100	159	160	406	800	1148
CD (DE + Import-Export)	100	133	142	136	161	164
TMR (DE + I)	100	123	125	123	142	148
Metabolic profile (per capita)	100	99	94	75	76	66
TMR/ha SAU	100	123	125	122	141	148

Source author's compilation

was still the basis of food. Biomass aimed at fuel followed an opposite trend: it represented 32% of total extracted biomass in 1900 and 21% in 2008, replaced by gas and electricity in households. As commented earlier, significant wastage was generated by the destruction of crop residues, which reached 3.6 Mt, i.e., 5.5% of DE in the 1990s. This squandering continues today.

Livestock has undergone a fundamental change. Livestock used to be organic-based and have close ties to the land, but it became industrial. Animals were mostly housed and landless. Therefore, livestock became much more dependent on feed supply and industrial inputs which mostly came from international trade. Total livestock increased sharply due to this transformation, from 54 million heads in 1900 to 838 million heads in 2008. Livestock composition, the destination of its products and services as well as its management and feeding thus significantly changed. In terms of liveweight, livestock size multiplied by 2.4, from 2.8 million tons at the beginning of the twentieth century (with peaks of around 3.4 million in the 1930s), to almost 7 million tons around 2008. These figures reflect a growing livestock specialization in poultry, pigs, and, to a lesser extent, cattle, mainly oriented towards the production of meat and dairy products. An illustration is the spectacular growth of Socialized Animal Biomass (SAB), which increased from 0.4 million tons of dry matter to more than 4 million, i.e., a multiplication factor of 11.5. This remarkable growth reflects the specialization in intensive livestock farming, which has generated big environmental impacts as described earlier, especially the increase of GHG emissions or the alteration of the nutrient flows caused by intensive livestock (Lassaletta et al. 2014).

In short, agroecosystems have undergone a profound change. They passed from agrosilvopastoral integration, where livestock and forestry agricultural activity was closely linked to the territory, to a growing segregation of land uses, causing links with the territory to break and the progressive substitution of internal flows by flows external to the sector, a significant portion of them coming from abroad (Infante-Amate et al. 2018). A large part of the pastures was abandoned or clearly underutilized and forested areas have grown either for commercial exploitation or for “conservation”. Traditional uses of these areas have diminished substantially. We can say that Spanish agriculture has specialized in a group of crops (fruit and vegetable production, olive groves) and in intensive livestock. Other agricultural activities have been abandoned or are being underutilized.

The behavior of Accumulated Biomass (AB) reflects this development. Its contribution to the NPPreal has been the largest of all, from 11.7 million tons of dry matter in 1900 to 23.7 million in 2008, more than doubling and occupying an increasing percentage of the NPPact, from 4.8 to 7.5%. Accumulated biomass in the aerial part of forests has been mainly responsible for this increase, multiplying by almost 20. This was due on the one hand to a threefold increase in forested areas, and on the other, because the use of firewood in Spanish forests was disappearing as the household energy transition progressed. The implementation of public conservation policies and the declaration of protected natural spaces also played a part. The case of Spain seems to fit with the so-called “Forest Transition” where forest areas grow at the cost of farmland. Academic literature associates this phenomenon with so-called *land sparing*, where one part of the territory is used so intensively that other parts,

especially those that cannot achieve very high yields, can be dedicated to forestry purposes. But it may also be due, as we shall see later, to soil imports from foreign countries.

Spanish society directly or indirectly appropriated a fifth (and currently almost a quarter) of all NPP_{act} . However, its interventions in the dynamics of agroecosystems have become more visible than at the beginning of our study period. Decisions on land uses have ended up directly affecting the rest of the non-appropriated biomass. Unharvested biomass (UB) grew by 21% in absolute terms throughout the period, but in relative terms, it was the type of biomass that contributed the least to the growth of total NPP, clearly below the average. Its evolution somewhat reflects the deterioration of the land fund element: in relative terms, its importance fell from 75% of the NPP_{act} in 1900 to 69.3% in 2008. This explains why Recycled Biomass (RcB) in agroecosystems grew generally less than DE, although the RcB increased. This drop was bigger in pastures and croplands.

The territorial imbalance described above and the breakdown of the internal loops of agroecosystems explain the importance that external inputs have acquired for the functioning of Agrarian Metabolism. As shown in Table 6.3, imports, i.e., materials imported from outside the agricultural sector, increased exponentially, from 0.1% of DC of materials, an insignificant figure, to 9.4% in 2008. Inputs from outside the agricultural sector increased 138 times in dry weight only; the weight was much bigger when taking into account embodied energy. Biggest increases in DE were precisely associated with phases of greater use and importance of external inputs. They currently represent 6.4% of the Total Material Requirement (TMR) of Spanish agriculture's metabolism. In fact, the agricultural sector's materials DC has increased by 64%, which is higher than DE growth; in turn, the TMR has grown by 48%, clearly showing today's comparatively higher cost of metabolic activity compared to that of the early twentieth century. However, the SVB, i.e., the plant biomass transferred to society, increased by only 26%, from 21 to 26 million tons of dry matter. This data clearly shows that the Spanish agricultural sector has specialized in livestock, responsible for the increase of both DC and TMR of agricultural metabolism, driven mainly by Reused Biomass (RB) and by feed imports.

The metabolic profile of the agricultural sector has declined sharply since 1900. In that year, the size of Spain's agricultural metabolism was 1.5 t of dry matter per capita. By 2008, it had fallen to 1 ton. There are two explanations for this drop: the growth of the Spanish population, which had multiplied by 2.5 by 2008, and, as we saw earlier, because of the partial outsourcing of the metabolic effort by importing energy and materials from outside the sector and even from outside the country. This behavior is common to other industrialized countries, despite the ever-increasing land costs of animal feed (González de Molina et al. 2017; Infante-Amate et al. 2018). Despite this, the metabolism of Spanish agriculture has increased its pressure on agroecosystems since the TMR/ha has risen by almost 50%, due to the intensification and specialization process.

Table 6.4 reflects the process of production intensification since 1900. Two distinct periods can be distinguished. The first period corresponds to the first half of the twentieth century, in which extraction of biomass intensified for all land uses, whether

Table 6.4 Evolution of productivity per hectare according to land uses (t/ha)

	1900	1933	1950	1970	1990	2008
DE/ha	1.1	1.3	1.3	1.2	1.4	1.5
DE crops/ha	0.5	0.7	0.6	0.9	1.2	1.1
DE primary crops/ha	0.2	0.4	0.3	0.5	0.8	0.8
DE pasture/ha of pasture	0.7	1.0	1.3	0.4	0.3	0.5
DE wood and firewood/ha of woodland	0.9	0.9	0.9	0.5	0.5	0.5
1900 = 100						
DE/ha	100	123	125	116	133	138
DE crops/ha	100	133	117	180	219	212
DE primary crops/ha	100	149	124	220	316	336
DE pasture/ha of pasture	100	144	186	57	48	69
DE wood and firewood/ha of woodland	100	110	103	61	56	60

Source author's compilation

for agricultural, forestry or livestock uses. This intensification was a logical response as the sector was still linked to the territory and depended on it for animal and human food as well as for providing raw materials to industry. It also depended on it to supply the bulk of domestic energy, i.e., to satisfy the basic needs of a population that had grown from 18 to 28 million inhabitants over the period. Except for some fertilizers that were already produced by the chemical industry based on non-renewable sources, these needs were largely met using biomass extracted from the territory; the economy was still of a basic nature and essentially organic, within a metabolic arrangement under industrial transition. The second period corresponds to developments from the 1950s to 2008: forest and pasture DE decreased substantially, while biomass extraction became more intense in croplands, especially in the main parts of the crops. This is the logical consequence of the energy transition and the use of disproportionate imported livestock feed in relation to the land's capacity to sustain it.

Consequently, Spanish agroecosystems have undergone a significant process of production intensification and specialization. The specialization has been twofold. On the one hand, some of the country's autonomous communities, which traditionally concentrated crops and occupied the territory in a relatively balanced way, currently display a higher degree of concentration of some crops and in a less balanced way. On the other hand, crops are grown now less dispersed and more concentrated in the autonomous communities than in the past, when they were more evenly balanced over the territory. The Gini index on Final Agricultural Production of seven types of uses (vegetables, fruits, wine, oil, eggs, meat, milk) shows this. It went from 0.285 in 1959 to 0.383 in 2000. That is, it grew by 34.4%, reflecting a significant increase of production specialization. In terms of uses, we observe that all, without exception, show a strong degree of territorial concentration based on the Gini index of distribution over Spanish regions. The case of vegetables stands out. Vegetables

are a star product of intensification and external commercialization and its degree of specialization has grown by almost 70%.

During the first half of the twentieth century, this intensification involved practically all areas and uses. In the second half of the century, the Spanish agrarian sector specialized in a group of intensively managed crops and intensive livestock, due to its dissociation from the land, among other factors. This fundamental change in the agrarian sector required, as we have seen, the injection of large quantities of external inputs, the scope of which is not properly reflected in dry weight ton measurements. When analyzing Spanish agriculture's metabolic activity from an energy perspective, more obvious conclusions can be drawn. The energy efficiency of agricultural production has declined considerably as we saw in Chap. 5.

6.4 The Pace of Intensification and Specialization ($I + S$)

The intensification process, however, did not unfold steadily nor was it boosted by the same drivers over the study period. We used decomposition analysis to better differentiate the phases underwent by Spanish agriculture since 1900. The decomposition analysis method is based on the proposal by Ang (2005) for additive decompositions. It allows to estimate the variation over time of a given variable (it is generally used to study changes in energy consumption) and then quantifies the weight on such variation of the variation in other types of variables generally expressed in other units (GDP, population, efficiency, etc.). The final result shows the effect of these variables expressed in the measure unit of the variable that is under analysis. In our case, we wished to analyze the change in the DE of crops at the state level, measured in tons of dry matter. For this, we estimated the variation at two different moments in time. We assumed that changes in DE change can be explained, first, by changes in the agricultural area: the larger the surface area, the larger the extraction, and vice versa (the cultivated area is expressed as A in Eq. 1). However, it is possible that Extraction per area unit changes over time. We capture this effect by incorporating intensification (I), which is estimated as the inputs (measured in embodied energy) per hectare. Finally, we incorporated efficiency (E) in the use of these inputs. It is possible that more inputs be added but that the response in the form of biomass production is ever smaller. We synthesize this equality in Eq. 1.

$$DE = A * I * E \quad (1)$$

Thus, the change in DE between year T and year 0 is equivalent to the sum of the changes in the variables considered:

$$\Delta DE_{\text{tot}} = DE^T - DE^0 = \Delta A + \Delta I + \Delta E$$

Graph 6.4 shows the result of the analysis throughout the period in the right column. It confirms that the use of inputs was the main factor of increase in DE of arable

Graph 6.4 Analysis of the decomposition of DE. *Source* author's compilation

lands. It also shows that biomass input production efficiency considerably reduced DE, reflecting its progressive decrease, as observed in EROI behavior. Variations in croplands ultimately scarcely explain DE behavior. The analysis also allows to distinguish four different periods. The first period corresponds to the first third of the twentieth century, when DE increased moderately, due not so much to the cultivation of new lands, despite the incorporation of almost four million hectares, but to the use of industrial inputs, whose volume in terms of energy multiplied by 6.6. Animal traction increased due to the growth of cultivated areas and the increase in work associated with more intensive management; but it was the use of fertilizers that grew the most and, to a lesser extent, that of new irrigation systems. In previous chapters, we highlighted, in fact, the key role of chemical fertilizers in agricultural growth during the first third of the twentieth century, especially phosphate fertilizers, the expansion of irrigated land and improvements in their water provision. However, efficiency per input decreased and this had a negative effect on DE.

The second period covers the years of Early Francoism, characterized by the fall in crop DE. The analysis mainly attributes efficiency loss to extracted biomass reductions. Although the use of inputs declined significantly in the forties, at the beginning of the fifties, the expansion of irrigation and the increase of energy invested in traction, still mostly animal-based, boosted inputs per hectare. However, inefficiencies caused by the need to allocate more biomass to animal feed, i.e., raising the amount of reused biomass, brought down efficiency levels. The third period corresponds to the forty-year period between the fifties and nineties. The results of the analysis clearly show the effects of industrialization on Spanish agriculture: a very sharp growth of crop DE essentially due to the use of external inputs that multiplied by almost 11 between both dates. Among these inputs, industrial inputs grew the most, to a similar extent, while non-industrial inputs grew little, because labor reduction

partially offset the increase in the use of feed, which multiplied by 30 during that period. Among the industrial inputs, mechanization, irrigation and crop protection inputs grew the most, although the role of chemical fertilizers was decisive during the first decades. As can be inferred from the land-use figures described in Chap. 2, croplands remained relatively stable and therefore, can hardly explain DE behavior. The analysis also clearly shows that DE increased while the efficiency of agricultural production (biomass obtained per TJ) was significantly reduced. As seen in Chap. 5, the EFEROI (External Final EROI) shrunk, from 9.24 units of extracted biomass in 1950 to 1.56 in 1990.

The decomposition analysis indicates a fourth period between the beginning of the nineties until 2008, of scant crops DE growth. The croplands went from 20.1 million hectares to 17.2, losing almost three million hectares for cultivation that did not, as in the past, go into swelling larger farms. This partly explains that the use of inputs continued to grow, especially animal feed, and livestock activity with it, whose impact is not fully reflected in crops DE. Decline in labor is particularly striking. In contrast, industrial inputs grew very little and sometimes even fell, as in the case of chemical fertilizers. Consequently, the stabilization and even the relative decrease of crop DE are related to livestock specialization and the transfer of the biomass necessary to sustain it to other territories.

In short, during the twentieth century, the functionality of agrarian metabolism changed substantially in the Spanish economy as a whole: from supplying an essential part of energy and materials, it became a biomass supplier for human or animal food and raw materials for industry. This brought about an increase in the demand for biomass in absolute terms leading to sustained production intensification and specialization over time. At first, the process took place more or less over the whole territory and for all uses. Later, it concentrated in croplands, especially those with better access to water and fertile soils. Since the end of the nineties, the twofold nature of the agrarian sector has become more pronounced. Currently, large under-utilized or neglected territories, especially in the interior pasture lands and drylands, coexist with croplands or highly specialized landless livestock activities in which production intensification continues. It is because some of the production pressure is transferred to third country territories through international trade that increasing domestic biomass consumption is compatible with the abandonment or underutilization of a portion of Spanish agroecosystems, thus deepening its double-sided nature. This explains DE stagnation as DC continues to grow. How did this situation come about? We have already seen that the process was driven by intensification and production specialization (hereon $I + S$). But what were the drivers or underlying forces of intensification and specialization themselves?

6.5 The Drivers of $I + S$

Based on the previous sections, the reasons must be sought both within the agricultural sector, that is, on the supply side, as well as outside the sector, taking into

account industry and agri-food sector biomass demand. This is all the more justified if we consider that, as we have just seen, for a long time, DE and DC did not co-evolve. Next, we examine the factors that explain $I + S$ processes, depending on whether they originated inside or outside the agricultural sector.

6.5.1 *Supply Side Drivers of $I + S$*

In Chap. 1, we presented the main hypothesis of this book, i.e., that the adoption of $I + S$ strategies was due to the difficulties of many agrarian households to maintain and reproduce themselves socially. Chapter 4 was devoted to the study of monetary flows, and we saw that $I + S$ strategies were common among small farmers but for a number of reasons eventually spread to all types of farms. Given the limited data at our disposal, we can only indirectly confirm these hypotheses for the first third of the twentieth century. Data from official land registry records (*Avance Catastral*), collected and studied by Carrión, confirm the overwhelming weight of small properties that were unable to reach the minimum levels of GVA required to cover the country's average consumption basket. This explains the need to maximize agricultural income, either by specializing in the production of crops with better market outlets, or by intensifying the production of subsistence crops. We also know that salaried workers, threatened by seasonal unemployment and the lack of alternative employment outside the sector, developed strategies to strengthen their position within the labor market through unions and social protest. The strategy resulted in wage increases that eventually affected the rest of the farmers who were relatively dependent on the external workforce. Given the difficulties in replacing human labor with machines, the most feasible strategy was to apply chemical fertilizers, increasing yields per unit area and compensating for the rise in labor costs. In this way, the $I + S$ strategy was adopted by practically all farmers. In fact, this explanation is supported by our decomposition analysis performed on the drivers of DE increase, in the absence of more precise data on agricultural macromagnitudes.

On the other hand, our hypothesis can be better verified for the second half of the twentieth century, since we dispose of the sector's accounts and other useful statistical information. The agrarian sector's intensification was measured in different ways, either through indicators such as DE/ha or DE/ha of cropland. Nevertheless, we advanced a hypothesis on the drivers of $I + S$ attributing a decisive weight to agrarian income and its capacity to cover average agricultural household expenditure. Therefore, it would be appropriate to approach the weight of the drivers of intensification in monetary terms rather than in biophysical terms. This can be achieved by using a proxy variable as reliable as possible. Intermediate consumption (IC), in monetary terms and reflected in the sector's accounts, effectively expresses the costs of intensification since its beginnings: as we have seen, ever since external inputs were used, the greater the use of inputs, the more intensely the agroecosystems were managed.

Let us remember that, as we saw in Chap. 4, the amount of agricultural income depended on the magnitude of intermediate consumption. Furthermore, in Chap. 5, we related the increasing use of inputs, fossil fuels in particular, to agroecosystem environmental damage over the last decade that endangered the reproduction of the most important fund after the agrarian population: the land and its capacity to produce biomass sustainably. As we saw, the use of inputs increased dramatically since the 1950s multiplying by 11 in terms of energy; this increase persisted throughout the study period, albeit at different rates. Except in the years prior to the current economic-financial crisis, farmers had to devote an increasing share of the production value to face the costs, significantly affecting income. These expenses reflect how $I + S$ efforts were conducted to compensate for falling paid prices and achieve sufficient income to cover average Spanish household expenditure. Agrarian household expenditure, apart from in the expected case of “Entrepreneurs with workers”, has always found itself below the national average since 1958. That is, most of the agrarian population’s access to goods and services has fallen below the rest of the country’s levels of access, especially that of agricultural laborers and small landowners with no employees.

IC has therefore contributed to making agrarian activity less viable. So much so, that it has had to resort to other mechanisms to compensate income decline: on the one hand, public subsidies, at first from the State and then from the EU; on the other hand, the mobilization of professional agricultural organizations and trying to raise the prices paid or increase the amount of aid. On an individual basis, farmers have tried to bring down labor costs, by reducing employment, and when this was not possible, by leaving the sector. In many cases, it was possible to maintain levels of income per employee and even increase them, at least until early this century. Labor costs dropped practically by half, representing 60.4% of costs in 1964–5 and 31.9% in 2008. To discover the weight of the main drivers of intermediate cost behaviors, we performed a decomposition exercise presented below.

We again followed the decomposition proposal of Ang (2005) as described above. In this case, we analyzed intermediate consumption variation, measured in euros of the year 2000, between 1962 and 2008, distinguishing other intermediate periods. The variables considered in the model are described as follows: first, the number of farms or agricultural holdings (expressed as F in Eq. 2) reflects the evolution of the sector itself and provides information on the abandonment of activity, given that the number of holdings logically influences the total amount of inputs used; second, hectares per holding (ha/F) measures their size and captures the increase in the size of agricultural holdings that has taken place as a result of the drop in their number and the aim of reaching a threshold of minimum profitability by increasing the size. This has had consequences on input use since it has usually led to the replacement of labor by machines and chemical means, raising productivity; third, income per hectare (I/ha) shows the profitability of each surface area unit and captures the behavior of farmers who have tried to increase income by producing more and, therefore, using more inputs. Finally, the fourth variable refers to the intermediate consumption share of total agricultural income (IC/I). It reflects the vicious circle produced by farmers’ intentions of offsetting IC increases by producing more thus paradoxically being forced to use more IC (Graph 6.5).

Graph 6.5 Decomposition analysis of Intermediate Consumptions (IC) explained by the number of agricultural holdings—farms—(F), hectares per farm (ha/F), income per hectare (I/ha) and the intermediate consumption share of income (IC/I) 1962–2008

$$IC = F * \frac{ha}{F} * \frac{I}{ha} * \frac{IC}{I} \quad (2)$$

The results for the whole period (1962–2008) show an IC increase of 11 billion euros. The increase was the result of the opposing strengths of the selected variables. The fall in income per hectare and farm income halted the rise of intermediate consumption, especially farm income. Farm abandonment led to a 6.3 billion euro drop in intermediate consumption. However, increases in farm size, measured as hectares per farm, as well as the growing weight of intermediate consumption over total income, were responsible for a much larger increase. The increases in farm size account for an increase of 4.2 billion. The weight of intermediate consumption in total income was, however, the main driver of total intermediate consumption increase. Its impact is estimated at 13.9 billion euros. Overall, agrarian intensification, measured as an intermediate consumption increase, is explained by forces that pushed in opposite directions, notably the abandonment of farms, which caused a drop in their numbers but, in turn, the loss of the sector's profitability forced farms to increase their consumption that, in turn, grew in size due to property concentration. This latter factor also pushed up intermediate consumption.

It is possible to find differentiate historical phases when analyzing the effects of decomposition. The first period runs between 1962 and 1977, during which IC was mostly driven by its increasing share of agricultural income and to a much lesser extent by farm size increases. Farm numbers hardly dropped and farms hardly contributed to IC variations. A second period can be distinguished between 1977 and 1992 when IC barely rose. It continued to grow in relation to agricultural income, but the growth was mostly offset by the decline of income per hectare. This was during the oil crisis and transition to democracy. The first democratic governments adopted agrarian policies that were sensitive to the pressures of the professional

agricultural organizations and workers' unions: they slowed down the process of labor substitution by machines and farm number reductions (Herrera 2007). A third period spans from 1993 to 2008. IC growth was higher than in the previous period. In this case, the growth was equally driven by the rise in the percentage of intermediate consumption over total income, farm size increase, and the growth in income per hectare. The overall growth was partially offset by a sharp decline in the number of farms. In other words, in this last period, we observe an unprecedented process of farming abandonment and relative increase in intermediate costs that was offset by intensifying farming and increasing farms size.

In view of the results of our decomposition exercise and the behavior of employment and farm numbers, agricultural macromagnitudes, it is worth breaking down the last period on the evolution of Spanish agriculture's metabolism following the last two periods—the first third of the twentieth century and Early Francoism—into two subperiods. The first sub-period starts in the sixties and runs until the early nineties; we can refer to it as the period of the industrialization of Spanish agriculture. The second runs from the early nineties until today and can be understood as the globalization of Spanish agriculture.

At the beginning of the 1960s, agrarian activity provided sufficient income to cover average Spanish household expenditure; soon the continued fall in income and the increase in average household expenditure significantly deteriorated farmers' living standards. Most were able to confront the situation by increasing production and reducing costs. The technologies associated with agricultural industrialization, i.e., fertilizers, phytosanitary products, improved and hybrid seeds, irrigation and mechanization made it possible to increase productivity, even in the least productive farms. In parallel, they tried to compensate for the increase in intermediate costs by reducing labor costs, that is, replacing work with machines and chemical means. Despite these efforts, the strategy did not yield the desired result and agrarian income remained insufficient to cover average Spanish household expenditure (Graph 6.6).

The second period, starting at the beginning of the nineties, coincided with the full implementation of the CAP. Agricultural income grew above household expenditure, though this was due to job destructions and numerous farm closures. Agricultural income did not improve, it continued to dwindle in constant terms, but was distributed among fewer farmers and fewer salaried workers. In fact, there was little possibility of increasing productivity by greater use of inputs or by substituting labor with machines. The marginal utility of technologies that had played a leading role in the industrialization of Spanish agriculture was reduced, especially for farms with low yields that could barely earn more income by incorporating inputs to increase production. Improving labor productivity and increasing farm sizes continued to be an effective strategy to offset this trend; but this was not possible for many farmers who had to abandon their activity or who did not dispose of any generational handover. The smaller farms were the most affected, and the farms under 20 ha represented the bracket with the highest number of closures. Terminations of activity were especially intense in the country's interior, in areas of low productivity and limited capacity for intensification.

Graph 6.6 Relationship between input use and cultivated land employees

In a context of declining paid prices, farms that were able to intensify their production attempted to raise their income by increasing their surface size or by orienting production towards utilizations with higher gross margins. The data presented in Chap. 4 show that gains in European size farm units (ESU) were clearly achieved thanks to intensive livestock and forced cultivation under plastic covers. Both tendencies led to enhancing the use of external inputs in terms of energy, that is, they have broadened the scope of $I + S$ in Spanish agriculture. In the case of pigs and poultry production, high gross margins were made possible thanks to massive imports of very cheap feed based on corn and soybeans. Overcoming the profitability crisis has therefore persistently relied on $I + S$, but only a tiny share of farms was concerned. Spanish agriculture has thus branched off in two directions: on the one hand, the sector continues to intensify and specialize, associated with intensive livestock farms, that are highly industrialized and integrated into the agri-food industry, together with farms based on forced cultivation under plastic; and on the other hand, a more extensive sector unable to reach these $I + S$ levels has abandoned its activity or subsists thanks to size gains, CAP subsidies, or organic farming. Converting to certified organic production has been a way out as agri-environmental measures generate income supplements that has allowed them to increase the number of ESU.

As illustrated, employment in the sector has declined continually since the middle of the century, accelerating in recent decades. Job destruction appears to be non-ending. Despite $I + S$ efforts, monetary flows have visibly been unable to ensure the reproduction of this fund element for the functioning of the agroecosystem. In 1950, more than 5.2 million people were employed in the agricultural sector, that is, almost half of total employees and 18.6% of the Spanish population. This figure has come down to 774,500 in 2016, accounting for 4% of employees and barely over 2% of the population. As we saw in Chap. 4, around two-thirds of farms have disappeared since the 1960s. The aging of farmers has taken on worrying proportions, calling

into question both the agrarian nature of households and the survival of farms. This explains the phenomenon of depopulation of Spain's interior, reflecting the non-viability of the industrialized agricultural model and the institutional arrangement in which it operates.

6.5.2 Demand Side Drivers of $I + S$

Changes in consumption patterns and population increase were two key drivers of agrarian intensification. Once again, we conducted a decomposition analysis to understand the drivers of cropland demand. The variable under analysis was actual demand for cropland and was calculated by adding the land embodied in imports to the country's croplands minus the land embodied in exports. To estimate the land embodied in imports, we made an estimation of the imported biomass produced in croplands in third countries. Then we applied a land demand factor to each case (for each product and in each exporting country), which varied according to whether it was a primary or processed product, if there was joint production in each crop, etc. A detailed description of the calculations can be found in Infante-Amate et al. (2018). We proceeded in the same way for exports. As mentioned throughout our study, the results show the Spanish economy's increasing land demand which is mainly due to the transfer of land use to other countries. At present, approximately 11 million hectares (Mha) of total surface area is used outside the country, the majority of which, about 10 Mha, is cultivated. Current cultivated areas accounted for approximately 17.1 Mha in 1900; however, actual land demand was 22.8 Mha, i.e., 1.4 times more. The greatest acceleration has been taking place since 1960. Imported land then amounted to 1.9 Mha and exported land barely exceeded 1.0 Mha. Net imports represented only 4% of the country's cultivated areas and total imports represented 11.6%. Five decades later, in 2008, net imports multiplied by 7, accounting for 37.7% of real demand. Total land imports represent 64.0% of the country's croplands. Given that a substantial part of that area is destined for export, we can fairly say that Spain requires almost as much surface area within its borders than outside due to biomass consumption activities.

But what drivers pushed up demand? We propose a new decomposition analysis to explain the land demands of croplands (L) taking into account: the population increase (P); changes in consumption patterns, especially diet, since most of the cropland's biomass consumption is destined to food (D , estimated as the kcal consumed per inhabitant) and land yields (Y , estimated as land required to produce each kcal).

$$L = P * D * Y \quad (3)$$

The twentieth century has been characterized by profound changes to the three factors under study. Land productivity has significantly increased, generating considerable savings in demanded area. According to Soto et al. (2016) production per

hectare (dry matter) of the cultivated areas has multiplied by 3.2, going from 1.8 to 5.7 t/ha between 1900 and 2008. However, other variables have weighed on demand for land in the opposite direction. The population has multiplied by 2.5, increasing from 18.6 million inhabitants to 46.5 million. Consumption patterns have also changed towards more land-demanding models. Not only has direct consumption increased (biomass has grown by 26% per inhabitant) but the diet has changed, with a greater presence of animal products, that are more land-use intensive. How has each of these changes affected the increase in acreage demands documented above?

Graph 6.7 shows the results of the decomposition analysis. Throughout the study period, cultivated area demands grew by 6.0 Mha. Production intensification allowed to save 27.1 Mha, however, the population increase required 17.6 Mha and the consumption patterns change required 15.6 Mha. Production and technological change could have been enough to continue feeding a growing population, however, changes in food consumption patterns made that impossible.

These drivers have behaved unevenly throughout the study period. In this sense, three major periods can be distinguished: between 1900 and 1933 these drivers increased demand for land by 3.8 Mha, made it drop by 0.7 Mha between 1933 and 1960 and pushed it up again by 2.9 Mha between 1960 and 2008. In the first period, the increase was mainly motivated by population growth. Although production intensification succeeded in saving enough land to face consumption changes, it was insufficient to sustain the rapid population growth. The second period was marked by lower population growth and the atypical behavior both of land intensification (productivity decreased) and consumption patterns (per capita consumption decreased). This was due to autarkic politics during Early Francoism. During the third period, the increase in total demand was somewhat lower than during the first, however, the drivers had stronger impacts: the population grew much faster (demanding 10.9 Mha), soil intensification accelerated (saving up to 30.9 Mha), and consumption

Graph 6.7 Decomposition of the variables that affect cropland demand. The variables considered are population changes, consumption pattern variations and land yields. All variables are expressed in millions of hectares

patterns became much more land-demanding (requiring 23.6 Mha). The second half of the twentieth century was thus characterized by an unprecedented acceleration of land demand drivers. In the last decade, however, demand has stabilized due to changes in consumption patterns.

The observed evolution can be interpreted as a “rebound effect” case: improvements in efficiency (i.e., land yields) were absorbed by changes in consumption patterns (i.e., an increase in food intake and waste by inhabitant and change in food consumed) so that aggregate consumption continued to grow. Globally, population increase between 1960 and 2005 was a more determining driver than diet. In fact, according to Kastner et al. (2012), southern Europe along with East Asia were the only territories where a diet change was a more important driver of land demand than population change.

What has this diet change consisted of and how did it come about? In previous analyses (González de Molina et al. 2013, 2014, 2017) we estimated apparent food consumption from 1900 to 2008. The results show a differentiated eating behavior between the first and the second half of the twentieth century. Table 6.5 shows the amount of both vegetal and animal biomass aimed at endosomatic metabolism in tons. Total biomass multiplied by 3.3 during the entire study period, apparent consumption grew significantly between 1900 and 1933 and grew again, to an even greater degree, from 1960 until today, almost doubling the amount of consumed biomass. The major driver of this growth was animal biomass that multiplied by 7, while vegetal biomass increased by a factor of 2.6. While animal biomass contributed just over 16% of total consumed biomass at the beginning of the century, that percentage had risen to 35% in 2008. The trends are easier to identify when analyzed in per capita terms.

As shown in Table 6.6, per capita consumption increased by 39.1%, that is, demand for food biomass grew not only because of population growth but also because of diet changes. The change was led by animal biomass: while the consumption of

Table 6.5 Apparent net biomass consumption (deducting losses) in t of fresh edible food (1900–2008)

Year	Vegetal biomass	Animal biomass	Total biomass
1900	8,809,163	1,722,193	10,531,356
1910	9,216,040	2,076,013	11,292,053
1922	10,872,487	2,378,680	13,251,168
1933	12,584,553	2,701,503	15,286,055
1940	10,655,118	2,913,993	13,569,112
1950	10,803,102	3,298,027	14,101,128
1960	13,930,829	4,546,685	18,477,614
1970	17,015,648	7,120,757	24,136,405
1980	20,064,341	9,513,501	29,577,841
1990	22,310,436	10,792,822	33,103,259
2000	21,676,647	12,119,428	33,796,074
2008	22,931,836	12,250,486	35,182,323

Source Author's compilation based on agrarian statistics

Table 6.6 Apparent consumption per food group (g/per capita/day in fresh edible food)

	1900	1933	1950	1970	1990	2008
Cereals	320.5	326.0	224.7	216.4	161.6	180.8
Legumes	46.6	49.3	35.6	35.6	16.4	16.4
Roots and tubers	241.1	383.6	249.3	263.0	235.6	131.5
Vegetables	263.0	276.7	238.4	293.2	405.5	345.2
Fruits	101.4	93.2	98.6	172.6	265.8	219.2
Nuts	13.7	8.2	8.2	5.5	8.2	8.2
Oilseeds	2.7	2.7	5.5	8.2	13.7	21.9
Alcoholic drinks	265.8	216.4	145.2	254.8	315.1	328.8
Oil	30.1	43.8	30.1	49.3	79.5	87.7
Sugar	16.4	30.1	24.7	82.2	71.2	71.2
Meat + fat	38.4	54.8	32.9	106.8	224.7	243.8
Eggs	8.2	11.0	11.0	27.4	32.9	24.7
Dairy products	197.3	216.4	252.1	391.8	449.3	419.2
Fish	11.0	24.7	27.4	52.1	54.8	65.8
Honey	1.1	0.8	0.5	0.8	1.6	1.9
Vegetal biomass	1301.4	1430.1	1060.3	1380.8	1572.6	1411.0
Animal biomass	255.9	307.7	323.8	578.9	763.3	755.3
Total	1557.3	1737.8	1384.1	1959.7	2335.9	2166.3

Source Author's compilation based on agrarian statistics

vegetal biomass per capita grew by only 8%, animal biomass tripled. This increase was constant over time, including during Franco's Autarky, but has been much more intense since the 1960s. The apparent consumption of animal biomass per capita grew modestly during the first half of the century (26% since 1900); but between 1960 and 2000, consumption more than doubled reaching 827.4 g/person/day having slowed down in the last decade. While animal biomass barely represented 16% of total consumed biomass in 1900, it currently reaches almost 35%: a transition from a plant-based diet to a diet where livestock products play a major part has undoubtedly taken place. The same table disaggregates previous data per food groups, revealing a substantial decrease in the consumption of cereals, legumes, roots and tubers and, conversely, a significant increase in the consumption of meat, dairy products, fish, oil, sugar and alcoholic beverages.

Table 6.7 shows the energy value expressed in calories per person per day. Consumed calories increased in line with biomass consumed, i.e., by 30% between 1900 and the year 2000, the year of maximum intake. Except in the forties and fifties, the amount of biomass loosely satisfied basic energy requirements. These requirements were calculated by Cussó (2005; Cussó et al. 2017) and determined at around 2260 for 1900; 2314 for 1960 and 2434 for 2011. The most significant fact, however, is that this increase is mainly due to food intake of animal origin. The cereals group,

Table 6.7 Apparent consumption of biomass in calories, deducting losses (1900–2008)

Year	Vegetal biomass		Animal biomass		Total biomass	
	Calories	%	Calories	%	Calories	%
1900	2328	91.2	224	8.8	2552	100.0
1910	2370	90.4	251	9.6	2621	100.0
1922	2588	90.2	281	9.8	2869	100.0
1933	2646	90.6	276	9.4	2922	100.0
1940	1959	88.6	251	11.4	2209	100.0
1950	1888	87.4	272	12.6	2160	100.0
1960	2400	86.6	374	13.4	2774	100.0
1970	2406	81.7	538	18.3	2944	100.0
1980	2409	78.5	659	21.5	3069	100.0
1990	2398	74.6	816	25.4	3214	100.0
2000	2434	72.8	908	27.2	3342	100.0
2008	2401	74.1	841	25.9	3242	100.0

Source Author's compilation based on agrarian statistics

including legumes and potatoes, used to form the basis of the diet and shifted from accounting for 40% of ingested energy in 1970 to just over 27% at present. In contrast, meat, eggs, and dairy products used to provide 17% of energy in 1970 increasing to 23% today. In the year 2000, both food groups provided a similar percentage of energy: 24 and 25%, respectively. Oil consumption has also increased and now provides almost a quarter of the calories in 2008. If we add oil, mainly olive oil, both groups of foods, accounting for 47% of calories, today form the basis of the Spanish diet (González de Molina et al. 2014).

Growth of DE and SB thus allowed feeding the Spanish population until the civil war undoubtedly on an essentially vegetarian diet. Caloric intake in the thirties was similar to that provided by the German or Austrian diet and higher than the average diet in Holland, France, Italy or Greece (Cussó 2005, 353). Table 6.7 shows the depth of the food crisis that Spain experienced as a result of the agrarian policy of successive Francoist governments until the beginning of the 1960s. In contrast with the idea that hunger and malnutrition were a thing of the past, overcome during Franco's dictatorship and thanks to the economic progress favored by the regime, the data persistently shows that "the hunger years" were an exclusively Francoist phenomenon, caused by the dictatorship, its economic policy and fierce repression after the end of the war. It would take two decades to overcome the crisis. Indeed, shortly before the Civil War began, the amount of calories per capita ingested by a Spanish citizen per day was 29% higher than needs, an amount that would not be reached until the beginning of the seventies.

During the last four decades of the twentieth century, there has been a major increase in calorie intake (20%), higher than that between 1900 and 1933 (14.5%), excessively beyond needs. Perhaps the most striking fact is that this increase has

been achieved through the rising intake of products of animal origin (see Table 6.7). In fact, the amount of calories provided by vegetables has fallen continually since the thirties, when they contributed the most (2646 calories).

Graph 6.8 shows the protein composition of food consumed throughout the twentieth century. According to calculations by Cussó (2005, 345) the Spanish population's protein requirements, between 35.6 and 35.8 gr per person per day, were amply covered. A steady and prolonged tendency to substitute vegetable proteins with animal proteins can be observed despite the fact that during most of the twentieth century it was vegetables that provided the bulk of the proteins. Currently, two-thirds come from animal biomass. The graph shows the major role of meat and dairy products in protein intake in recent years to the detriment of cereals, legumes, and potatoes.

Graph 6.9 shows the composition of consumed foods in lipids or fats. A distinctive sign of Mediterranean consumption patterns has been the intake of vegetable fats, among which olive oil stands out. However, there has been a growth in animal origin fat consumption and it now reaches over a third. The contribution of fats today comes basically from olive oil, meat, and dairy products. The percentages provided by the nutritional assessment of the Spanish diet, based on official data provided by the Panel of Food Consumption (Varela Moreiras et al. 2008, 48) are quite similar. Meat consumption has more than quadrupled, from 56 g/capita/day in the 1960s to 243 g/capita/day at present, pork and chicken meat having grown the most. Milk consumption increased from 291 g/capita/day to 488 g/capita/day and that of eggs from 15 g to 25 g/per capita/day.

The data analysis allows distinguishing three different periods in the evolution of Spanish diets. A first period runs from the beginning of our study, in 1900, until the Civil War, a period in which the transition towards a typical Mediterranean diet initiated long before reached its peak. A second phase, between the forties and the seventies, runs during the Franco dictatorship: after having overcome a long and deep food crisis, levels and patterns of consumption proper to the 1930s were gradually

Graph 6.8 Apparent net protein consumption, by food group, in grams per inhabitant per day

Graph 6.9 Lipid contribution of apparent consumption, grams per inhabitant per day

recovered. Thus, until the 1970s, typical Mediterranean diet consumption patterns would predominate in Spain, implying adaptations to the conditions and dynamics of Spanish agroecosystems (González de Molina et al. 2014). However, since that decade, typical developed country food consumption patterns have been adopted (European Commission 2015), moving increasingly away from the WHO recommendations (Rodríguez Artalejo et al. 1996; Nicolau and Pujol 2011), a phenomenon that has been called the ‘westernization’ of the diet (Kearney 2010). Del Pozo de la Calle et al. (2012) calculated the so-called Mediterranean Diet Score (MDS) and found that Spain obtained a score of 4 in 2008, on a scale of 0–9, where 9 is the maximum adaptation to the Mediterranean diet. These habits explain why 60.9% of the Spanish population is overweight (39.3%) or obese (21.6%) (Aranceta-Bartrina et al. 2016). They are also associated with degenerative diseases (Tilman and Clark 2014) and colorectal cancer (De Marco et al. 2014, 69). The diet is based, as we have seen, on high consumption levels of livestock products, on the excessive intake of proteins and fats of animal origin and on the increasing deficit of carbohydrates.

Demand for meat, dairy products, and eggs, has thus especially increased, fundamentally changing the agricultural sector’s production orientation: since the 1960s, production has been largely oriented towards animal feed. This trend has intensified in recent decades. The Spanish agrarian sector reacted between 1960 and 2008 through the spectacular growth of livestock, the massive introduction of inputs, the concentration of biomass extractive efforts in cultivated areas and, paradoxically, the relative abandonment of pasture and forest lands. But these changes in food demand have been met only in part by domestic production. Livestock and changes to its composition, with monogastric animals playing a greater role, has been made possible thanks to growing imports of biomass for animal feed from other European Union and Latin American countries (Infante and González de Molina 2013). Foreign trade is therefore key in the Spanish agri-food system: on the one hand, foreign trade makes the specialization of Spanish agriculture (in oil, horticultural products and pig meat)

possible, providing outlets in international markets, especially in Europe; and on the other hand, foreign trade supports Spain's growing consumption of meats and dairy products, providing a very important percentage of animal feed. This phenomenon is consistent with the data obtained by research on the evolution of the nitrogen cycle in Spain between 1961 and 2010, which showed Spanish livestock's growing dependence on imported protein, especially from Latin America (Bouwman et al. 2013; Lassaletta et al. 2014).

In short, until the 1960s, the Spanish diet was "coupled" with DE and SB satisfied the bulk of food demand. We could say that the domestic market and food demand were the main drivers of agricultural production and its production orientation. In other words, the $I + S$ of Spanish agriculture was stimulated by population growth, but also, as we will see next, by diet improvements compared to 1900. This linkage had dramatic consequences, causing an unprecedented food crisis when the Francoist regime's international isolation and its autarchic policy reduced the flow of SB. Spanish food production enjoyed, until then, a high degree of autonomy and what we would call today food security, in direct contrast with the situation today, where foreign trade is decisive and food autonomy has declined considerably: the livestock sector (and its supply of meat and dairy products) is currently dependent on feed imports. The sector is also dependent on Central European market, a preferential outlet for its fruit and vegetable production, the main specialization of Spanish agriculture. The issue can also be approached the other way around: domestic agricultural production accounted for Spaniards' food consumption to a very high degree, and therefore, changes in production can largely explain changes in food consumption habits.

What caused these important diets changes and, consequently, the demand for vegetable products and above all animal products? The relationship between per capita income increase and the increase in energy content and animal proteins in diets is well known (European Commission 2015, 8, for a review, see Tilman and Clark 2014). This certainly occurred in Spain, facilitated by cheaper food (Kearney 2010) and the loss of relative weight of food expenses in household budgets, which went from 48.7% in 1960 to 16.8% in 2015 (Martín Cedeño 2016, 222). But income growth only explains increases in meat and dairy product consumption as well as the gradual loss of the Mediterranean diet. It does not explain, however, why this increase in meat has been based on monogastric livestock, dependent on imported quality grains and not on pastures or harvest residues. Graph 6.10 compares the evolution of the prices paid by consumers for pork and chicken meat and other foods of animal origin, with the evolution of selected groups of basic vegetable foods. We can observe that foods of animal origin have become progressively cheaper, while vegetables have become more expensive. This explains why pork and chicken meats, eggs, milk, and yogurt have eventually become as affordable as bread, cereals, legumes, fruits and vegetables. The cheapening of pork is especially striking, due to the economies of scales of increasingly concentrated intensive farms and the import of cheap grains (corn and soybeans), which has cheapened end prices of these meats. In 2015, Spain even turned into the biggest pork exporter in the EU (Rousseau 2016).

Graph 6.10 Comparison of the prices paid by consumers for some animal (a) and vegetable products in 2016 constant euros (b), in 2016 constant euros and in percentage of 1981 prices (c). *Source* Household Budgets Survey and Continuous Household Budgets Survey (INE 1980–2105)

Moreover, the acute processes of livestock farm concentration, production process industrialization (Domínguez Martín 2001; Clar, 2005, 2008; Clar et al. 2015) and vertical integration in the agri-food industry, explains increases in offer and reduced production and prices. Both pig and poultry farming are a good illustration of this major transformation (Segrelles Serrano 1993; Clar 2010; Fundación Cajamar 2011; MAPAMA 2013 and 2016a, b).

As we have seen, the globalization of food markets has turned Spain into a net importer of biomass, favored by the comparatively lower prices of agricultural commodities (soybean, corn, etc.) in international markets, the basis of intensive livestock feed (Mayer et al. 2015; Falconí et al. 2016). What has actually happened, as we have shown above, has been a shift towards third countries with lower production costs for parts of the land consumed by the Spanish agri-food system. Our results suggest that foreign trade has saved c. 18 million hectares (data for 2010) that would have

been cultivated in the country's interior territory in case it had not been possible to access those markets and maintain current levels of consumption.

6.6 Conclusions

The traditional narrative judges the agrarian transformations that took place during the twentieth century positively, especially since the 1960s with the sector's industrialization. It emphasizes that Spanish agriculture underwent a significant intensification process leading to a threefold production increase and multiplying its value by five based on constant prices. The secret to this success was production intensification and specialization, achieved thanks to yield increases per unit area. Growth of cereals, fruits and vegetables, forage plants and olive groves were especially intense and reflected Spanish agriculture's progressive specialization in these crops. Greater still was livestock production growth, which multiplied by a factor of 8.2 over the same period. Its overall weight in the sector increased, reaching almost 17% of agricultural production value. Meat and egg production was the major player in this unusual livestock growth. Milk production multiplied by five, though it represented the major livestock production in 1900. The picture emerging from Spanish agriculture's biophysical analysis is less bright and downplays the scale of this growth, weighing it down with the effects on the environment and farmers, that is, on the sector itself. Conventional discourse barely contemplates the centrality of the sector as a whole: it attributes a subordinate role to agriculture and focuses on assessing agriculture's contribution to the country's economic growth.

From a biophysical perspective, which necessarily considers NPP as a whole, biomass grew by only 28.5%, a figure far from that of evaluations in monetary values and fresh weight. How can we account for the difference between both narratives? Between 1900 and 2008, Spanish agriculture transitioned from an organic metabolic regime to an industrial regime, and this process has accelerated in recent decades. The transformation consisted of a greater appropriation of biomass produced by agroecosystems for human use to the detriment of other species. This has been possible by transferring extraction efforts from pastures and forests to croplands; translocating the photosynthetic capacity of plants grown from straw to grain (arable crops) or from the trunks and leaves to the harvestable fruit (woody crops) simplifying the multifunctionality of the crops; reducing rotations and breaking the integration between different land uses; and shifting the production orientation from human consumption to animal consumption (livestock farming), driven by changes in the diet. These changes have prevented the completion of physical-biological cycles and have required the use of large amounts of external inputs manufactured and driven by fossil fuels. Production limitations proper to organic-based societies have been apparently overcome (Wrigley 2016), allowing for substantial Spanish population growth and, above all, for increasing levels of consumption.

These transformations, however, have been possible at the cost of a deterioration of the fund elements not only of Spanish agroecosystems but also of third countries. Biophysical funds have mostly undergone negative changes: not only have the funds

that allow to maintain ecosystem services in good conditions such as soil fertility, biodiversity, carbon sequestration, water quality, etc. deteriorated, but they have become an active source of pollution and lead to the depletion of scarce resources such as fossil fuels or sources of mineral nutrients. In contrast, the weight or dissipative effects of livestock have risen disproportionately, consuming almost 60% of both DE and foreign trade biomass and requiring a similar amount of inputs. Livestock has lost its ties to the land and its maintenance is almost decoupled from it. Livestock represents the biggest source of emissions in the sector and contamination by slurry. The relationship between both funds has been almost completely lost, weakly maintained by extensive and semi-intensive livestock, whose production and consumption weight is hardly relevant.

Perhaps the most significant deterioration is the ongoing shrinking of the agrarian population. The existing population is aging and threatened by a lack of generational replacement. It is, however, a key fund for the future viability of sustainable agrarian activity. On the other hand, the technical means of production, i.e., the other social fund has increased in size. As we saw in Chap. 3. It has acquired excessive weight and has turned the metabolism of Spanish agriculture into a structure of high entropy dissipation, which requires a constant and growing supply of energy, mostly from fossil sources. The congruence between the two social funds, population and technical means of production, has also been broken: not only from the perspective of their respective sizes but also regarding the information flows making it possible to manage the technical means. These flows barely come from the farmers themselves, but from the companies that supply the inputs. Agrarian activity has become a lucrative market for input industries that promote technologies that are remote for farmers whose main purpose is to ensure the continuity of the business. The congruence between physical funds and social funds has thus been broken, but also the congruence between them: the activity does not ensure the reproduction of the agrarian population and hinders the reproduction or replacement of the technical means of production. Its use helps to produce more, but only in a limited way, and yet it has a negative impact on the territory and generates monetary costs that further depress the income that the other funds must support. The industrial metabolic regime, which was imposed from the 1960s, has implemented a form of operation that compromises not only the environmental health of agroecosystems but also the viability of the agricultural activity itself as we know it today.

The significant contribution of the agrarian sector to a country's economy should certainly be relevant, if only because it produces the food required to support the population, providing employment and maintaining an ecological infrastructure that is essential for the functioning of society. But a legitimate question is whether increasing levels of land or labor productivity should be achieved at the expense of the deterioration of the fund elements that make agrarian activity itself possible and whether successive increases in labor and land productivity can be maintained indefinitely. What limits should we set to the constant transfer of capital, income, labor, to the activity's profitability losses, job destruction, lack of generational change, etc.? The hypothesis defended in this book proposes that the prevailing industrial model, due to its intrinsic characteristics, leads to either collapse of agriculture or to

the spending of considerable public resources (subsidies) to delay its collapse. It is urgent to redefine the role of the agrarian sector in the economy and, consequently, to determine which criteria should be used to value the place of agriculture in the economy. This redefinition requires thorough discussions that have only just begun and that are likely to continue over the next few years. We hope that the conclusions of the analysis presented in this book will contribute to the debate.

References

- Ang BW (2005) The LMDI approach to decomposition analysis: a practical guide. *Energy policy* 33(7):867–871
- Aranceta-Bartrina J, Pérez-Rodrigo C, Alberdi-Aresti G, Ramos-Carrera N, Lázaro-Masedo S (2016) Prevalencia de obesidad general y obesidad abdominal en la población adulta española (25–64 años) 2014–2015: estudio ENPE. *Revista Española de Cardiología* 69(6):579–587
- Bouwman L, Klein Goldewijk K, van der Hoek KW, Beusen A, van Vuuren DP, Willems J, Rufino MC, Stehfest E (2013) Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900–2050 period. *PNAS* 110(52):20882–20887
- Clar E (2005) Del cereal alimento al cereal pienso. Historia y balance de un intento de autosuficiencia ganadera, 1967–1972. *Hist Agrar* 37:513–544
- Clar E (2008) La soberanía industrial: Industrias del complejo pienso-ganadero e implantación del modelo de consumo fordista en España: 1960–1975. *Rev Hist Ind* 36:133–165
- Clar E (2010) A world of entrepreneurs: the establishment of agribusiness during the Spanish pork and poultry boom, 1950–2000. *Agric Hist* 84(2):176–194
- Clar E, Pinilla V, Serrano A (2015) El comercio agroalimentario español en la segunda globalización, 1951–2011. *Hist Agrar* 65:195–228
- Costanza R, Graumclih LJ, Steffen W (eds) (2007) *Sustainability or Collapse? an integrated history and future of people on earth*. The MIT Press, Massachusetts
- Cussó X (2005) El estado nutritivo de la población española 1900–1970. Análisis de las necesidades y las disponibilidades de nutrientes. *Historia Agraria* 36:329–358
- Cussó X, Gamboa G, Pujol-Andreu P (2017) El estado nutritivo de la población española, 1860–2010: diferencias de género y generacionales. In: Documento presentado al XII Congreso Internacional de la Asociación Española de Historia Económica, (Salamanca, 5–9 de septiembre de 2017)
- de Marco A, Velardi M, Camporeale C, Screpanti A, Vitale M (2014) The Adherence of the diet to mediterranean principle and its impacts on human and environmental health. *Int J Environ Prot Policy* 2(2):64–75
- del Pozo de la Calle S, Cuadrado Vives C, Ruiz Moreno E, Valero Gaspar T, Ávila Torres JM, Varela Moreira G (2012) Valoración Nutricional de la Dieta Española de acuerdo al Panel de Consumo Alimentario. Madrid. Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente
- Domínguez Martín R (2001) La ganadería española: del franquismo a la CEE. Balance de un sector olvidado, *Historia Agraria* 23:29–52
- European Commission (2015) World food consumption patterns, trend and drivers. In: *EU Agricultural Markets Briefs*, 6
- Falconí F, Ramos-Martín R, Cango P (2016) Caloric unequal exchange in Latin America and the Caribbean. *Ecol Econ* 134:140–149
- Fundación Cajamar (2011) *El Sector del Porcino en España*. Almería, Fundación Cajamar
- Gierlinger S, Krausmann F (2012) The physical economy of the United States of America: extraction, trade, and consumption of materials from 1870 to 2005. *J Ind Ecol* 16(3):365–377
- González de Molina M, Soto D, Infante-Amate J, Aguilera E (2013) ¿Una o varias transiciones? Nuevos datos sobre el consumo alimentario en España (1900–2008). In XIV Congreso Internacional de Historia Agraria (Badajoz, 7–9 de noviembre 2013). <https://doi.org/10.13140/2.1.1823.5684>

- González de Molina M, Soto D, Aguilera E, Infante-Amate J (2014) Crecimiento agrario en España y cambios en la oferta alimentaria, 1900–1933. *Hist Soc* 80:157–183
- González de Molina M, Soto D, Infante-Amate J, Aguilera E, Vila Traver J, Guzmán GI (2017) Decoupling food from land: the evolution of Spanish agriculture from 1960 to 2010. *Sustainability* 9(12):23–48
- Infante-Amate J, González de Molina M (2013) ‘Sustainable de-growth’ in agriculture and food: an agro-ecological perspective on Spain’s agri-food system (year 2000). *J Clean Prod* 38:27–35
- Infante-Amate J, Soto D, Aguilera E, García Ruiz R, Guzmán G, Cid A, González de Molina M (2015) The spanish transition to industrial metabolism long-term material flow analysis (1860–2010). *J Ind Ecol*, 19(5):866–876. Available in: <https://doi.org/10.1111/jiec.12261>
- Infante-Amate J, Aguilera E, Palmeri F, Guzmán G, Soto D, García-Ruiz R, González de Molina M (2018) Land embodied in Spain’s biomass trade and consumption (1900–2008): Historical changes, drivers and impacts. *Land Use Policy* 78:493–502
- Kastner T, Rivas MJI, Koch W, Nonhebel S (2012) Global changes in diets and the consequences for land requirements for food. *Proc Nat Acad Sci* 109(18):6868–6872
- Kearney J (2010) Food consumption trends and drivers. *Philos Trans R Soc B* 365:2793–2807
- Krausmann F, Gingrich S, Eisenmenger N, Erb KH, Haberl H, Fischer-Kowalski M (2009) Growth in global materials use, GDP and population during the 20th century. *Ecol Econ* 68(10):2696–2705
- Lassaletta L, Billen G, Romero E, Garnier J, Aguilera E (2014) How changes in diet and trade patterns have shaped the N cycle at the national scale: Spain (1961–2009). *Reg Environ Chang* 14(2):785–797
- MAPAMA (Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente) (2013) Informe 2012 sobre el estado del Patrimonio Natural y de la Biodiversidad en España. Madrid
- MAPAMA (Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente) (2016) Caracterización del Sector Porcino Español, año 2015. Madrid
- MAPAMA (Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente) (2016) Informe del consumo de alimentación en España, año 2015. Madrid
- Martín Cerdeño V (2016) Cincuenta años de alimentación en España. Mercasa, Madrid
- Mayer A, Schaffartzik A, Haas W, Rojas-Sepúlveda A (2015) Patterns of global biomass trade. Implications for food sovereignty and socio-environmental conflicts. *Environ Justice Organ, Liabilities Trade*, 20
- Nicolau R, Pujol J (2011) Aspectos políticos y científicos del modelo de la transición nutricional: evaluación crítica y nuevas perspectivas. In: Bernabeu-Mestre J, Barona JL (eds) *Nutrición, salud y sociedad: España y Europa en los siglos XIX y XX*. Valencia. Universitat de València, Seminari d’Estudis sobre la Ciència, pp 19–57
- Rodríguez Artalejo FJR, Banegas MA, Graciani R, Hernández Vecino Y, Rey Calero J (1996) El consumo de alimentos y nutrientes en España en el período 1940–1988: análisis de su consistencia con la dieta mediterránea. *Medicina Clínica* 106(5):161–168
- Rousseau O (2016) Denmark loses place as top EU pork exporter. *Global Meat News* [web page], 24 March 2016. Available in: <https://www.globalmeatnews.com/Article/2016/03/24/Denmark-loses-place-as-top-EU-pork-exporter>
- Schandl H, Schulz N (2002) Changes in the United Kingdom’s natural relations in terms of society’s metabolism and land-use from 1850 to the present day. *Ecol Econ* 41(2):203–221
- Segrelles Serrano JA (1993) La ganadería industrial en España: cabaña porcina y avicultura de carne. Univ Alicante, Alicante
- Soto Fernández D, González de Molina M, Infante-Amate J, Guzmán Casado G (2016), La evolución de la ganadería española (1752 y 2012): del uso múltiple al uso alimentario. Una evaluación de la fiabilidad de los censos y de las estadísticas de producción. Seminario Anual de la Sociedad Española de Historia Agraria, (Madrid, noviembre de 2016)
- Tilman D, Clark M (2014) Global diets link environmental sustainability and human health. *Nature* 515:518–522

Varela Moreiras G, Ávila Torres JM, Cuadrado Vives C, Del Pozo de la Calle S, Ruiz Moreno E, Moreiras Tuny O (2008) Valoración de la dieta española de acuerdo al panel de consumo alimentario. Madrid. Ministerio de Agricultura, Alimentación y Medio Ambiente

Open Access This chapter is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, duplication, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, a link is provided to the Creative Commons license and any changes made are indicated.

The images or other third party material in this chapter are included in the work's Creative Commons license, unless indicated otherwise in the credit line; if such material is not included in the work's Creative Commons license and the respective action is not permitted by statutory regulation, users will need to obtain permission from the license holder to duplicate, adapt or reproduce the material.