1. Introduction

There are some earlier references, but it is common to attribute the term ‘Industry 4.0’ to the report by Kagermann et al. (2013) (see also Kagermann 2015), which was drawn up to make a diagnosis of German industry and its ability to cope with the new technological scenario of digitalisation, or digital transformation, as well as of the reforms required to assimilate it in an optimal way. The name comes from the estimate by the authors of the report that this digital transformation is, in fact, the beginning of the fourth industrial revolution, characterised by the development and introduction of cyber-physical systems (CPS). These are defined as: ‘Systems with embedded software (as part of devices, buildings, means of transport, transport routes, production systems, medical processes, logistic processes, coordination processes and management processes) which: directly record physical data using sensors and affect physical processes using actuators; evaluate and save recorded data, and actively or reactively interact both with the physical and digital world; are connected with one another and in global networks via digital communication facilities (wireless and/or wired, local and/or global); use globally available data and services; and have a series of dedicated, multimodal human-machine interfaces.’ (Acatech 2011: 15)

The term ‘Industry 4.0’ has been successful and is already widely used, although it has met with reticence in the academic world. For example, Valenduc (2018) and Valenduc and Vendramin (2017) argue, on the basis of the concept of the techno-economic paradigm (cf. Perez 2010), that it is not really a new paradigm but rather the transition between the installation and deployment phase of what, according to Perez (2010), would be the fifth paradigm since the industrial revolution. This began around 1973 and is based on the microprocessor, information and communications technologies (ICT) and biotechnology. In an earlier document from 2012, the European Commission, following (for example) Rifkin (2012), was still referring to the ‘third industrial revolution’ (European Commission 2012: 7). In fact, in the case of Industry 4.0, it is not so much a question of new technologies as of their application to the production process in search of greater flexibility, efficiency and competitiveness, so such objections are not without significance.

In exposing the scenario behind Industry 4.0, ideas and arguments may be repeated, but the most familiar in the analysis of organisational and technological changes is that from the 1980s which led from vertically-integrated Fordism to the model known – among other denominations – as lean production. For example, in Roland Berger (2016: 5) one can read: ‘It will also allow... a switch from push-production – make and
build up inventory – to pull-production – make to order.’ Aoki (1990), Coriat (1990) and Womack et al. (1990) are three studies from that time that insist on the idea of switching from push-production to pull-production, with the model of the Japanese automotive industry as an example. Dorrenbacher et al. (2018) also refer to a renewed impact of the principles of lean production on European MNCs (multinational corporations).

Other names referring to the same process are digital transformation, digitalisation, smart industries or advanced manufacturing, which is the one most used in the United States (PCAST 2011). Although there are subtle differences in concepts, particularly between the German and the American visions, what these different names share is an emphasis on the development of cyber-physical systems and the use of large amounts of information, both for the operation of intelligent machines in the production process and for quality improvement, predictive maintenance or adaptation to the needs of specific customers (customisation and mass customisation). Taking into account the above-mentioned nuances, in this work, for convenience, we will use the term ‘Industry 4.0’.

The adoption of technologies that could be encompassed by Industry 4.0 is a recent phenomenon that is expected to have significant economic consequences, both quantitative and qualitative as regards the demand for labour and possessing a likely impact concerning the location of production activities. In this sense, the available works that anticipate such effects are generic, with estimates for a country as a whole and even for the global economy (see, for example, Acemoglu and Restrepo 2019; McKinsey 2017; PwC 2018; Roland Berger 2016; WEF 2016). The main result of these kinds of works is a set of estimates of the possible macroeconomic effects of the spread of Industry 4.0, which leaves open a whole set of questions concerning the qualitative characteristics of this process. What is the rate of introduction of the different technologies in Industry 4.0? Do MNCs have a strategy for adopting these new technologies in their different assembly plants? What effects is the introduction of Industry 4.0 having on employment in assembly plants? What are the main advantages of the introduction of Industry 4.0 in the opinion of those agents directly involved?

This chapter aims to provide answers to these questions by obtaining direct information from qualitative interviews with representatives of a number of automotive assembly plants located in Spain. Plants in the automotive sector have added interest, since this sector has been indicated as one of the most susceptible to the introduction of Industry 4.0 technologies and, in addition, MNCs in this sector could be taken as a model for the possible effects of the expansion of Industry 4.0 on the location of value chains (Dachs et al. 2019b; Deloitte 2020). In contrast to generic trends, the field work and its results offer a more realistic picture of the degree of implementation of Industry 4.0 in the Spanish automotive sector, allowing an understanding of the qualitative aspects related to intra-company dynamics and competitive pressure.

The information obtained through the field work identifies a higher level of integration of the production process in a company’s enterprise resource planning (ERP) system, as the main technology being implemented. Automation is increasing, but no structural change seems to be detected. Besides, initiative on the introduction of Industry 4.0 in
MNCs corresponds to the level of the plant and is highly dependent on the motivation of the personnel directly involved: the introduction of Industry 4.0 technologies is being carried out with the close collaboration of local agents. On the other hand, the changes indicated have not, for the moment, led to appreciable cuts in employment, although there are indications of reassignments of workers to new tasks as well as a demand for new profiles and new skills in certain jobs.

The chapter is organised thus. Following this general introduction, we detail in section two the literature on the Industry 4.0 process itself, as well as its impact on employment, global production and the Spanish automotive industry. We set out our approach to the field work in section three, while section four analyses our results as regards the chronology of Industry 4.0, the process of its introduction and its main advantages, the impact on working conditions and employment, and its effects as regards the positions of plants within MNC value chains. We end in section five by drawing some conclusions.

2. Literature Review

2.1 Industry 4.0: technological delimitation

In both the United States and Germany, the starting point is the assumption of the historical strength of the automotive industry, its weight in R&D activity or in the employment of highly-skilled workers, as well as the decline experienced in recent decades (PCAST 2011, 2014; Kagermann et al. 2013). The latter has different characteristics in the two countries, although it is much softer in the German case. Thus, manufacturing employment in the United States has gone, between 2000 and 2017, from 14 per cent to ten per cent of total employment and in Germany from 20 per cent to 17 per cent; as for gross value added, in the United States this has dropped from 16 per cent to 12 per cent while in Germany it has remained stable at 23 per cent, although in 1991 it was up at 27 per cent (data from the OECD and Statistisches Bundesamt). There is concern about halting this decline and the fear that not only industrial value added, but also pre- and post-production services, will end up leaving the country.

The lists of technologies included in the concept of Industry 4.0 are highly similar. Strange and Zucchella (2017) group them into four categories: the Internet of Things; big data analytics; robotics; and additive manufacturing (3D printing). Meanwhile, CB Insights (2019) distinguishes 14 technologies grouped into four categories: necessary (Internet of Things, industrial sensors, robots/collaborative robots (or ‘cobots’) and predictive analytics); experimental (edge computing, industrial drones, personalised manufacturing, augmented reality and virtual reality, wearables and industrial blockchain); threatening (machine-vision and machines-as-a-service); and transitory (3D printing and data interoperability).

The world of Industry 4.0 is one of optimisation and flexibility. Central to this is information, collected and analysed in real time and aimed at connecting all elements of the factory, performing simulations and obtaining models through virtualisation, as well as the continuous exploration of new services for potential customers. Information
management must translate into the optimisation of decision-making and, therefore, improvements in the efficiency of resource use (Kagermann et al. 2013). A large part of these activities is related to services associated with the development or end-consumer phases of the relationship and form part of the so-called ‘servitisation’ of the industry (Vandermerwe and Rada 1988; Raddats and Kowalkowski 2014; Raddats et al. 2019).

Industry 4.0 comprises a transversal technology – that is, it is applicable to a multitude of productive sectors – although its adoption can be expected to be gradual, with different rhythms both sectoral and corporate, in a process in which the organisational culture of the company and the mentality of managers themselves can be decisive.

Given that our work on which this chapter draws focuses on the production process, we have used in our interviews with companies and social agents the following breakdown of those Industry 4.0 technologies which are directly related to production:

- logistics solutions for inventory and warehouse management;
- self-guided vehicles (AGVs);
- data extraction systems (CBS): sensors and real-time control;
- augmented reality systems;
- virtual reality systems;
- automation of management procedures: order management, reports, production programming, remote maintenance, etc.;
- cobots;
- 3D printing;
- functional printing (printed electronics);
- knowledge and information sharing systems (between workers or with suppliers);
- intelligent systems: support for decision-making in production planning, process optimisation and predictive maintenance;
- industrial drones;
- artificial intelligence and neural networks.

The ultimate goal is improved profitability, which arises both from value creation and improved asset utilisation rates as well as reduced labour costs (Roland Berger 2016; BCG 2015). There is a very strong emphasis on planning and logistics, especially supply and inventory management, but also on reducing maintenance time by incorporating preventive maintenance.

2.2 Industry 4.0 and employment

One of the most controversial aspects of the implementation of Industry 4.0 is its impact on employment, although it should be clarified that most of the work does not concern Industry 4.0 as such but automation. A first estimate, seeking to capture an equivalent phenomenon and which had a considerable impact, was that of Frey and Osborne, published as a working paper in 2013 and as an article in 2017, which estimated that 47 per cent of jobs in the United States were at a high risk (i.e. over 70 per cent) of being automated whereas only 33 per cent of jobs had a less than 30 per cent risk of
being automated (see Frey and Osborne 2013, 2017). Their estimate was based on an approach which focused on occupations.

Arntz et al. (2016), using a contrasting individual job-oriented approach as a point of reference, estimate for a sample of 21 OECD countries that around ten per cent of jobs are likely to be made redundant over the next two decades as a result of technological progress, although they note that there are significant differences among them (see also Arnold et al. (2018), who argue that this impact does not have to translate into a similar increase in unemployment and that, in the long-term, the overall effect on employment will be positive). For the United States, the figure is nine per cent.

For their part, Nedelkoska and Quintini (2018), applying the criteria of Arntz et al. (2016) to data from 32 countries and across a wider group of workers, estimate that 14 per cent of jobs are at high risk of automation (i.e. with a probability of automation greater than 70 per cent), while another 32 per cent would have a probability between 50 and 70 per cent. Countries that, according to Nedelkoska and Quintini (2018), present a lower risk of automation to the median worker are located in northern Europe (Norway, Finland, UK, Sweden, Netherlands and Denmark), northern America (United States and Canada) and New Zealand. In contrast, the countries with the highest risk are located in southern and eastern Europe (Slovak Republic, Lithuania, Greece and Spain), in addition to Germany and Japan.

Frey and Osborne (2017: 265) find that ‘A substantial share of employment in services, sales and construction occupations exhibit high probabilities of computerization,’ although Nedelkoska and Quintini (2018) had concluded that automation mainly affects jobs in industry and agriculture, with few service industries being at a high risk of automation. Furthermore, the latter come to the a priori surprising conclusion that up to 71 per cent of the variation between countries may be explained by intra-sectoral differences (differences in the organisation of production within the same sector) while only up to 29 per cent of it may be accounted for by inter-sectoral ones (the industry mix).

PwC (2018) provide estimates on the percentage of jobs at risk due to automation for 28 countries, ranging from 22 per cent in Korea to 44 per cent in Slovakia. The countries most affected are in eastern Europe: in addition to Slovakia, they are Slovenia, Lithuania and the Czech Republic. However, it obtains a negative relationship between job automation risk and the density of industrial robots (industrial robots per 10,000 employees in manufacturing industry), by which we can understand that some countries (such as Korea, Singapore, Japan or Germany) present a lower risk because they have already made part of the adjustment.

The perception that the impact is distributed by activity, and that the net balance is positive, is widespread. In addition to the work already mentioned by Arnold et al. (2018), BCG (2015) forecasts a net increase in employment, at least in Germany. Thus, it estimates that Industry 4.0 could increase employment between 2015 and 2025 by 350,000 (five per cent), resulting from the creation of 960,000 new jobs and the disappearance of 610,000, based on generating additional economic growth annually
of one per cent. The reduction in employment will take place in factories, mainly due to the introduction of robots. This is a conclusion which is also supported by Roland Berger (2016) which, in a simulation for an automotive supplier, obtains the result of a reduction of almost half of employment (45 per cent) although it adds: ‘People are still at the heart of the system’ (Roland Berger 2016: 5).

Meanwhile, McKinsey (2017) estimates that, in a midpoint adoption scenario, automation could replace, depending on the country, between nine per cent (India) and 26 per cent (Japan) of employment (from a set of reference countries that also includes Mexico, China, the United States and Germany). It does not make estimates of the net balance but, from historical analysis, concludes that technical change generates net employment.

The way in which automation affects employment is related to its differing impact on occupations and skill levels. It is generally accepted that automation particularly affects tasks that require a lower level of skills, especially in production. Thus, Nedelkoska and Quintini find: ‘A rather monotonic decrease in the risk of automation as a function of skill level’ (2018: 50). Dauth et al. (2018), for Germany, and Acemoglu and Restrepo (2017), studying the specific case of robots, come to a similar conclusion.

Acemoglu and Restrepo (2019) went on to establish a theoretical model to analyse the ways in which automation affects employment. The net impact of automation in a sector and on added employment is the result of two effects that pull in opposite directions. First, there is a productivity effect, since automation increases added value and generates demand for labour in non-automated tasks, which therefore acts in a positive fashion. Second, however, there is a displacement effect which arises because automation displaces work from tasks previously assigned and tends therefore to reduce employment. To the extent that it cannot be ensured that the productivity effect is greater than the displacement effect, there is no guarantee that the final impact on employment will be positive. Furthermore, ‘Different technologies are accompanied by productivity effects of varying magnitudes and hence we cannot assume that one set of automation technologies will impact labour demand in the same way as others’ (Acemoglu and Restrepo 2019: 11). In their view, this could explain the differences observed, for example between Germany and the United States, following the introduction of industrial robots.

The case of industrial robots has received specific attention and there is a consensus that they contribute to reducing employment in the industries in which they have been installed. However, differences arise when appreciating the overall effect on the economy as a whole. In their analysis of the implementation of robots in the United States, Acemoglu and Restrepo (2017) estimate that, relative to a local labour market (commuting zone) with no robots, an increase of one robot per thousand workers leads to a reduction in the employment to population ratio by 0.37 percentage points and in average wages by 0.73 percentage points. This led them to an estimate of total job losses for the country as a whole between 1990 and 2007 of 360,000–670,000. The negative effects are concentrated in manufacturing, while finance, the public sector and non-robotised manufacturing show positive effects. Negative (or, at best, null)
effects are distributed across all occupations (except managers) and all education levels. Those with the lowest wages are most affected, which results in increased wage inequality.

Dauth et al. (2018) analyse the implementation of robots in Germany, concluding similarly to Acemoglu & Restrepo (2017) in terms of the existence of job losses in the industries where they have been installed as well as in terms of their impact on wages and in the widening of the wage gap. However, they also find that the losses in manufacturing are almost offset by gains in other activities, especially business services. They estimate that one robot per thousand workers replaces 2.11 jobs in industry (manufacturing jobs) while generating two jobs in services (the aggregate effect on employment relative to the population will thus be -0.018 percentage points). In other words, robots change the composition of employment but not its aggregate level. In addition, they conclude that part of the adjustment takes place within the factories themselves, with the outcome of job losses being reflected in fewer jobs for young people.

The relatively greater damage to wages resulting from automation seems to exist in contradiction to the trend of the polarisation of employment into high and low skill areas, to the detriment of those in the middle. Representative works on this position are those of Autor and Dorn (2009) and Goos et al. (2009, 2014). We will not go into the content of these contributions here, although we should point out that such a result is, perhaps, greatly influenced by the identification that is made between salaries and skill level, such that low skill is attributed to low salaries and high skills to high salaries. By way of hypothesis, it could be ventured that the relative reduction in industrial employment and the expansion of lower-paid, but not necessarily lower-skilled, service activities (for example, many care services and feminised occupations), as well as the trend itself towards lower wages in industry, may have something to do with this wage depression at the average level.

2.3 Industry 4.0 and the global organisation of production

It has not been explicitly considered in the empirical analysis, but there is one remaining aspect that seems relevant to consider here: the impact that Industry 4.0 technologies may have on the organisation of production on a global scale and, particularly, that of the automotive industry. Globalisation is associated with the fragmentation and geographical dispersion of production, facilitated by information and communications technologies (Dicken 2015). The result is the configuration of so-called ‘global production networks’ (GPNs: Yeung and Coe 2015), or ‘global value chains’ (GVCs: Gereffi et al. 2005; Gereffi and Fernandez-Stark 2016). This has occurred within the process of extending the operations of MNCs and their establishment of complex networks of productive and organisational relationships with their suppliers, both internal and external. However, this offshoring process may be coming to an end (De Backer and Flaig 2017), with the detection of movements of activities, either of the company itself or of its suppliers, to the company’s country of origin. This process began as reshoring, although today the term ‘backshoring’ is widely used. Backshoring is not necessarily the return of a previously-offshored activity since a company may
have been able to expand by building new production capacity or acquiring companies in the destination country (Dachs et al. 2019a).

Backshoring has attracted much interest in recent years and studies are beginning to proliferate which try to quantify it and to establish its impact, although general theoretical models are still to be developed and the vast majority of empirical analyses are based on case studies. Barbieri et al. (2018) carry out an exhaustive review of the literature on reshoring, with a base of 57 documents (53 articles and four book chapters). Two papers arising from the analysis of a large sample of companies taken from the 2015 European Manufacturing Survey (EMS) have been contributed by Dachs et al. (2019a, 2019b).

It is not easy to quantify the extent of the phenomenon. Heikkilä et al. (2018), in a study of Finnish companies, find that 13 per cent of companies had moved production to Finland between 2010 and 2015 (26 per cent had moved activities outside the country in the same period, since backshoring and offshoring coexist and the latter remains even more significant). Johansson and Olhager (2018), in their analysis of the Swedish case of backshoring, estimate the percentage of companies at 27 per cent between 2010 and 2015. These are high percentages, far removed from the 4.3 per cent obtained by Dachs et al. (2019a). However, all three studies are in agreement on the more intense impact of backshoring on high-tech activities, as well as on the reasons cited for engaging in it. The latter can be summarised as the search for greater flexibility and quality, an under-utilised capacity problem and aspects related to logistics, such as transport and coordination.

This leads us directly to the relationship that may exist between Industry 4.0 technologies and backshoring since, as we have seen, Industry 4.0 facilitates increased flexibility, adaptability, improved coordination and adaptation to specific customer requirements. We should also add reductions in costs, particularly labour costs, as well as the reduction in the share of labour in income (Dauth et al. 2018; Acemoglu and Restrepo 2019) as a result of the change in the capital/labour ratio. Therefore, Industry 4.0 is directly related to the objectives being pursued under backshoring, while it also makes it possible to sidestep one of the most powerful reasons for offshoring, which is savings in labour costs (Di Mauro et al. 2018), as well as the lack of flexibility in labour rules and laws (Heikkilä et al. 2018). Dachs et al. state: ‘The modernization and innovation of these home plants by implementing advanced production technologies and accelerating the digital integration of value adding processes (Industry 4.0) might play an important role, as economies of scale and high capacity utilization become all the more important in such high-tech and high-invest lead plants’ (Dachs et al. 2019a: 7).

In their second paper, devoted specifically to the relationship between backshoring and Industry 4.0, Dachs et al. (2019b) find a positive and significant relationship between backshoring and investment in Industry 4.0 technology. They estimate that Industry 4.0 brings two benefits to companies: firstly, increased productivity and capacity utilisation, which translates into lower production costs; and, secondly, greater flexibility and quality, which enables customised production with very low marginal costs.
In the case of the automotive industry, one more element could act, in addition to investment in Industry 4.0, to feed backshoring: the switch to electric vehicles and possible changes in trends in the demand for cars, the types of vehicle ownership and in mobility patterns all imply far-reaching changes in the industry that may reinforce the concentration of activity in companies’ countries of origin.

2.4 Spanish automotive industry and Industry 4.0

The Spanish automotive industry is very significant, both for the country’s economy and in comparative terms with other EU countries. Total employment in the industry (NACE C29) was 158,000 people in 2017, 8.2 per cent of the country’s manufacturing sector (data from the National Statistics Institute, INE). It generated ten per cent of manufacturing value added (€11.3bn) and is also a relevant destination for investment since, in 2017, it accounted for 15.8 per cent of all manufacturing investment.

However, the overall impact of the automotive industry on the Spanish economy (including related services and gross fixed capital formation) is much larger. According to data from ANFAC (Spanish Association of Automobile and Truck Manufacturers), GDP related to the automotive industry represents about 8.6 per cent of Spanish GDP.

Twelve assembly plants are located in Spain (there are actually two Nissan plants, the one in Ávila being dedicated, however, to the manufacture of components for Renault); one plant is owned by Ford while eleven are owned by European manufacturers:

- Ford: Valencia;
- Iveco: Madrid, Valladolid;
- Mercedes-Benz: Vitoria;
- Nissan: Barcelona (Nissan announced the intention to close this plant in May 2020);
- PSA: Madrid, Vigo, Zaragoza;
- Renault: Palencia, Valladolid;
- Volkswagen Group: Barcelona (Seat), Pamplona (Volkswagen).

There have been no greenfield investments in plants assembling vehicles in Spain for thirty years (Aláez-Aller et al. 2015). In addition, SERNAUTO (Spanish Association of Equipment and Component Manufacturers) estimates that there are more than 1,000 companies dedicated to the manufacture of components (equipment and spare parts), belonging to 720 groups. Consequently, it is only possible to find companies that have Spanish capital at the level of component manufacturers.

The location of operations in the automotive value chain in Europe has been characterised by two hierarchical structures (Lung 2007; Pavlinek 2015): one for assembly (with high-end models being assembled mainly in core countries – France and Germany – while the peripheral states of Europe have become specialised in the assembly of lesser vehicles); and the other based on functions (R&D has been concentrated in the core regions of the EU which have become the home for development centres for assemblers).
This double hierarchy determines the type of product assembled in Spain, its role as a preferential destination for export to European markets and that multinational groups do not, in general, develop R&D activities related to product development in their Spanish plants. In general, it could be said that only automotive suppliers with Spanish capital develop R&D activities in Spain (Aláez-Aller et al. 2015).

In relation to the type of product assembled in Spain, the place occupied by Spanish automotive producers in the EU value chain has been limited to the assembly of vehicles with medium/low added value. A breakdown by segment of ANFAC data for passenger car assembly in Spanish plants reveals that this remained true in 2018, when 362,621 medium SUVs, 672,513 small SUVs, 596,083 small-sized vehicles, 441,562 compacts, 54,486 medium-sized vehicles and 83,029 large vans were assembled in Spain as were, additionally, 548,467 commercial vehicles and 55,499 industrial vehicles. In 2018, production was 2.8 million cars (2.2 million, 79 per cent, being passenger cars), of which 2.3 million were exported. With these figures, Spain is the second largest European manufacturer and the ninth largest in the world, with a 2.9 per cent share of the global market. Approximately 60 per cent of exports go to four European markets: France, Germany, United Kingdom and Italy.

The OECD calculates the value added contained in exports and their origin, domestic or imported. In the case of imports, this can be used as an indicator of the import content of exports. For 2015, this value was 40.7 per cent in the transport equipment industry compared to 31.2 per cent for manufacturing as a whole. This indicates a greater intensity of backward linkages – that is, greater integration in global value chains. In the same year, the automobile industry was responsible for 30.2 per cent of the imported value added contained in manufacturing exports (source: OECD).

Little is known about the situation of Industry 4.0 in Spain. There is no study that quantifies in any way the degree of implementation of such technologies and their impact. There are reports, usually official ones, on the extent of ICT focused on the deployment of networks, services, electronic administration, etc. (see, for example, Ministerio de Hacienda y Administraciones Públicas 2016), but this does not amount to data on Industry 4.0. Roland Berger (2016) does provide information on specific aspects of digitalisation, although these are agent assessments. One exception to this overall picture, however, is the report of the Observatorio ADEI (2017), which carried out a simulation exercise based on two scenarios: firstly, the convergence of advanced occupations with the United States, United Kingdom and Germany; and, secondly, the reduction in the working age population and the structural unemployment rate. On this basis, the Observatory estimates net job creation by 2030 of 2.4 million: 3.2 million jobs will be created in advanced occupations (jobs which are adaptable to digitalisation initiatives), with a further 0.6 million jobs added in occupations not susceptible to automation; while 1.4 million jobs will be lost.

Furthermore, the IFR (International Federation of Robotics) provides data on robots. Thus, in 2018 Spain ranked tenth in terms of annual robot installation (annual variations may be significant) with 5,300 units: far behind China, in first place with 154,000; and Germany, in fifth place with 26,700. In terms of robot intensity (robots per 10,000
employees), in 2018 Spain ranked 15th with 168 (the global average is 99), far behind Singapore (831), Korea (774), Germany (338) and Japan (327), which are in the leading positions, which explains the negative judgement made in reports and studies on the country’s overall level of digitalisation (Roland Berger 2016; Bondar 2018). However, if we specifically consider the automotive industry, the situation is comparatively better: the intensity of robots was 1,110 in 2018 and Spain is in ninth position, in a ranking led by Korea (2,589) and with much less marked differences. This position is more in line with the weight of the Spanish automotive sector (second European and ninth worldwide manufacturer).

Some regional reports have, however, been prepared on the degree of implementation of Industry 4.0 based on company surveys. For example, AIN (2019) looked at Navarra; Bilbao, Camino and Intxaiburru (2016) focused on the Basque Country; Xunta de Galicia (2018) examined Galicia (with detailed reports for different sectors); UGT (2017) focused on Castilla y León; the Government of Aragon (2018) looked at SMEs in Aragon; and Hernández et al. (2018) examined Catalonia, which estimates the impact of automation in terms of a net creation of 13,000 jobs (+0.7 per cent) and a loss in manufacturing industry of some 12,000 jobs (-3.2 per cent).

### 3. Field survey

Our work aims to close the data gap by examining the incorporation of Industry 4.0 technologies in the automotive industry and the impact these are having on the industry. The empirical information comes from original field work which we carried out between October 2019 and February 2020. Given the absence of prior data, our approach has been to adopt the method described by Lewis (1998: 456) as ‘iterative triangulation’, based on ‘systematic iterations between literature review, case evidence and intuition.’ It is not a question of testing a theory, but of constructing one. Therefore, the sample is not random or stratified but, using the terminology of Eisenhart and Graebner (2007: 27), it is theoretical; that is: ‘Cases are selected because they are particularly suitable for illuminating and extending relationships and logic among constructs.’

Our sample consists of the Volkswagen plant in Navarra, which manufactures two car models and is expected soon to start assembling a third; eight supplier plants (see Table 1); and various social actors consisting of a consultancy firm, a local automotive cluster and two trade unions.

The questionnaire, focusing on the issues revealed by a review of the literature, was validated through interviews with industry experts and academics. The effort was made to eliminate ambiguity in the questions (on the construction and use of questionnaires in operations management and manufacturing studies, see Flynn et al. 1990 or Synodinos 2003) and, in the end, two different questionnaires were used: one for companies and one for the social partners.

Information was obtained by conducting thirteen semi-structured interviews (the questionnaire consisted of structured and semi- or unstructured questions), so that
interviewees could express their point of view in an open way. An e-mail was sent to firms and to social actors, explaining the purposes of the study and enclosing the questionnaire in advance so that the most suitable interviewees could be chosen and information collated beforehand. The interviews were conducted directly by the authors. This assured a high level of participation and prevented bias due to non-responses. This method also helped to prevent problems due to respondents misunderstanding questions, leaving some answers blank or incomplete, or answering inappropriately. Most of the interviews lasted between sixty and ninety minutes.

The questionnaire comprised 21 questions divided into six parts: identification; adoption of Industry 4.0 technologies; reasons for the implementation of these technologies; ways of incorporation; impact on employment and on job content and nature; and impact on headquarters strategy and the position of the subsidiary.

Our sample of plants (see Table 1) is characterised by an enormous variety of situations (origin of capital, activity within the automotive sector and size of plant) which limits the capacity to formulate detailed conclusions on the existence of differences in the implementation of Industry 4.0 technologies based on such variables. Nevertheless, the plants interviewed share a series of characteristics that are common to most plants in the automotive sector in Spain and which, as has been explained in section 2.4 of this work, are derived from how the Spanish automotive sector has developed: most of the plants are integrated into foreign capital MNCs; Spanish plants only undertake product-related R&D activity in very exceptional cases; the main activity of Spanish plants is assembly; and Europe is the main market for Spanish plants in the automotive sector.

Table 1  Characteristics of plants interviewed

<table>
<thead>
<tr>
<th>Plant</th>
<th>Number of employees</th>
<th>Person interviewed</th>
<th>Origin of capital</th>
<th>Main activity</th>
<th>Position in the value chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>GKN</td>
<td>180</td>
<td>Quality manager; production department engineer</td>
<td>UK (Melrose)</td>
<td>Transmission; original equipment (short series); aftermarket</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Vibracoustic</td>
<td>80</td>
<td>Plant manager</td>
<td>Germany</td>
<td>Chemical treatment of automotive parts</td>
<td>Tier 1 Tier 2</td>
</tr>
<tr>
<td>SAS</td>
<td>280</td>
<td>Plant manager</td>
<td>France (50%)/Germany (50%)</td>
<td>Assembly; sequential deliveries</td>
<td>Tier 1</td>
</tr>
<tr>
<td>BENTELER</td>
<td>50</td>
<td>Plant manager</td>
<td>Austria</td>
<td>Assembly; sequential deliveries</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Plásticos Brello</td>
<td>60</td>
<td>Plant manager</td>
<td>Spain</td>
<td>Plastic parts</td>
<td>Tier 1 Tier 2</td>
</tr>
<tr>
<td>Flex-n-Gate</td>
<td>100</td>
<td>Product engineer</td>
<td>USA</td>
<td>Welding; stamping</td>
<td>Tier 1</td>
</tr>
<tr>
<td>SKF</td>
<td>280</td>
<td>HR officer (training and staff recruitment)</td>
<td>Sweden</td>
<td>Bearings</td>
<td>Tier 1</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>4,800</td>
<td>Process engineers</td>
<td>Germany</td>
<td>Car assembly</td>
<td>OEM</td>
</tr>
<tr>
<td>Grupo Aldakin</td>
<td>150</td>
<td>R&amp;D department</td>
<td>Spain</td>
<td>Industrial automation and robotics</td>
<td>Tier 1</td>
</tr>
</tbody>
</table>
4. **Analysis of results**

4.1 **Chronology of implementation of Industry 4.0 technologies**

The companies interviewed recognise that the most relevant change as regards the digitalisation of their activity has been the integration of their production process with an ERP (enterprise resource planning) system. Compared to previous iterations, new model ERPs allow the production process to be directly connected to management tasks.

Firstly, therefore, the adoption of a new ERP means a considerable effort for plants, not so much financial as in adapting to the new system (business managers estimated the period of preparation of the plant before starting to use the new ERP was between nine and eighteen months). This change began in most of the plants interviewed around 2016; the timing for adoption, as well as the main characteristics, being dependent on the size of the plant and the origin and characteristics of the company that owns it. Consequently:

— it was adopted first in the largest plants with multinational capital, with smaller, locally-owned plants still in the process of implementing an integrated ERP. Meanwhile, larger companies are in the phase of obtaining greater advantages from integrated ERP and migrating it to the cloud;

— the type of ERP adopted by plants which are dependent on larger MNCs is usually SAP and was imposed by the company that owns the plant. Smaller plants and those with local capital have opted for other ERPs more suited to their characteristics;

— plants recognise the multiple advantages of digitised ERP: real-time process information; process control and stability; predictive maintenance; 100% traceability; paperless production; and a significant limitation of human error in decisions on the production process.

Secondly, the adoption of Industry 4.0 technologies has meant an increase in the degree of process automation which, according to plant managers, has been characterised by the following main features and timing (see also Table 2):

— the introduction of conventional robots continues on an upwards trajectory, at least in quantitative terms. However, technological advances in the field of industrial robotics are particularly uneven – the software has advanced significantly but the hardware barely at all. Consequently, there is no obvious technological break when it comes to traditional robots. This means that the limitations of robot hardware need, in a practical setting, to be both recognised and worked around before organisations can take advantage of all the possibilities that have been facilitated by advances in the software;

— the introduction of cobots is, however, recent (the first examples refer to 2017) and remains very limited. In some cases, the slowness of cobots (as opposed to...
traditional robots) has been mentioned as the main drawback which has limited their introduction to very specific cases, including the existence of clear ergonomic problems in a particular workplace;

the first AGVs (Automated Guided Vehicles) in any of the plants in the sample date back to 2015, but their generalisation is more recent; in the majority of our plants, they started to be introduced from 2017 onwards although their use is progressing very quickly, especially with regard to operations within the plant. The enormous field for the development of these vehicles can be anticipated in that only one of the plants interviewed has recognised the use of AGVs in outdoor operations. The speed of their introduction derives from their advantages in terms of safety and reliability, the justification which lies behind the investment (a key argument for obtaining MNC authorisation for capital expenditure on AGVs is that they will replace active workers) and the financial facilities that AGV suppliers offer for their acquisition (as an example, it is possible to lease such vehicles);

the automation of inventory control is spreading and the use of labelling has become general. However, examples of fully automated warehouses are rare and the substantial investment involved is only justified in highly particular cases even though the advantages of a fully automated warehouse are recognised by plant managers. One plant had invested in an intelligent, fully automated warehouse for the management of only one key component (an investment made in 2017). Where there are plans to build new warehouses, these will be digitised and automated but the automation of existing warehouses is an investment that appears to be lagging behind.

No direct link is recognised between process integration into the ERP and increased automation. As an example, in one of our plants, new conventional robots were purchased in 2014, prior to the adoption in 2016 of a new ERP.

The timing of the adoption of 3D printing follows very different patterns: the larger plants started using 3D printing around 2012 (they have recently replaced the initial machines with more sophisticated 3D printers); while smaller plants started using 3D printing in 2019 (where they are using it at all). All plants agree that 3D printing is not an option to replace, even partially, conventional production; yet all cite that it offers huge advantages in the manufacture of specific tools or prototypes.

The use of virtual reality and augmented reality in the production process is limited to R&D projects. Actual deployments of virtual reality are the case in only one plant (for the purpose of training workers before starting the assembly of a new product), while applications of augmented reality are currently being tested in two plants (in respect of maintenance tasks).

There is unanimity among the plants both on the huge accumulation of data on the production process resulting from its integration into the ERP as well as on the lack of strategies to take advantage of the analytical potential of this. Big data analytics is used in only two plants and for specific projects related to quality problems. For its part,
the use of artificial intelligence has been practically limited to machine-vision in the identification of defects.

Table 2  
Industry 4.0 technologies introduced in automotive industry plants

<table>
<thead>
<tr>
<th>Industry 4.0 technology</th>
<th>Timing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of the production process with ERP system</td>
<td>Since 2016. Still in progress</td>
<td>Process control and stability; real-time information; predictive maintenance; 100% traceability = no paperwork</td>
</tr>
<tr>
<td>Automation (cobots)</td>
<td>Since 2017. Few examples</td>
<td></td>
</tr>
<tr>
<td>AGVs</td>
<td>Since 2017. Fast development</td>
<td>Being rented. Adoption easy to justify (cost/benefit)</td>
</tr>
<tr>
<td>Inventory control and automation</td>
<td>Since 2017. Still in progress</td>
<td></td>
</tr>
<tr>
<td>3D printing</td>
<td>Initially in 2012; most adopters since 2019</td>
<td>Limited use (no production): prototypes, tools, etc.</td>
</tr>
<tr>
<td>Virtual reality</td>
<td>Only in R&amp;D</td>
<td>Training</td>
</tr>
<tr>
<td>Augmented reality</td>
<td>Only in R&amp;D</td>
<td></td>
</tr>
<tr>
<td>Artificial intelligence</td>
<td>Since 2018</td>
<td>Only for very specific problems</td>
</tr>
<tr>
<td>Data analysis systems</td>
<td>To be developed</td>
<td></td>
</tr>
</tbody>
</table>

4.2 Process of introduction of Industry 4.0 technologies

The process of the introduction of the technologies encompassed by Industry 4.0 into automotive plants followed some common guidelines in the majority of plants in our sample. The initiative for introducing a particular technological improvement starts with the plant in most cases, with original ideas found usually among local suppliers of capital goods and in local engineering companies that have worked on previous projects with the plant.

The main problem faced by plants in adopting technological improvements relates to the need for the approval of capital expenditure by the head office of the company that owns the plant. Plants have very little autonomy in capital expenditure decisions and, therefore, have to seek approval by submitting a justification that, in most cases, involves recovering the planned expenditure over a very short period of time (periods of one to three years). The probability that the submitted project will be approved is increased where its implementation involves a reduction in the workforce. In this process, the plant manager takes on special significance since he or she is the direct link to MNC decision-making centres, and his or her ability to sell the plant proposal is key in obtaining final approval for it.

It is not common for the MNCs which own plants to impose the adoption of Industry 4.0 technologies on any plant, except in the case of ERP for which the MNC will have negotiated licences for use throughout the company. The remaining projects are very specific to the plant and respond both to the need to solve specific problems and to the plant’s capacity to realise process improvements.
One of the business managers interviewed considered that the origin of the introduction of Industry 4.0 technologies could be linked to a change in mentality at the plant around 2012, when the search for solutions to production challenges was directed towards the outside while, at the same time, collaboration between company departments was increased. In contrast, the previous path to resolving production problems had been to rely almost exclusively on internal resources.

According to our interviewees, the internal dynamic of the plant is the key factor in differentiating between those plants that are actively adopting new technologies and those that are simply replicating the experiences of neighbours or adopting the suggestions of MNC headquarters.

4.3 Main advantages of the introduction of industry 4.0 technologies

The main advantages that the plants recognise arising from the adoption of Industry 4.0 technologies are summarised in Table 3. The specific characteristics of the plant determine the type of technologies that are of special interest to each one. As an example, suppliers working on sequential deliveries for a vehicle assembly plant must meet a very strict schedule of cost reduction over the lifetime of the assembled model and, therefore, feel specific pressure to achieve continuous cost reductions. In addition, the plant’s ability to meet the planned cost reduction schedule is a key feature of being able to win new assembly supply contracts when the assembly of a new model is being negotiated. These sequential delivery plants do not have the capacity to influence the production awarded and, therefore, the technologies introduced will focus mainly on cost reduction and on resolving known quality problems.

On the other hand, unlike supplier plants working on sequential deliveries, one of the plants in our sample is responsible for a very specific product, the demand for which is met in short runs. Here, the introduction of new technologies has been aimed fundamentally at achieving a greater degree of flexibility as well as offering an image of innovative capacity that will encourage the award of new contracts.

In addition to these specific aspects, all the plants also include among the advantages of adopting these new technologies their positive effects on quality, the health and safety of workers and the image of the plant. The latter is key not only with regard to customers but also within the MNC itself, in the context of plants recognising that increased levels of competition are not only external but also internal as regards other plants within the company.
4.4 Impact on working conditions and employment

One of the sections of the questionnaire was specifically designed to examine the effects of the adoption of new technologies on employment and working conditions.

With regard to the quantitative effects on employment, all plant managers agreed that there have been no redundancies directly linked to the introduction of Industry 4.0 technologies, although they do acknowledge that there have been relocations of workers due to the further automation of certain phases of the process. In this sense, new technology is running in an apparently contradictory direction to the general idea that such technologies fundamentally presuppose the substitution of human intervention with machines. The only obvious reduction in the number of workers is associated with the introduction of AGVs, which clearly replace forklifts. Nevertheless, it is acknowledged that the plants are in a process of reducing the workforce in the medium- and long-term, and are trying to do so while not generating enforced lay-offs.

With regard to changes in the qualifications and skills of workers, the increase in the level of digitalisation and automation of plants has meant:

— new skills on the part of maintenance employees, especially with regard to programming, which complement their traditional mechanical skillsets;
— new profiles of recent hires which recognise the need to have increased IT specialists among staff;
— new recruits will have a higher level of training than previous intakes, requiring, even for operator positions, a minimum level of occupational training.

However, suppliers in the chain recognise that the new machines introduced into the process do not require particularly sophisticated skills since improvements in the human-machine interface, together with job-specific training, make it easier for an operator to remain at his or her post and take on other, simpler tasks. The digitalisation of the process and automation have reduced the contribution of the human factor to key decisions in the production process, such as what to produce and in what quantities, the diagnosis of problems, etc., but have not meant the total elimination of the operator who now has to assume the previously peripheral tasks of monitoring the machine, cleaning, etc.

Table 3  Main advantages to the introduction of Industry 4.0 technologies

<table>
<thead>
<tr>
<th>Industry 4.0 technology</th>
<th>Cost reductions</th>
<th>Quality</th>
<th>Productivity</th>
<th>Health and safety at work</th>
<th>Plant image</th>
<th>Labour shortages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of production process with ERP system</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Automation (cobots)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>AGVs</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Inventory control and automation</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>3D printing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Our interviews allow us to anticipate a future in which increased automation may nevertheless reduce the number of operators in a plant while increasing the number of people employed in maintenance tasks. Simultaneously, the decreasing number of operators will not require a very high level of training while those occupied in maintenance will have to improve their level of competence in terms of being able to carry out programming tasks to take charge of production equipment that is increasingly sophisticated.

Training activities in plants have, therefore, been partially affected by the introduction of Industry 4.0 technologies. On the one hand, the introduction of changes in the ERP and increasing automation have been accompanied by specific training, provided by external companies as part of the contract for the implementation of new technologies. On the other, the training of the workforce in general, and of maintenance staff in particular, must increasingly encompass IT and programming courses.

In any case, there is a general recognition that an increase in automation has meant improvements in the ergonomic conditions of the workplace.

4.5 Position of plants within MNCs

In the automotive sector, a tendency has been detected for MNCs to encourage competition between plants so that the allocation of workload for each depends on its competitive position within the MNC. As has already been pointed out, the plant managers we interviewed recognise that the initiative for the introduction of new Industry 4.0 technologies corresponds, for the most part, to the level of the plants themselves. It is the plants, therefore, that have the autonomy to decide which technological improvements they would like to carry out, although the authorisation of capital expenditure is the responsibility of the headquarters. Although the introduction of Industry 4.0 may be undermining the locational advantage of the availability of flexible and cheap labour, the plants in our sample do not perceive their position within the MNC to be affected in this regard. However, they do recognise that they are being continuously monitored as regards their profitability which, in many cases, depends directly on the costs of production. Some of the plants in our sample work on sequential deliveries and, therefore, their current location is completely dependent on the location of their customer’s plant.

Once a technological improvement has been introduced in one plant, it would be possible to extend this to the rest of the plants within the MNC. At this point in the process, plants realise that there are two, opposing effects that the dissemination of their Industry 4.0 improvements could have on the position of their plant within the MNC:

— on the one hand, a plant that is very active and successful at introducing technological innovations could, in disseminating them to the rest of the plants owned by the MNC, achieve a certain prestige as an agent of technological improvement, thus strengthening its position within the MNC;
on the other, the rapid diffusion of such improvements to other plants (normally competitors within the MNC) could erode the advantages of the plant in terms of cost and quality. This would recommend the delay of such diffusion in order to maintain the competitive advantage obtained over the other plants in the company.

In this sense, our interviews suggest that MNCs have not developed formal systems which facilitate the dissemination of technological improvements among the plants. In the interviews we conducted, only one case could be recognised of an MNC that has developed an incentive system in which plants could share technological improvements. Within the plants we interviewed, there are instances of the application of an Industry 4.0 technology being first developed in the Spanish plant and then transferred to other plants in the group. In one case, a Spanish engineering company that had worked with one of the plants was hired by another MNC plant located in a central and east European country in respect of the digitalisation of its production process.

In principle, it could be anticipated that MNCs might develop a common services department that would promote the adoption of Industry 4.0 technologies throughout the group. In this instance, all the plants supplying the MNC would work under the same system and with a very similar process, sharing technological problems and solutions. The extreme case would be represented by those MNCs that operate on the basis of sequential deliveries, with the geographic location of their assembly plants adjusted to the location of their customers. Here, it might be acceptable for some plants, depending on their location, to carry out activities relative to their own locational context, which may require alternative technological solutions. For example, in one location the problem might be a poor energy supply, which would encourage the introduction of more energy-efficient technologies; while in another the main problem might be labour shortages, which would naturally encourage a greater degree of process automation to reduce the need for labour. In this sense, the strategy of granting the initiative for the introduction of Industry 4.0 technologies to the plants themselves would be rational since the problems faced by each are highly dependent on the economic context of their location.

Even here, however, this should be complemented with the existence of internal mechanisms within the MNC that encourage the dissemination of technological improvements among the plants, granting decision-making capacity on their adoption to the plants’ own management teams. A strategy that promoted adaptation to the local environment in terms of collaboration with local companies while, at the same time, promoting the dissemination of solutions across the group would create a level of competitive advantage over and above what we detected was the case for most of the plants in our sample.
5. Conclusions

Since the introduction of the term ‘Industry 4.0’ to refer to a virtual fourth industrial revolution (Kagermann et al. 2013), numerous papers have been published with the aim of estimating the effect of the introduction of these new technologies on employment and, even more relevant for those countries without domestic capital MNCs, to estimate the possible backshoring effects of assembly activities. Most of the work has focused on anticipating the macroeconomic effects on the labour market in the medium- and long-term, but this has not provided information on the qualitative aspects nor on the degree of implementation of Industry 4.0 and the resistances and complications that could occur during the adoption process. The work on which this chapter is based has been intended to contribute to the literature on the subject by providing qualitative information obtained directly through interviews.

Our area of study has been focused on the automotive sector (one of the most dynamic in the adoption of Industry 4.0) and plants located in Spain, both that of an assembler (VW group) and those of eight different tiered suppliers.

Our analysis of the information obtained through field work allows us to recognise a process of an increasing level of digitalisation (mainly through the integration of the production process with the company’s ERP), starting about five years ago. At the same time, although independent of digitalisation, automation is increasing. No structural change seems to be detectable, but there has been an intensification of this process (an increase in the number of robots and the introduction of AGVs). In addition, those we interviewed recognise that greater digitalisation has allowed a huge amount of information to be accumulated on the production process, but it is also accepted that, for the moment, all this information is not being used.

The research highlights that initiative over the introduction of Industry 4.0 solutions lies at plant level and is particularly dependent on the motivation of the personnel directly involved, including the process engineers (in detecting possible improvements) and the plant manager (in negotiating to gain authorisation for capital expenditure from MNC headquarters). The introduction of this technology in Spanish plants is being carried out with the collaboration of local agents: engineering companies; capital goods suppliers; technology centres; and, to a lesser extent, universities. The changes indicated have not, for the moment, led to appreciable cuts in employment, although there are indications of the reassignment of workers to new tasks and a demand for new profiles and new skills in certain jobs (for example, maintenance personnel being required to have programming knowledge).

The increase in the degree of digitalisation is still very recent and the essential characteristics of the process of introducing these new technologies remain in the definition phase. However, both the ability to introduce such innovations and to adapt those that have been developed are key issues in determining the competitive position of plants and companies. This is even more relevant when the analysis focuses on an environment as competitive as the automotive sector, in which competition between regions and countries is determined not only by competition between companies but
also by growing internal competition within the company, manifested in the closure of some plants and the expansion or opening of new ones in different locations. It was particularly interesting in the light of this that MNCs do not have formal systems for disseminating the innovations introduced in a plant to the rest of their plants working in the same sector.

To this context, which is volatile and in which competitive pressures are acting in different directions, not only in that of digitalisation, we must add the uncertainties generated by the switch to electric vehicles and changes in demand behaviour and in the form of car ownership, as well as mobility patterns. This may condition, and certainly deepen, some of the trends observed as a result of the implementation of Industry 4.0 technologies.

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