

No plant, no problem? Factoryless manufacturing and economic measurement

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Keywords: factoryless manufacturing, contract manufacturing, economic measurement, web scraping.

JEL classification: D22, E01, L24, L60

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Abstract

‘Factoryless manufacturing’ describes the strategic decision by businesses to outsource part or all of their production to a sub-contractor, sometimes overseas. Although it seems to be widespread in some sectors of manufacturing, the phenomenon is not captured by existing economic statistics. Failure to measure its extent implies there may be misattribution of production activity across sectors and countries. In particular, the decline of manufacturing could be somewhat overstated. We present web-scraped evidence on the extent of factoryless manufacturing in the UK, finding that firms in sectors such as chemicals and pharmaceuticals are more often involved in contract manufacturing, whereas in the US it is more prevalent within electronics. We also present case studies on UK automotive and pharmaceuticals based on systematic analysis of annual reports and websites. Given the sector-based focus of many economic policies, these findings point to the need for consistent measurement of factoryless manufacturing through official surveys.

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1 Introduction

One of the dominant features of modern production is the extension of value chains and reorganisation of production activities into ‘tasks’ (Acemoglu and Autor, 2011; Baldwin and Robert-Nicoud, 2014). Firms increasingly operate as part of extended chains or networks, with the allocation of activity often determined by firm-specific capabilities (e.g. (Pisano, 2017; Teece et al., 1997; Tasse, 2014). International trade in tasks is growing, driven by global value chains (GVCs) and the geographic fragmentation of production stages (Baldwin, 2006). Today around two thirds of global trade consist of intermediate inputs, while intangible inputs such as R&D and IP account for 13% (McKinsey Global Institute, 2019). One of the key enablers of this trend is digitalisation as it makes it easier to reallocate tasks within and among firms, including into those remaining in high-income economies and those outsourced to lower income economies (Kamal et al., 2015; Baldwin, 2017). This reallocation poses challenges to measurement and the analysis of important dynamics in economic production, as statistics on flows within value chains are not collected, nor easy to collect (Houseman and Mandel, 2015; Ahmad et al., 2019). Yet this information is vital for the understanding of growth and productivity dynamics, nations’ or regions’ comparative advantage, and even the relative role of manufacturing and services sectors.

This paper focuses on a specific aspect of value chains: factoryless manufacturing (FM), or in other words the use of contract manufacturing services such that the production of either intermediate products or entire product lines is outsourced to subcontractors, possibly located in another country. FM involves firms that design and innovate, and retain intellectual property, and also retail the products, but contract out (some of) the actual production. They are also referred to as ‘factoryless goods producers’ (FGPs). They are one example of the digital economy trend toward renting fixed capital assets rather than owning them, along with others such as cloud computing (Coyle and Nguyen, 2018). High profile examples include Apple, which does not manufacture hardware, Nike, which does not make shoes or clothing, and Dyson, which does not manufacture consumer white goods. For example, Dyson uses several contract manufacturers in South-East Asia to manufacture all of its electronic appliances.¹ Sir James Dyson makes this claim for the relationship: “We are not contracting out; we are heavily involved with the manufacturers and teaching them how to make each of our products as it comes out”.²

The phenomenon has potentially significant implications for economic measurement and analysis. One set of implications concerns the analysis of different sectors of the economy. For example, adoption of FM can result in businesses being classified outside of manufacturing into the distribution sector (Morikawa, 2016). In other words, some ‘manufacturing’ companies, including some large ones, may not be classified statistically as manufacturers. In addition, practice may vary between countries. The phenomenon thus

¹ For instance, Malaysia-based SKP Resources was awarded a 5-year contract worth £550 million to produce Dyson’s upright vacuum cleaners, hand dryers and bladeless fans.

² The Edge Markets, 1st October 2018: <http://www.theedgemarkets.com/article/dyson-transforming-johors-highvalue-manufacturing-ecosystem>

needs to be seen against the backdrop of employment and output in ‘manufacturing’ declining by almost 40% in the UK in the last 20 years to only 9% of value-added and employment (McKinsey Global Institute, 2019). The use of contracted manufacturing services may be contributing to this trend. Unfortunately, empirical evidence concerning the scale is limited. In a comprehensive US study, Bernard and Fort (2015) show that reclassifying factoryless producers from the wholesale sector could move up to 1.9 million workers back into manufacturing sectors.

In considering the likely scale of FM in the UK, some indication comes from Office for National Statistics (2019a) estimates that in 2016 around 6.7% of the UK’s total service sector revenues came from production activities.³ Further, around two thirds of those were generated by businesses operating in wholesale and retail trade, the precise sectors that were found to make heavy use of contract manufacturing in the US economy. In terms of shares, 15.9% of total revenue in the retail trade sector (except of motor vehicles and motorcycles) came from production, while the equivalent figure for wholesale trade was 7.6%.⁴

High turnover shares from production can also be found in other service sectors, including ‘architectural and engineering services’ (24.9%), ‘scientific research and development’ (17.7%), ‘computer programming, consultancy and related activities’ (14%) and ‘activities of head offices; management consultancy activities’ (13.7%). A full list of service sectors and respective shares of production activities in total turnover is included in Appendix A. The numbers raise questions on what products firms within these sectors are actually producing, and whether some of these firms could and should be reclassified to manufacturing (e.g. if production makes up the bulk of a firms’ revenues). As approximately 15m people work in the private service sector, up to 1m could potentially be reclassified if the 6.7% proportion is taken as a guideline. This is a very rough and ready figure but serves to illustrate the importance of the phenomenon.

In this paper we also report findings, using a web scraping approach, to show the use of contract manufacturing across different sectors. We find that in the UK it is most widely used in the chemicals sector (18% of the sample), as well as Life Sciences and Pharmaceuticals (18%), which is different to the US where it is most prevalent in Electronics and Electronic Manufacturing (14%), followed by Life Sciences and Pharmaceuticals (11%).

A further set of implications of FM concerns the analysis of production and productivity dynamics. If the way FGPs combine inputs to produce output in their production function differs from the usual assumptions of a linear chain of value added, this can have implications for the way we measure value-added and productivity (Bernard and Fort, 2017). Some authors consider that the process of industrial reorganisation is continuing with the evolution of ‘distributed manufacturing’, a concept which involves a production network of providers of various inputs into the process of producing a combination of goods and services to serve specific end-user needs (Srai et al., 2016). Firms focus on their strategic capabilities

³ Preliminary estimates available via: <https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/datasets/annualsurveyofgoodsandservicesindustrybyproductmatrix>

⁴ These figures refer to actual production undertaken by firms in the sector and exclude reselling goods produced by others.

and operate a complex network of relationships in a production ecosystem. The contributory influences are the phenomena of additive manufacturing (enabling small scale and customised runs at dispersed locations) and the ‘internet of things’ as well as now-traditional outsourcing and offshoring choices (Bryson et al., 2013), all enabled by digital connectivity and processing. Manufacturing involves a cluster of related services, often technically-specific, so the concept of the relevant sector needs to include these (Hauge and O’Sullivan, 2019). This type of production dynamic does not fit the idea of a linear value chain, allocating value added to specific stages in clearly defined sectors.

Figure 1: “Let us act as your factory”. Contract manufacturing advertising by John Wishart Machine Works, Chicago. Source: Popular Mechanics Vol.7(5), p. 570, May 1905.



The use of contract manufacturing services is not a new phenomenon and has probably existed since the early industrial era (see Figure 1). But digital technology has greatly expanded the possibilities (Baldwin, 2017). There are a number of reasons why companies would outsource their manufacturing production, including saving on costs, producing close to final markets, and mitigating commercial risks associated with upfront fixed capital investments. It also allows them to focus on their core competences or capabilities, which could be higher value-added activities such as product development, design or marketing (Penrose, 1959; Quinn and Hilmer, 1994). These drivers are somewhat comparable to companies increasingly shifting IT services to large cloud computing providers, instead of investing in on-premise equipment themselves (Coyle and Nguyen, 2018). FGPs tend to have higher levels of productivity and wages due to their focus on retaining in-house the high value-added stages of production (Bernard and Fort, 2015; Morikawa, 2016).

Factoryless manufacturing is one of a number of varying forms of international production arrangements such as merchanting, toll processing and sub-contracting (reviewed in detail in UNECE (2015)). Another related trend is the emergence of ‘manufacturing on demand’ websites based on large networks of approved manufacturers. These digital platforms promise to be faster and cheaper than alternative manufacturing options, while guaranteeing the quality of the final product. Essentially, they rely on digital technologies to streamline the ordering process via online platforms that allow the uploading of designs (including CAD files), instant quoting, matching with suppliers, and tracking of an order. For example, at the time

of writing xometry.com provides instant quotes for 700,000 parts and claims to have access to 13 million machine hours through their network of 2,500 vetted manufacturing partners in the US. Another start-up platform, fictiv.com provides similar services based on a network of 200+ partners and has been described as the “Airbnb of manufacturing”.⁵ As it provides access to manufacturers in China, an order placed through the platform involves a cross-border flow of intangible IP in exchange for physical products. According to Forbes, it serves companies producing autonomous cars, medical devices and consumer electronics and claims to have delivered more than 3 million parts to date.⁶

However, understanding these is severely hampered by the lack of availability of data on international production arrangements. In this paper we consider definitions of factoryless manufacturing and survey the few attempts to measure its scope. We contribute new estimates of its scope for the UK and US using web scraping techniques, and find it is quite extensively used in several industries, and to a somewhat greater extent than the same method indicates is the case for the US. We consider the practical implications for economic measurement, including international trade and national accounting, and offer a number of recommendations for statistical practice.

2 Defining factoryless manufacturing

There are several overlapping definitions of factoryless manufacturing (FM) and attempts to measure it. The lack of a standard definition of FM, and of factoryless goods producers (FGPs), or even consistent terminology, and the overlaps with other forms of international production arrangements noted above, reflects the limited availability of coherent and comparable data across time and countries. However, FM can be considered in a sense the most ‘extreme’ arrangement as the entire production process transforming materials and intermediate goods into final goods is carried out by other firms, while the FGP retains the IP and the relationship with customers.

In one of the earliest definitions of FM, the Economic Classification Policy Committee (ECPC, 2010: p.3-4) of the US Office of Management and Budget (OMB) considered a production arrangement as factoryless manufacturing if a business: “Outsources all of the transformation steps that traditionally have been considered manufacturing, but undertakes all of the entrepreneurial steps and arranges for all required capital, labour, and material inputs required to make a good.” By relating to relatively broad concepts such as entrepreneurship and ‘traditional manufacturing’ this definition is fairly broad. It included the requirement for FGPs to own the material inputs to production, consistent with the System of National Accounts (SNA 2008) and the Balance of Payments and International Investment Position Manual (BPM6). In 2011 the ECPC recommended that from 2017 all FGPs should be re-classified to

⁵ Inc. Magazine; Salvador Rodriguez, 17th Aug. 2016: <https://www.inc.com/salvador-rodriguez/fictiv-is-the-airbnb-of-3d-printing.html>

⁶ Forbes; Amy Feldman, 8th May 2018: <https://bit.ly/2KyLDBg>

the manufacturing sector.⁷ However, it later conceded that to do so more research was needed first to properly identify and classify all FGPs.⁸ Kamal et al. (2015) followed the OMB definition but concluded that the ‘ownership of material inputs’ was not a practical indicator for classification purposes.

The UNECE Guide to Measuring Global Production (UNECE, 2015) defines factoryless goods producers as firms that (p.14): “Supply inputs of IPPs, such as the technology, know-how and product design, but fully outsource the material transformation process required to produce the output.”⁹ Hence this definition places the focus on the provision of intangible inputs, while the sourcing of raw materials as well as labour and machinery is left with the contract manufacturer. The guide also specifies that the final product cannot be sold independently by the sub-contractor and that the price the principal pays for the produced output is fixed.

Further variations of these definitions can be found in a number of subsequent academic studies. For example, Bernard and Fort (2015) define a factoryless manufacturer as a business that (p.518): “Has no manufacturing establishments in the United States, but performs pre-production activities such as design and engineering itself and is involved in production activities, either directly or through purchases of contract manufacturing services (CMS).” This definition is useful as the ownership of actual production plants is fairly straightforward to measure in business surveys. One drawback is that a firm might still own plants in its home country. Bayard et al. (2015) analyse factoryless manufacturing among the US S&P500 firms, defining it as (p.84): “The use of contract manufacturing to produce some or all of the final products sold by a company, provided the company controls the intellectual property or design.” This definition highlights the important issue with firms that outsource some but not all of their production to contract manufacturers. Morikawa (2016) analyses FGPs in Japan based on standard business surveys using the definition (p.11): Firms satisfying all of the following three criteria: (1) they have no sales from the firms’ own manufacturing activity, (2) they have no domestic subsidiaries classified as manufacturing, and (3) they outsource the manufacturing process to other (domestic or overseas) firms.”

Some US surveys have trialled including questions relating to FM. The BEA 2011 Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons (BE-120) defines contract manufacturing services as: “Manufacturing services on materials and components owned by others and covers processing, assembly, labeling, packing and so forth undertaken by businesses that do not own the goods concerned.” The BEA 2009 Benchmark Survey of U.S. Direct Investment Abroad (BE-10A) adopts a broader definition, describing a potential production arrangement of: “Contracting with a firm to process materials and components, including payments for fabricating, assembling, labeling, and packaging materials and components.” This does not specify the ownership of the material inputs and the final good. Table 1 summarises the characteristics varying between definitions of FGPs.

⁷See US Federal Register Notice 76, FR 51240-51243, 17. August 2011.

⁸See US Federal Register notice 79, FR 46558-46559, 8. August 2014.

⁹ IPP = Intellectual Property Products

Table 1: Characteristics included in definitions of FGPs

Key characteristics	Included in definitions?
Owns and provides intellectual property and product design specifications	Always
Owns and provides necessary inputs	Some definitions
Is owner and seller of final product	Always
Pays a pre-defined price for final product	Some definitions
Does not own production facilities at home / abroad	Most definitions
Is not directly involved in transformation process	Always

3 Measuring factoryless manufacturing

FM can pose measurement challenges for the measurement of national income, productivity, industrial production, international trade, employment, wages, profits, and producer price indices, as well as sector classification (Doherty, 2015). Two issues stand out: sector classification, and international trade statistics. As noted, even reallocating FGPs to the manufacturing sector to get closer to measuring the ‘true’ sectoral composition of the economy could be significant considering the political attention the ‘shrinking’ manufacturing sector has received in Western countries in recent years. Nevertheless, Bayard et al. (2015) argue that the total value-added in an economy should be unaffected by such reallocation.¹⁰

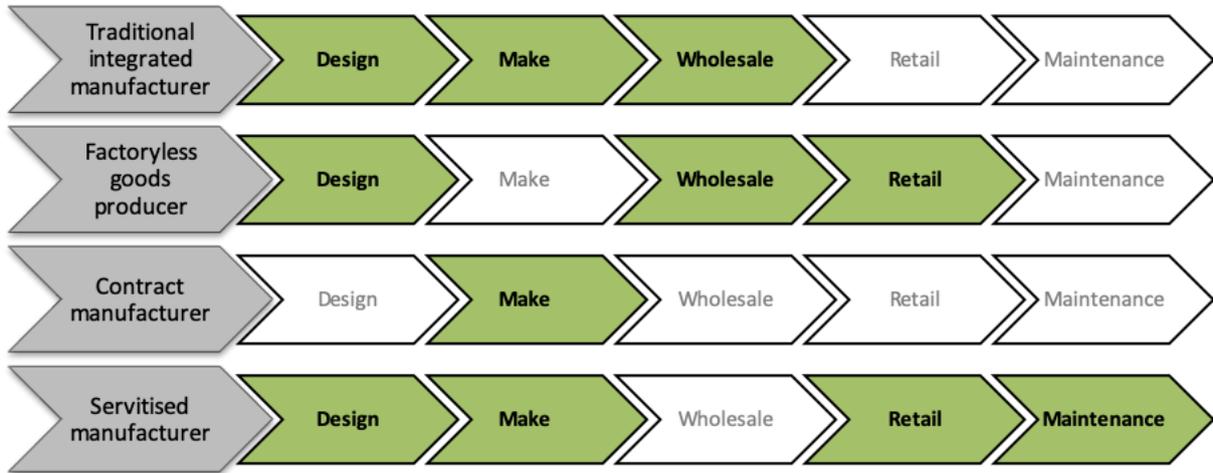
The standard NAICS or SIC classifications are anyway not invariant to the value chains operating in different sectors of the economy. For example, ‘construction’ (Section F of SIC) excludes architecture and engineering (M71), and project management, which are high value-added activities but not vertically integrated; and includes relatively low value-added maintenance and repair. On the other hand, ‘motor vehicle manufacture’ (C29) includes the high value-added design and engineering phases, which are vertically integrated by the major manufacturers, but excludes lower value-added repair and maintenance (G45) (Winch, 2003). Without doubt, business model choices as to which part of the value chain to occupy will cut across conventional sector definitions (see Figure 2). The classification issue is not trivial. One US study found that reclassifying FGPs could shift between 0.4 to 1.9 million workers from wholesale trade to manufacturing (Bernard and Fort, 2013, 2017), in other words 3-14% of total manufacturing employment in 2007¹¹.

FM also seems to be an important production model in other sectors including pharmaceuticals, apparel, toys and games, electronic components, and ICT equipment (Bernard and Fort, 2015; Bayard et al., 2015). Also, Bayard et al. (2015) show that reclassifying wholesale traders engaged in FM into

¹⁰The ‘hybridisation of services and manufacturing’ (Bryson et al., 2013) also means that a growing number of manufacturing firms are generating revenues by selling services. For example, Crozet and Milet (2017) find that 12% of manufacturing firms in France do not sell any products at all. However, they do not discuss whether some of these firms could be contract manufacturers.

¹¹ The study is based on the Census of Wholesale Trade for 2002 and 2007.

Figure 2: Value chain choices in manufacturing



manufacturing would raise manufacturing value-added between 5% and 20% in 2002 and 2007, although doubts about how the relevant survey questions were phrased limits the reliability of the answers.¹² In addition, their analysis of company reports revealed that in 2012 around 46% of S&P 500 firms reported the use of some contract manufacturing (up from 30% in 2002). More importantly, 20% of these firms exclusively relied on FM for their production, compared to 16% in 2002. In more recent survey-based work, [Kamal \(2018\)](#) uses responses to the US Economic Census (establishment level) and the Company Organisation Survey (firm level) to establish that FGPs have lower shares of production workers, higher R&D expenditure and more patents and trademarks than traditional manufactures, and suggests these features could be used to identify FGPs algorithmically. [Morikawa \(2016\)](#) found that in 2013 around 18.4% of the surveyed Japanese firms classified as not in manufacturing could be classified as FGPs, and 3.1% as offshoring-FGPs. The former figure fell from 19.7% in 2009 while the latter increased from 2.4% over the same period. These studies are summarised in [Table 2](#).

The trade measurement issues are even thornier. Under current accounting standards FM is in principle treated as if it were merchanting, meaning the FGP (i.e. the principal) is performing service activities while the foreign contract manufacturer is engaged in production ([UNECE, 2015](#)). However, factoryless manufacturing can impact statistics for total exports and imports as well as the sectoral composition of trade flows ([Doherty, 2015](#)). The totals can be distorted if certain flows are not captured in current business surveys conducted by national statistical institutes. The composition changes if FGPs (at home or abroad) are classified differently than in the past.

¹² The 2002 survey asked if “Materials fabrication/processing/assembly/blending” had been “performed for this establishment by another company” (p.113). Unfortunately, this definition could also apply to overseas establishments of the same company. In 2007 the question asks more specifically to self-identify as an FM and whether the company owns the rights to the design of a product. However, it fails to ask whether these designs are the result of in-house R&D or simply acquired.

Table 2: Estimates of impact of potential reclassification of factoryless manufacturers

Impact of potential reclassification	Country	Study
Manufacturing employment underestimated by 3-14% in 2007	United States	Bernard & Fort (2017)
Manufacturing value-added underestimated by 5-20% in 2007	Unites States	Bayard, Byrne & Smith (2015)
No. of manufact. establishments underestimated by 3-18%, 2013	Japan	Morikawa (2016)

In principle, FGPs relying on foreign sub-contractors to produce their products should record this as imports of manufacturing services, not final goods as would be the case if they were wholesale traders (Bayard et al., 2015). Figure 3 presents a schematic representation of this, highlighting how specific flows may be measured in practice. A crucial element is the location of the final consumer of a product. If she is based in the home country of the FGP (i.e. the principal) then the sale of the final product (such as a drug or vacuum cleaner) should be treated as domestic consumption. This is because even though the drug was manufactured abroad the ownership always remained with the principal, and ownership is what counts for the statistical standard. If, on the other hand, the final consumer is located in the same country as the contract manufacturer (or another third country) it should be treated as a goods export. This seems counter-intuitive as an export should be recorded even though the product does not cross the domestic border to be sold overseas. However, one has to think about the export occurring at an early stage in the production process, i.e. when the FGP transfers the intellectual property needed to produce the final product.

It is not clear how in practice different national statistical institutes are recording this phenomenon – if at all. However, the implications are clearly profound. For example, if Dyson is producing a vacuum cleaner in Malaysia and then sells it in Japan, we cannot be sure whether this is recorded as a UK goods export.¹³ The reverse holds if a contract manufacturer based in the UK is producing for a foreign FGP using that principal’s intellectual property. Therefore, a number of specific statistical challenges need to be addressed:

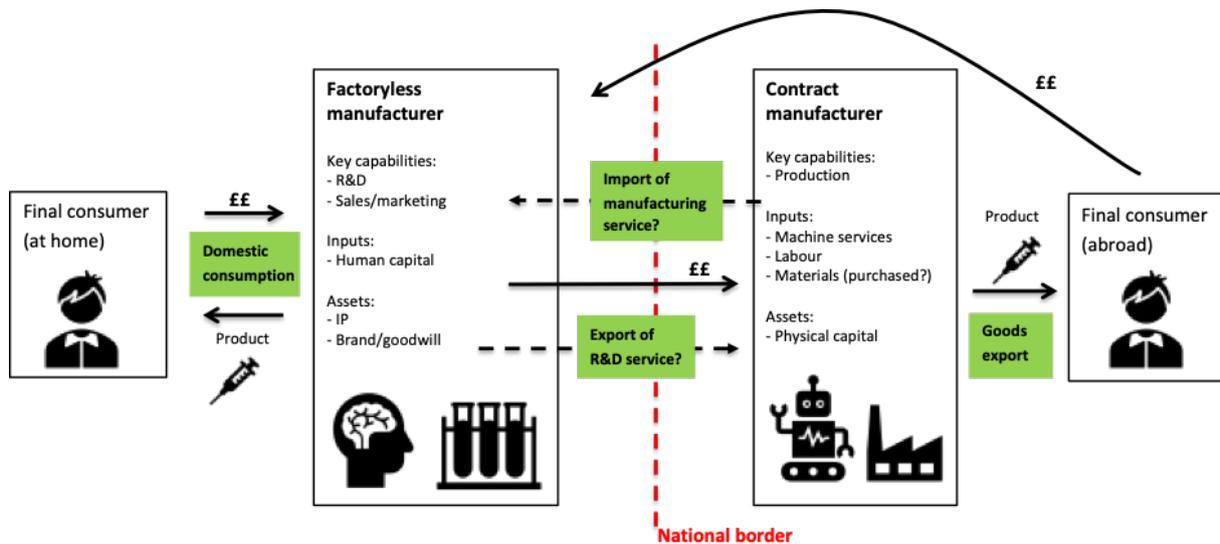
- Is the value of the intellectual property transferred by the FGP to the contract manufacturer recorded as an intangible input in the production process and as a service export?
- How do the statistics record any material inputs the FGP is providing to the contract manufacturer? Doherty (2015) argues these should not be treated as goods exports.
- If measuring factoryless manufacturing leads to a reclassification of firms (e.g. from services to manufacturing) then also the composition of trade flows is affected, though this should in principle

¹³ Similarly, how is the sale of a Jaguar E-PACE recorded when it is produced by a Canadian-owned plant in Austria but then sold across the border in Germany?

leave the totals unchanged.

- This also means that goods imports by (newly classified) ‘factoryless manufacturers’ might have to be excluded from current total goods imports. Based on this, goods imports could be lower, service imports higher with direct implications for their respective trade balances.
- At the same time there would be service exports by the factoryless manufacturer related to charges for using intellectual property, patents or trademarks during the production process. If they are not recorded at the moment, then total service exports could be understated.

Figure 3: Schematic representation of an FGP with an overseas-based contract manufacturer



4 Factoryless manufacturing in key industries

4.1 Pharmaceuticals

The use of contract manufacturers (CMs) plays an important role in the manufacturing of pharmaceuticals. According to the pharmaceutical market research firm ISR, around two thirds of the total manufacturing activity is outsourced to CMs, while a quarter of pharmaceutical companies outsource all of their production.¹⁴

Some manufacturing activities are more likely to be outsourced, including those using emerging technologies (which are higher risk), specialised technologies (which are only needed occasionally), or

¹⁴ Their finding is based on a web-based survey of 101 companies in 2016, mainly from North America and Europe that are all involved in outsourced manufacturing. <https://isrreports.com/outsourced-pharmaceutical-manufacturing/>

mature technologies (which are widely-available and of lower strategic importance).¹⁵ On the other hand, products that involve core technologies that are of high strategic importance are more likely to be kept in-house. [Bernard and Fort \(2015\)](#) find that factoryless manufacturing is more likely to occur in the pharmaceutical industry (accounting for 24% of total US FGPs in the wholesale sector in 2007). They describe pharmaceuticals (and production of apparel) as a “typical” industry where the location of design or R&D is detached from the location of production. Similarly, [Bayard et al. \(2015\)](#) show that around 70% of US pharmaceutical companies in 2012 used some contract manufacturing (up from 48% in 2002).

The UK has a significant pharmaceutical industry.¹⁶ We searched all available annual reports of pharmaceutical companies listed on the London Stock Exchange for the use of ‘contract manufacturing services’.¹⁷ In general we found in the reports a number of explanations for why pharmaceutical companies would incorporate contract manufacturing in their production model, including: avoiding risky capital investment (e.g. if a product fails in late phases of clinical research), having flexibility when future demand is uncertain, achieving cost savings as CM suppliers can specialise, and improving the ability to focus on their own strategic goals and R&D. Many of the listed companies both produce their own-brand products and at the same time act as CMs for other companies.

For example, GlaxoSmithKline (GSK), one of the market leaders in the production of pharmaceuticals, vaccines, and other consumer healthcare products, is a prominent user and supplier of contract manufacturing services.¹⁸ On its website it lists capabilities in contract manufacturing within the areas of antibiotics, inhalation, foams, liquids and active pharmaceutical ingredients. The company also reports its use of contract manufacturers for a wide range of products,¹⁹ and highlights the importance of regular auditing and quality assurance to reduce associated risks.²⁰ It recently announced a strategic decision to

¹⁵ Jim Miller, “What’s Next for the CMO Industry?”, <http://www.pharmsource.com/whats-next-for-the-cmo-industry-2/>

¹⁶ According to the ONS, the pharmaceutical sector had a gross value added of £13 billion in 2017 (7% of all manufacturing), <https://www.ons.gov.uk/economy/grossvalueaddedgva>

¹⁷ More specifically, we searched for the terms “contract manufact”, “third party”, “outsour”, and “subcontract”. This is because companies may use different terminology to refer to the same phenomenon. To avoid confusion, we provide direct quotation from the Annual Reports and websites where appropriate. Our approach is similar to the one adopted by [Bayard et al. \(2015\)](#). We also considered other pharmaceutical companies that have significant presence in the UK.

¹⁸ In 2017 the group employed 98,481 people and generated combined revenues of £30.2 billion with operating profits of £4.1 billion. “We rely on materials and services provided by third party suppliers to make our products, including active pharmaceutical ingredients (API), antigens, intermediates, commodities, and components for the manufacture and packaging of Pharmaceutical, Vaccine and Consumer Healthcare products.” – GSK, Annual Report 2017

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²⁰ “Contract manufacturers making our products are expected to comply with GSK standards and are regularly audited to provide assurance that standards are met.” – GSK, Annual Report 2017

reduce the number of subcontracted CMs by a quarter to reduce its supply chain complexity.²¹

One of the market leading CMs in the sector is BioXcellence, which is the contract manufacturing business of the Germany-based Boehringer Ingelheim.²² The CM subsidiary is run independently and produces for a number of pharmaceutical companies, including 15 of the top 20 pharmaceutical companies globally using plants in Austria, China, Germany and the US.²³ While Boehringer Ingelheim has offered contract manufacturing services for more than 25 years, BioXcellence is a brand that was launched only in 2012 specifically to market contract manufacturing capabilities. In 2017 the parent company reported total sales of €678 million in biopharmaceuticals under contract manufacturing arrangements, more than 50% higher than the €449 million in 2013 (see Boehringer Ingelheim annual reports). Boehringer Ingelheim is itself also a buyer of contract manufacturing services. Headquartered in Hertfordshire, Consort Medical is a ‘Contract Development and Manufacturing Organisation (CDMO)’ that serves pharmaceutical companies with drug and device development, formulation and manufacturing.²⁴ It manufactures products both as a contract manufacturer, as well as using its own intellectual property.²⁵ On its website Consort describes itself as a ‘leading’ contract manufacturer with ‘significant experience’. In its 2016 annual report the company states: “The global pharmaceutical contract manufacturing market was estimated to be valued at US\$58bn in 2014 and is forecast to reach US\$84bn in 2020”.

Dechra Pharmaceuticals is a UK-based supplier as well as buyer of contract manufacturing services.²⁶ Between 2005 and 2015 the company’s revenues from contract manufacturing have increased from £6 to almost £20 million. However, in 2017 they declined to £17 million, in line with the company’s long-term strategy to move away from third party manufacturing to focus on producing its own brands.

Another provider of contract manufacturing services is the UK-based Hikma Pharmaceuticals. Its clients include Boehringer Ingelheim, which is also a major stakeholder in Hikma. However, according to Hikma’s 2017 annual report, a significant reduction in orders from Boehringer has reduced its revenues.²⁷ The British-Swedish multinational AstraZeneca reports that the production of some of its intermediate

²¹ “Since 2015, we have streamlined the number of contract manufacturers (CMOs) we use by 24% to reduce complexity in our supply chain” – GSK, Annual Report 2017

²² In 2018 the group employed around 50,000 people and generated combined revenues of 17.5 billion with operating profits of 2 billion.

²³ Advertised as “Your product – Our passion” on the company website, which further states that “We have helped our customers bring 31 commercial biopharmaceuticals to the market, with three of these products ranking among the world’s Top 20 best-selling biotech products.” <https://www.bioxcellence.com/about-us/our-track-record>

²⁴ Consort Medical is listed on the London Stock Exchange and split into two divisions: Bepak and Aesica. The group’s revenues reached £311 million in 2017, with profits of £42.7 million. Bepak focusses on drug delivery devices (e.g. inhalers or auto-injectors), while Aesica provides active pharmaceutical ingredients (APIs) and other drugs.

²⁵ “[our product development includes] both contract manufacturing and products with our own proprietary intellectual property (IP)” – Annual Report 2017

²⁶ “We provide contract manufacturing services to other pharmaceutical companies” – Dechra Pharmaceuticals plc, Annual Report 2012.

²⁷ Hikma plc Annual Reports: <https://www.hikma.com/investors/hikma-annual-report/>

inputs is outsourced to third party providers, including most the Active Pharmaceutical Ingredient (API) manufacturing, formulation and packaging.²⁸ However, the company retains the final stages of production in-house to have full control of product integrity and quality. Similarly, BTG – a producer of medicine products and pharmaceuticals – outsources the production of key intermediate products to third party suppliers. The company also licenses its intellectual property rights to third party companies to develop and sell products.

Another large buyer and supplier of contract manufacturing services is Shire, which specialises in treatments for rare diseases.²⁹ The company is listed in London but headquartered in the US. It reports that in 2017 it paid almost \$460 million for contract manufacturing services, compared to \$325 million in 2015. Following the acquisition of Baxalta in 2016, Shire also became a provider of CMS and reported almost \$100 million in sales related to contract manufacturing. Finally, SkyePharma, which is part of the British Vectura Group, offers manufacturing services from development, production and packaging. It operates its main plant in Lyons, France.

Companies that did not describe the purchase or provision of CM in their most recent annual reports include Midatech Pharma, Oxford BioMedica, Worldwide Healthcare Trust plc, and Smith & Nephew. However, this does not necessarily mean that they are not engaged in such production arrangements as they are not required to report them and/or might use different terminology to describe them.³⁰

4.2 Automotive

Auto production is another sector where FGPs and contract manufacturing is reasonably widespread. One of the leading contract manufacturers in the automotive industry is the Canadian firm Magna International, which can produce entire vehicles with internal combustion, hybrid or fully electric engines. For example, since 1979, Magna has produced more than 300,000 units of the Mercedes-Benz G-Class using a dedicated workforce in its contract manufacturing facility in Graz.³¹ In addition, it produces some models within BMW's 5 Series as well as Jaguar's I-PACE and E-PACE vehicles.³² In July 2017, Jaguar Land Rover announced that: "From late 2017, the Jaguar E-PACE will be the first vehicle to be produced as part of Jaguar Land Rover's contract manufacturing agreement with Magna Steyr, an operating unit of Magna Inc, in Austria. It will be joined by the all-electric Jaguar I-PACE from 2018."³³

²⁸ Based on company Annual Reports 2015, 2016, 2017.

²⁹ "Shire conducts its own manufacturing operations for certain of its products and is reliant on third-party contract manufacturers to manufacture other products and to provide goods and services." – Shire Annual Report 2016

³⁰ We tried to mitigate this risk by searching broadly and reading around relevant sections of the companies' annual reports.

³¹ <https://www.magna.com/insights/article/a-legendary-team-for-a-legendary-vehicle>

³² <https://www.magna.com/insights/article/building-a-unique-reputation>

³³ <https://media.jaguarlandrover.com/news/2017/07/jaguar-e-pace-built-two-continents-satisfy-customer-demand>

However, the news release goes on to highlight that the car was “designed and engineered” in the UK, and the main reason for using the contract manufacturing arrangement is the fact that its UK plants are at operational capacity. Some sources estimate global sales of the E-Pace to be close to 28,000 in 2018.³⁴ However of these around 2,200 were sold to Chinese customers who are supplied by the Jaguar Land Rover factory in Changshu.³⁵ Sales from the I-Pace model added another 6,500 vehicles likely to be entirely produced by Magna Steyr in 2018.³⁶

According to company accounts, Magna Steyr produced 144,500 complete vehicles in 2018, which represents a significant increase compared to 77,900 in the year before and 75,000 in 2016.³⁷ For the year 2019 Magna expects to generate around \$7 billion from selling complete vehicles, amounting to around 17% of its total revenues.³⁸ This figure is also remarkable considering that sales of complete vehicles contributed only around \$2.94 billion (or 7.5%) to the company’s total revenues in 2017 and \$2.2 billion in 2016.³⁹

Overall, Bayard et al. (2015) estimate that around 22% of transport equipment manufacturers within the S&P500 were using a factoryless manufacturing model. What seems relatively clear is that these vehicles are exclusively produced for a specific client and the provider of the contract manufacturing service is not able to market or sell them itself. They also do not control the design and R&D process or own the intellectual property. However, it is not immediately clear where the creation of economic value is recorded in the statistics and when ownership of the final product changes (from Magna to Jaguar or Mercedes-Benz). In 2017 total annual production of the Mercedes G-Class reached 22,000,⁴⁰ of which only 4,157 were newly registered in Germany⁴¹ and 62 in Austria.⁴² This means that a Canadian-owned plant in Austria is producing a complete vehicle for a German-owned company selling the vast majority of the model outside both its home market and the country where it was produced.⁴³ It is unclear where ownership is transferred and whether we are dealing with goods or service exports or imports.

To give one further example, the Chinese electric vehicle start-up NIO shelved its initial plan to build its own vehicle factory in Shanghai. Instead it will continue to use its current contract manufacturer,

³⁴ <http://carsalesbase.com/european-car-sales-data/jaguar/jaguar-e-pace/>

³⁵ <http://carsalesbase.com/china-car-sales-data/jaguar/jaguar-e-pace/>

³⁶ <http://carsalesbase.com/european-car-sales-data/jaguar/jaguar-i-pace/>

³⁷ <https://www.magna.com/company/investors/financial-reports-public-filings/quarterly>

³⁸ <https://www.magna.com/company/newsroom/releases/release/2019/02/22/press-release---magna-announces-fourth-quarter-and-2>

³⁹ Magna Annual Report 2017: <https://www.magna.com/company/investors/financial-reports-public-filings>

⁴⁰ <https://www.automobil-produktion.de/hersteller/neue-modelle/magna-steyer-startet-produktion-der-neuen-mercedes-g-klasse>
html

⁴¹ https://de.wikipedia.org/wiki/Liste_der_Neuzulassungen_von_Personenkraftwagen_in_Deutschland_nach_Segmenten_und_Modellreihen

⁴² https://gelaendewagen.at/artikel19/suv_zulassungen_2018_03.php

⁴³ 4,188 were sold in the US and 635 in Canada. <https://canada.autonews.com/article/20180129/CANADA01/301299998/mercedes-benz-g-class-poised-to-sell-out-in-canada-automaker-says>

JAC Motors.⁴⁴ NIO, which is listed on the New York Stock Exchange, reported total production of 12,775 vehicles via JAC Motors in 2018.⁴⁵ On the company website NIO describes its business model as: “We design, jointly manufacture, and sell smart and connected premium electric vehicles.” Though it is headquartered in Shanghai it operates a design headquarters in Munich with 100 employees and global software development is operated out of its San Jose, California office with 520 employees.⁴⁶

Three current trends in the auto sector are likely to increase the reliance on contract manufacturers to produce complete vehicles: electrification, digitalisation and artificial intelligence (i.e. self-driving capabilities). The production of electric vehicles is less complex and involves fewer moving components, enabling further outsourcing because production and quality control is easier.⁴⁷ At the same time, digitalisation means that the value-added in vehicles is increasingly coming from software development and data services, meaning that the actual physical production is of relatively less strategic importance to the firm. Hence there are less concerns over knowledge-outflows related to outsourcing of production. Finally, advances in artificial intelligence and the development of self-driving systems has attracted a large range of tech companies (e.g. Google, Uber, Baidu, Didi Chuxing, Lyft, Tencent, Apple), and spin-offs or start-ups (e.g. Aptiv, Zoox, Oxbotica) that might not have any production capabilities but instead rely on third-party CMs.

5 New measures of UK and US contract manufacturing

Given the lack of data on the use of contract manufacturing arrangements we scraped information from company websites in the UK and US. We used a machine-learning web crawler developed by Glass.ai to look for specific themes that companies in the UK and US describe on their websites. This is similar to the approach adopted by Bayard et al. (2015), who manually searched the annual reports of companies in the S&P 500. However, their study was restricted to the largest companies in the US classified as being in the manufacturing sector. We looked at the universe of UK and US businesses with a website, regardless of their size or sector classification. However, our method does have a number of limitations. First, we are unable to capture businesses without a website, although it is likely that all businesses we are interested in will have a website. Secondly, we are not able to capture firms that do not disclose their production model on their website, so our figures may understate the scope of contract manufacturing. Nevertheless,

⁴⁴ NIO Inc. press release, 5th March 2019: <https://ir.nio.com/news-events/news-releases/news-release-details/nio-inc-reports-unaudited-fourth-quarter-and-full>

⁴⁵ NIA Inc. SEC 6-k form, 6th March 2019: <https://ir.nio.com/static-files/a73c4fd2-bbe3-45e2-9834-39c7c2edfa70>

⁴⁶ NIO website, accessed 7th March 2019: <https://www.nio.io/about>

⁴⁷ “Battery-powered EVs have only 20 to 30 moving parts in their drivetrains, compared to 130 to 170 moving parts in an internal combustion engine” (Mc Kinsey Global Institute, 2019: page 82) <https://www.mckinsey.com/~media/McKinsey/Featured%20Insights/Innovation/Globalization%20in%20transition%20The%20future%20of%20trade%20and%20value%20chains/MGI-Globalization%20in%20transition-The-future-of-trade-and-value-chains-Full-report.aspx>

the intelligent crawler can partially overcome this issue as it is not tied to specific keywords but can read text at large scale in an unsupervised way. It is also largely representative for the UK economy, as comparisons of Glass.ai data with official business registers have shown (Bishop and Mateos-Garcia, 2019). Further, in the previous section we presented some findings based on reading annual reports of UK businesses operating in the pharmaceutical and automotive sectors, which provides a cross-check. Thirdly, we are not able to distinguish between buyers and sellers of contract manufacturing services. However, when we manually checked a random sub-sample of the results it emerged that most businesses referring to it are providers rather than users of CM. This is intuitive, as a business that is selling products that were not necessarily produced in-house (e.g. Mercedes G-Class, Jaguar F-Pace), would not necessarily mention it on its website for strategic or marketing reasons.

For our text-based analysis the Glass.ai algorithm searched for the number of businesses that have activities based on contract manufacturing.⁴⁸ Crucially, the intelligent crawler is not restricted to specific terms but can “understand” what a company is doing even though it might not use the exact term “contract manufacturing”.⁴⁹ The choice of terms is based on the findings from the case studies of contract manufacturing in the pharmaceutical and automotive sectors. In our case it listed businesses classified within the following keywords:

- Contract Manufacturer
- Contract Manufacturing Services
- Contract Manufacturing Organization

Overall, we identified 491 organisations in the UK and 2,534 in the US in this way. Further, we break those down by sector which is presented in Tables 3 and 4, for the UK and the US respectively.⁵⁰ Here it is important to mention that the Glass.ai crawler uses a sectoral classification based on natural language processing and artificial intelligence to classify a business into around 100 sectors. Hence, these may not correspond to the firms’ formal NAICS or SIC industrial classifications. To check the quality of our results we manually read key sections of 25 randomly selected websites in the UK and found that 21 were

⁴⁸ Description from Glass.ai website (January 2019): “Glass is an automated web research capability for Market, Economic and Social Research. Artificial Intelligence and Natural Language Processing techniques have been created to build an intelligent web crawler that reads the web, recognising sites that have the characteristics of commercial, non-profit or governmental organizations. These characteristics include finding a description of the business or activity, identifying the people mentioned on the site - which may also include roles and biographies - and extracting the postal addresses referenced. Other information is captured around news content and job listings to form a picture of each organization.”

⁴⁹ Using Natural Language Processing (NLP) the algorithm can understand text at scale, identifying “business description” on websites, e.g. in the “About” section. The machine-learning model to assign the sector to a company was initially trained on a sector classification taken from LinkedIn.

⁵⁰We were able to use a live beta version of the product to access information for 1,365,121 websites of organisations in the UK and 4,298,45 websites in the US, which Glass.ai reads on a regular basis. According to Glass.ai this represents around 70% of all websites in the US and even more for the UK and includes all medium-sized and big companies.

Table 3: Sector distribution of firms with a base in the UK that use or provide Contract Manufacturing Services. N=498. Source: Glass.AI, June 2019

Sector	Share
Chemicals	18%
Life Sciences & Pharmaceuticals	18%
Biotechnology	15%
Electrical and Electronic Manufacturing	13%
Mechanical & Industrial Engineering	9%
Cosmetics & Toiletries	3%
Machinery	3%
Textiles	3%
Plastics	2%
Venture Capital & Private Equity	2%
Outsourcing and Offshoring	1%
Logistics & Supply Chain	1%
Packaging & Print	1%
Food & Beverages	1%

actual sellers of contract manufacturing services.⁵¹ Details of manual searches by company are provided in Appendix B. For the UK (see Table 3) around 18% of businesses with activities in contract manufacturing were classified as operating in the ‘Life Sciences & Pharmaceuticals’ sector, closely followed by ‘Chemicals’ (17%), ‘Biotechnology’ (15%) and ‘Electrical and Electronic Manufacturing’ (13%). Around 10% were classified within ‘Mechanical & Industrial Engineering’, 8% in ‘Medical Devices’. ‘Cosmetics & Toiletries’, ‘Machinery’ and ‘Textiles’ each had around 3% of businesses active in CM. This is a striking finding since the top 5 sectors when searching for businesses in the UK without keywords are: Construction (5%), Hospitality & Restaurants (4%), Charities & Foundations (4%), Automotive (4%), and Health, Wellness and Fitness (3%). In the US (see Table 4), the sectors with the highest share of businesses active in contract manufacturing were in ‘Electrical & Electronic Manufacturing’ (14%) and ‘Life Sciences & Pharmaceuticals’ (11%), followed by ‘Plastics’ (10%) and ‘Medical Devices’ (9%), ‘Chemicals’ (8%), and ‘Machinery’ and ‘Semiconductors & Electronic Systems’ (both 7%). The share for ‘Mechanical & Industrial Engineering’ and ‘Biotechnology’ is around 6% each. Again, we are somewhat confident in our results as these shares are very different to the overall sectoral decomposition of Glass.ai data. When searching without keywords, most organisations are classified as ‘Charities & Foundations’ (5%), followed by ‘Hospitals and Medical Practices’ (4%), ‘Real Estate and Property Management’ (4%), ‘Hospitality & Restaurants’ (4%) and ‘Construction’ (4%).

To some extent our findings are similar to Bayard et al. (2015) who report that around the majority

⁵¹ Since we do not have reason to suspect that the “false positives” are biased towards certain sectors we believe our results in terms of distribution across sectors still hold.

Table 4: Sector distribution of firms with a base in the US that use or provide Contract Manufacturing Services. N=2,534. Source: Glass.AI, June 2019

Sector	Share
Electrical & Electronic Manufacturing	14%
Life Sciences & Pharmaceuticals	11%
Plastics	10%
Medical Devices	9%
Chemicals	8%
Machinery	7%
Semiconductors & Electronic Systems	7%
Biotechnology	6%
Plastics	2%
Industrial Automation	3%
Outsourcing & Offshoring	3%
Cosmetics & Toiletries	2%
Mining and Minerals	2%
Logistics & Supply Chain	1%
Food & Beverages	1%
Investment Banking & Advisory	1%
Computer Hardware	1%
Packing & Print	1%
Venture Capital & Private Equity	1%
Textiles	1%

of contract manufacturers in the US are classified within ‘Electrical equipment’ and ‘Computer and communication equipment’ (together 11%), followed by ‘Machinery’ (11%), ‘Pharmaceuticals and Medicine’ (9%), ‘Chemicals’ (8%)⁵² and ‘Medical Devices’ (6%). The largest difference between our results and theirs can be found in the ‘Food & Beverages’ sector, as we find only 1% of US companies with contract manufacturing activities, while they reported a figure of 14%. Some of these are due to the difference in methods since they are only looking at the annual reports of the largest US companies and used a precise keyword search.

We consider this web-scraping of text applying Natural Language Processing (NLP) offers a promising approach to understanding the FM phenomenon. The methodology using Glass.ai technology has also been applied in the context of measuring the scope of the UK’s immersive technology sector (Mateos-Garcia et al., 2018). Kinne and Lenz (2019) developed their own neural network classification model to identify innovative firms in Germany on the basis of their website text. One possible extension of the results we report here would be to develop a predictive model for survey responses concerning variables such as employment and turnover, validating them where possible with Companies House data, as in Mateos-Garcia et al. (2018). However, this is a far larger task than their exercise for a specialist sector, and it would be preferable to record the FM phenomenon through the official business surveys. A further extension would be to consider the implications of FM for trade statistics and the mapping of international production relationships through web-scraping and NLP. The next section discusses the evidence available from existing trade statistics.

6 Evidence from existing UK official survey data

At the moment none of the business surveys conducted in the UK ask directly about the use or provision of contract manufacturing services. This differs from the US, where relevant questions have been introduced in business surveys, though not on a continuing basis (Bernard and Fort, 2015).⁵³ According to Doherty (2015), the import of contract manufacturing services in the US is currently quite likely to be recorded as a resale of products (i.e. merchanting). As a result, sectors with relatively high resale figures will likely capture some activity of factoryless manufacturers. To explore this in the case of the UK we look at selected products reported in the International Trade in Services Survey (ITIS) which the ONS conducts on an annual basis (see Table 5).⁵⁴ However, we have to be cautious when interpreting those figures in relation to factoryless manufacturing, since it is not clear how businesses actually interpret them and

⁵² It is likely that the Glass.ai crawler classifies firms in ‘Plastics’ instead of ‘Chemicals’.

⁵³ A list of questions from US surveys has been included in Appendix C.

⁵⁴ The ITIS survey has been revised in 2013 to comply with international standards and a question on ‘manufacturing services’ was added. One caveat is that the survey excludes travel, transport and banking industries. A copy of the full questionnaire can be found via: <https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/methodologies/internationaltradeinservicesitis>

Table 5: UK trade in services, selected products. Source: International Trade in Services Survey, ONS January 2019.

	2013	2014	2015	2016	2017
Exports (£ million)					
Merchanting	3585	1392	2241	2691	7223
Manufacturing services	2555	2103	2350	2735	3518
Charges for IP	1446	1561	1737	1455	1985
Imports (£ million)					
Merchanting	437	1099	372	345	304
Manufacturing services	760	581	627	601	925
Charges for IP	669	586	686	919	1310

whether they feel the need to report the use of contract manufacturing at all.

Merchanting: On the exports side, businesses are asked to report “Total sales during the reporting period of goods purchased for resale that have remained outside the UK.” In 2017 this amounted to £7.2 billion, which is twice as high as in 2013 (Office for National Statistics, 2019a),⁵⁵ while businesses in the wholesale & retail industry accounted for 82.5% of those. On the import side the ONS asks for “Total goods purchased for resale during the reporting period that have remained outside the UK,” with businesses reporting a total of only £300 million, down from £440 million in 2013.

Manufacturing services: In addition to merchanting activities of UK business, ITIS asks about “Manufacturing services on goods owned by others,” which on the import side is defined as “fees charged by foreign businesses for the processing, assembly, labelling and packing of goods overseas that are owned by your business.” In 2017 total imports of manufacturing services reached £925 million, up from £730 million in 2013, with around a third of the total reported by businesses in the wholesale & retail industry.

Charges for intellectual property (IP): As discussed above, the use of contract manufacturing services overseas by a UK company should theoretically be recorded as a UK export of research and development services. One question in ITIS comes close to this definition by asking businesses to report “Charges or payments for the use of Patents and other intellectual property that are the end result of research and development without transfer of ownership.” In 2017 UK businesses exported a total of almost £2 billion under this category, up from £1.5 billion in 2013.⁵⁶ However, the Wholesale & Retail industry officially only recorded £2 million of the total, which, given the scale of contract manufacturing in the sector, strongly suggests that there is under-reporting. It may be that respondents do not interpret some of their intellectual property in those terms. By looking at current business surveys conducted by ONS

⁵⁵ ONS dataset: International Trade in Services Survey, January 2019. <https://www.ons.gov.uk/businessindustryandtrade/internationaltrade/datasets/internationaltradeinservicesreferencetables>

⁵⁶ This figure is also high compared to ‘outright sale of IP’ which only accounted for £180 million.

we can thus identify a number of categories that are potentially related to factoryless manufacturing by UK businesses. However, since none of these questions is specific it is hard to say what kind of coverage this give us.

- In 2017, UK exports of goods that have been purchased for resale purposes but remained outside the UK amounted to £7.2 billion. Of these £6 billion were reported by the Wholesale & Retail industry.
 - It is possible that some businesses report sales of goods produced abroad under contract manufacturing arrangements within this category. If those businesses are classified within Wholesale & Retail trade, then there would be a case for reallocating them to the manufacturing sector. At this stage we do not know for certain whether these types of production arrangements are captured here and hence cannot make predictions about the potential magnitude of a reclassification.
- In 2017, UK imports of manufacturing services reached £925 million and of these the Wholesale and Retail sector accounted for £320 million.
 - Whenever an FGP sells goods abroad that were produced under contract manufacturing arrangements, there should be a recorded import of these services. Within ITIS this is the category that most closely matches this theory and yet manufacturing companies only account for around £390 million of the total. Possibly, some of the remaining £535 million are in fact imports of contract manufacturing services.
- In 2017, UK exports of R&D services without transfer of ownership reached £2 billion, while the Wholesale & Retail sector reported virtually none.
 - Evidence from industry reports and company reports suggests there are quite a number of UK businesses that use contract manufacturers abroad. If those subcontractors make direct use of UK R&D outputs in their production process, it should be recorded in the relevant statistics. However, there are (at least) two possibilities for why this might currently not be the case. Most likely, UK businesses do not report (or know where to report) if they provide foreign subcontractors with designs and production specifications for the provision of contract manufacturing services. A second option is that the necessary intellectual property is first transferred within the firm to a legal subsidiary abroad which then passes it on to the subcontractor. In this case these transfers should however show up under “trade in services between related enterprises” which ITIS does ask for. In 2017 transfers under this category amounted to £17.6 billion, of which £1.7 billion were in the Wholesale & Retail industry. Unfortunately, businesses do not have to specify what types of services are included.

7 Discussion

It is clear there are a number of challenges related to the official measurement and analysis of factoryless manufacturing, including:

- Firms are operating production models that mix in-house production with contract manufacturing, for some products (as in the auto sector examples) or for some intermediate inputs;
- Companies can be buyers and suppliers of contract manufacturing services at the same time (as in the pharma examples); complicating clear-cut attribution of revenues – or firms – to ‘services’ and ‘manufacturing’;
- Firms may own production facilities in various countries that might provide and/or purchase contract manufacturing services. This highlights the complexity of within-company transfers of intellectual property, making attribution of value added by country even more challenging;
- The increasing importance of intangible inputs in manufacturing, and the transfers between FGPs and CMs, makes it difficult to track cross-border flows of intellectual property that is needed for the production of high and medium-high technology products.

Factoryless manufacturing is an increasingly significant phenomenon. It is important to start collecting relevant statistics if the dynamics of production in modern economies are to be understood, and for sector-based policies to be appropriately designed and targeted. Here we have presented a list of key characteristics of FGPs and their suppliers (Table 2) and highlighted key dimensions for survey questions to consider (Figures 2 and 3). The requirements for improving national statistics include:

1. Adopt a consistent and unambiguous definition and terminology (here we have used factoryless goods producer and contract manufacturer).
2. Add questions to the appropriate business surveys. We recommend approaching this via more than one survey.
3. Ensure coverage of both the purchase and supply of contract manufacturing services, which can be carried out by the same firm.
4. It is not sufficient to look only at companies in the wholesale and retail trade sector, as the US surveys did. Other FGPs could be classified into other service sectors such information and communication or even within manufacturing.
5. Designing the survey questions needs to account for various important dimensions to collect useful replies and minimise confusion among respondents.
6. As many companies use factoryless manufacturing for only some of their products, or may act as CMs for other firms, it is necessary to go down to the product level. Definitions that require FGPs

to own no production facilities at all are too restrictive. It is more desirable to think of the ‘degree’ or ‘production volume’ that is actually factoryless. For some companies this could be 100%.

The underlying issue is the lack of statistics – not just across borders but within them – that reflect the reality of how businesses increasingly organise their activities, focusing on core capabilities and reorganising tasks internally and in their wider production network. While our web scraping of company websites provides some evidence about the scope and sector composition of FGP, indicating a trend in line with results reported in earlier literature, far more detail and scope is needed for the purposes of economic policy.

8 Conclusion

This paper has provided novel evidence concerning the prevalence of factoryless manufacturing in the UK economy, specifically its significant scale in some sectors of manufacturing. In the UK the phenomenon is more widely spread among businesses in the chemical and pharmaceutical sector, as well as biotech and electronics. In the US, on the other hand, it is mainly found in electronics and pharmaceuticals, plastics and medical devices. It is noteworthy that these sectors are all high value added and export intensive production sectors. It is possible that the actual proportion may be higher if companies opt not to describe their production arrangements on their websites for strategic reasons. The production decisions of firms to use factoryless manufacturing imply that existing sector classification of firms in official statistics may consequently be somewhat misleading, with potential policy implications.

In the UK the Office for National Statistics has recently established an International Business Unit, working in the first instance with large multinationals to develop appropriate data collection ([Office for National Statistics, 2019b](#)). While it is desirable to see further progress in official surveys in recording firms’ production arrangements, so that official production, employment and trade statistics can better reflect the structure of the economy and cross-border production chains, the methodology we use here could potentially be extended in future to model turnover and employment in factoryless goods production, once representative samples based on official surveys become available.

A Appendix

A.1 Turnover in service sectors

CPA/SIC Code	Product/Industry Group	Description	Production (share in turnover)
35.1	Electricity, gas, steam and air conditioning supply	Electric power generation, transmission and distribution	0.2
35.2 to 3		Gas; distribution of gaseous fuels through mains; steam and air conditioning supply	1.7
36	Water supply; sewerage, waste management and remediation activities	Water collection, treatment and supply	0.3
37		Sewerage	3.7
38		Waste collection, treatment and disposal activities; materials recovery	3.4
39		Remediation activities and other waste management services	5.5
45	Wholesale and retail trade; repair of motor vehicles and motorcycles	Wholesale and retail trade and repair of motor vehicles and motorcycles	2.2
46		Wholesale trade, except of motor vehicles and motorcycles	7.6
47		Retail trade, except of motor vehicles and motorcycles	15.9
49.1 to 2	Transportation and storage	Rail transport	0.1
49.3 to 5		Land transport services and transport services via pipelines, excluding rail transport	2.4
50		Water transport	0.1
51		Air transport	0.4
52		Warehousing and support activities for transportation	2.4
53		Postal and courier activities	1.7
55		Accommodation and food service activities	Accommodation
56	Food and beverage service activities		1.2
58	Information and communication	Publishing activities	2.4
59		Motion picture, video and TV programme production, sound recording and music publishing activities	2.1
60		Programming and broadcasting activities	4.1
61		Telecommunications	4.1
62		Computer programming, consultancy and related activities	14
63		Information service activities	0.5
64	Finance and insurance	Financial service activities, except insurance and pension funding	0
65.1 to 2		Insurance and reinsurance, except compulsory social security	0
65.3		Pension funding	0
68.1 to 2	Real estate	Buying and selling, renting and operating of own or leased real estate, excluding imputed rental	2.1
68.3		Real estate services on a fee or contract basis	0.1
69.1	Professional, scientific and technical activities	Legal activities	0
69.2		Accounting, bookkeeping and auditing activities; tax consultancy	0.1
70		Activities of head offices; management consultancy activities	13.7
71		Architectural and engineering activities; technical testing and analysis	24.9

72		Scientific research and development	17.7
73		Advertising and market research	0.6
74		Other professional, scientific and technical activities	7.4
75		Veterinary activities	1.8
77		Rental and leasing activities	3.7
78		Employment activities	0.5
79	Administrative and support service activities	Travel agency, tour operator and other reservation service and related activities	0
80		Security and investigation activities	9.2
81		Services to buildings and landscape activities	2.6
82		Office administrative, office support and other business support activities	9.8
85	Education	Education	0.2
86	Human health and social work activities	Human health activities	0
87		Residential care activities	0
88		Social work activities without accommodation	0.8
90	Arts, entertainment and recreation	Creative, arts and entertainment activities	3.7
91		Libraries, archives, museums and other cultural activities	3.7
92		Gambling and betting activities	0
93		Sports activities and amusement and recreation activities	2.5
94	Other services	Activities of membership organisations	0.9
95		Repair of computers and personal and household goods	12.1
96		Other personal service activities	8.7
Total			6.7

A.2 Further testing on Glass.ai data

To check the quality of the results from the Glass.Ai search we manually checked a random subsample of 25 companies based on search results for the UK. Overall, we found that 21 of them are genuine providers of contract manufacturing services. Some might also use contract manufacturing services, especially the larger ones. The “false positives” were mainly active in specialised media, communication and publishing as well as science parks. Below is the list of 21 companies with relevant quotes from their websites or annual reports. We also report the “sector” as assigned by Glass.Ai behind the company name.

Recipharm (Life Sciences and Pharmaceuticals) “Recipharm’s largest business stream is manufacturing services. Our pharmaceutical manufacturing expertise means we can deliver a large number of pharmaceuticals in a variety of dosage forms, requiring the use of a broad range of technologies. ” (Source: <https://www.recipharm.com/our-story/business-overview>)

Roslin Cell Therapies (Biotechnology) “RoslinCT is a leading GMP contract manufacturing organisation. RoslinCT offers a range of integrated services from technology transfer, process and assay development through to GMP manufacturing, QP certification and batch release of cell-based therapies for clinical trials. We established and validated GMP manufacturing facilities within SCRM in 2012 and continue to grow the GMP contract manufacturing business from this site.” (Source: <https://www.roslinct.com/about>)

Symbiosis Pharmaceutical Services (Life Sciences and Pharmaceuticals) “Our company was established in 2011 to meet specific client expectations of offering flexible, responsive, transparent and timely sterile contract manufacturing, whilst maintaining the high levels of technical and quality excellence required by regulatory bodies. The decision to create Symbiosis was driven by the need to address specific gaps highlighted in the sterile drug product manufacturing marketplace. In essence, our aim was to create a business model that delivered the value of saving clients’ drug development time by offering shorter lead times to manufacturing slots and product release.” (Source: <http://www.symbiosis-pharma.com/about/symbiosis-philosophystory/>)

Almac Group (Life Sciences and Pharmaceuticals) “As a world leading Contract Pharmaceutical Development and Manufacturing organisation, we will help you across the full biopharmaceutical product lifecycle, from drug development through to commercialisation. With extensive facilities in Europe, North America and Asia, we will work with you in the most appropriate manner for your situation: either on a single, standalone project or on a longer term basis as your strategic partner.” (Source: <https://www.almacgroup.com/development-manufacturing/>)

Techtron (Chemicals) “Techtron is a BRC accredited contract formulator, manufacturer and packer of chemical liquids and has over 30 years’ experience of putting liquids in bottles, in volumes ranging from 50ml to 1000L, with flexibility for short runs. We work with a variety of customers within a range of market sectors.” (Source: <https://www.techtron.co.uk/about-us>)

Custom Pharma Services (Life Sciences and Pharmaceuticals) “Established in 1979, Custom Pharma Services has grown to become your expert resource for contract development, contract manufacturing and

packaging in the United Kingdom. As a leading contract development and manufacturing organisation, Custom Pharma Services tailors our services to meet every individual client's needs. We can guide you through your entire programme — from preformulation through manufacturing, packaging and delivery — or we can step in at any stage to deliver to you the services you need when you need them.” (Source: <http://www.custompharma.co.uk/company/>)

Medigene AG (Biotechnology) “For the Company’s own development projects, the gross margin adjusted for inflation was assumed to lie approximately between 78%-86%. Further, it is assumed that production of these products will be outsourced to corresponding services providers (contract manufacturer); accordingly no investment in the Company’s own plant, except for research purposes, has been budgeted. Marketing, administration and general costs are planned as a lump-sum percentage of annual revenue.” (Medigene AG, Annual Report 2018, p. 81)

Quest Nutra Pharma (Life Sciences and Pharmaceuticals) “Quest provides contract-manufacturing services for strategically selected partners. We can contract manufacture existing products from our portfolio and also custom develop and manufacture new products, formulations and concepts for our partners. All the products are manufactured and quality tested in our GMP facilities.” (Source: <https://www.qnutrapharma.com/contract-manufacturing>)

Briar Chemicals (Chemicals) “Briar Chemicals provides world class contract manufacturing services to global leaders in agrochemicals, fine and speciality chemical sectors.” (Source: <http://briarchemicals.com/about/>)

Filtronic (Telecommunications and Wireless) “Filtronic Contract Manufacturing Service provides customers with a full manufacturing and test capability for their own products. The Contract Manufacturing Service enables customers to realise their own designs using Filtronic’s precision hybrid manufacturing facilities, supported by a strong operations and manufacturing engineering team. This enables cost-effective manufacture and sustained cost reduction services for customers requiring complex, high mix products to high reliability and quality levels” (Source: <http://www.filtronic.com/broadband/contract-manufacturing-and-design-service/contract-manufacturing/>) SDF Electronics (Electrical and Electronic Manufacturing) “All our electronic systems are manufactured by us “in house” in order to ensure the quality of our products. As well as PCB assembly we also provide cable assembly and mechanical assembly, we can also provide contract manufacturing services for other companies products. We have built up a range of services to ensure that we can provide our customers with everything they need for the production of their products. From PCB and cable assembly to mechanical assembly, we can provide these services to you.” (Source: <http://sdfelectronics.co.uk/services/>)

Clonallon Laboratories (Medical Devices) “We offer all our customers and clients the opportunity to customise their products to meet their exact requirements. We endeavour to maintain flexibility and adaptability when providing outsourcing solutions. With product and contract manufacturing we focus on effective communication to ensure outsourcing is an opportunity and not a cost. We reliably look after the logistics – from sterilisation services and product assembly, to supply chain

management. We continue to improve on our lead times and supplier relationships throughout our network. Every step of the supply chain is analysed to ensure the timely delivery of correct products. We manufacture to client specifications and the quality of our service is always a priority.” (Source: <https://clonallon.com/contract-manufacturing-services/>)

Biosynergy Europe (Biotechnology) “Should you be outsourcing some key manufacturing processes? Our clients are faced with the twin challenge of higher research and development costs and shrinking exclusivity periods. They choose to outsource because it allows for the best utilisation of resource and a more rapid, cost-effective route to proof of principle. Partner with us and your development programs will proceed rapidly without the associated costs of design, construction and validation of a production facility. You will be able to quickly scale your requirements up or down, knowing that we understand your particular requirements.” (Source: <http://www.biosynergyeurope.com/index.php?page=why-outsource>)

Aesica Pharma (Life Sciences and Pharmaceuticals) “Aesica is a leading pharmaceutical contract development and manufacturing organisation (CDMO) for both APIs and finished dose forms. Our full service, end-to-end pharmaceutical development and manufacturing solution comprises capabilities in formulation development for API and finished dose, manufacturing at all scales and packaging services.” (Source: <https://www.consortmedical.com/>, also discussed in the main text)

JD Burford (Machinery) “J D Burford Ltd is a family run business with over 40 years experience in metal spinning, metal pressing and metal finishing, customer designed components and products. Today, our business has expanded meaning we are now equipt to offer a wide range of sub contract manufacturing services allowing us to be a “ONE STOP SHOP”, for all your metal spinning and ancillary process requirements. We strive to provide our customers with high service and quality levels, whether we are manufacturing a small component or a finished product.” (Source: http://www.jdburford.co.uk/about_metal_spinners_wales.htm)

Cala Chem (Chemicals) “CalaChem is a world class contract / toll manufacturer of speciality chemicals and agrochemical actives. With over 90 years of experience in the chemical industry we aim to be your service partner of choice. We offer a very open and collaborative approach. We want you to consider CalaChem as an extension of your own manufacturing facilities. We listen and understand your challenges and risks before identifying the right solutions which meet your needs.” (Source: <https://calachem.com/contract-manufacturing-services/>)

Prototype Electronics (Electrical and Electronic Manufacturing) “Prototype Electronics are PCB assembly manufacturers offering a responsive contract manufacturing service from our modern and comprehensive facilities situated in Dorchester, UK. As an ISO 9001:2008 approved supplier, we offer a total PCB manufacturing solution, from prototyping, design and procurement to SMT, BGA and electronic PCB product assembly services.” (Source: <http://protoelect.co.uk/>)

Perrigo Company plc (Health) “We may utilize available capacity by performing contract manufacturing for other companies.” (Perrigo Annual Report 2018) 1602 Group (Electrical and Electronic Manufacturing) “We manufacture a combination of our own products and contract manufacturing for other similar

companies. Working on our own wide range of customised products gives us the perspective to be able to think like you. Outsourcing to 1602 Group gives you the flexibility to have a manufacturing facility in the UK without the overhead. You can drop by and discuss the product or even pick up a few urgent parts. We have engineers on site to help you with turning your design into reality. We use a combination of sophisticated planning tools and real people with common sense to provide a highly flexible service with consistent results and a competitive price.” (Source: <http://1602group.com/contract-Manufacturing.html>)

Lower Lodge Candles (Retail) “In addition to our own collections, we produce scented candles for high-profile luxury brands, parfumeurs and boutique stores. We offer a fully bespoke contract manufacturing service from initial concept to shelf ready product, where we ensure that every aspect of the development and production process meets our exacting standards. Our specialist technical department conduct rigorous batch tests to guarantee consistency and quality across all products. In addition, we offer complete traceability on every candle and diffuser we produce. Our extreme attention to detail and commitment to excellence, along with our dedicated customer service is why our discerning clientele come back to us time and time again.” (Source: <https://www.lowerlodgecandles.com/resources/aboutus>)

Ernest Jackson (Medical Devices) “With a heritage dating back to 1817, Ernest Jackson has 200 years experience and expertise in developing, manufacturing and marketing medicated confectionery and vitamin pastilles. Ernest Jackson offers a wide range of well-known branded products, as well as a comprehensive contract manufacturing service. At the factory site in Devon, Ernest Jackson has the capability to manufacture pastilles, sugar boilings and paste lozenges, made to exacting standards, some to formulae handed down by generations and others to meet the ever evolving market requirements.” (Source: <https://www.ejackson.co.uk/contract-manufacturing>)

A.3 Overview of existing surveys and questions relevant for capturing CMS

Organisation	Survey	Question	Year
US Bureau of Economic Analysis (BEA)	Benchmark Survey of U.S. Direct Investment Abroad (BE-10A)	<i>Purchase:</i>	2009
		1. Did this U.S. reporter purchase contract manufacturing services from others (including foreign affiliates)? (Yes/No)	
		2. The U.S. Reporter owned some or all of the materials used by the contract manufacturers and the companies providing the manufacturing services were: a. Located inside the U.S. (Yes/No) b. Located outside the U.S. (Yes/No)	
		3. The U.S. Reporter did not own the materials used by the contract manufacturers and the companies providing the manufacturing services were: a. Located inside the U.S. (Yes/No) b. Located outside the U.S. (Yes/No)	
		<i>Perform:</i>	
		1. Did this U.S. reporter perform contract manufacturing services for others (including foreign affiliates) outside the U.S.? (Yes/No)	
US Bureau of Economic Analysis (BEA)	Benchmark Survey of Transactions in Selected Services and Intellectual Property Products with Foreign Persons (Form BE-120)	<i>Purchase:</i>	2011
		(1) Did you purchase contract manufacturing services from foreign persons in fiscal year 2011?	
		(2) Are you able to report the fee you paid for contract manufacturing services? If yes – Enter the amount you paid foreign persons for contract manufacturing services	
		(3) The payments for manufacturing services in question 2 were (check the appropriate box): <ul style="list-style-type: none"> • Based on accounting records. • Estimated by persons knowledgeable regarding these transactions. 	
		(4) Destination of goods produced after you purchased contract manufacturing (check the appropriate box): <ul style="list-style-type: none"> • Goods do not enter United States • Goods are imported into the United States • A portion of the goods remain abroad and a portion are imported into the United States • Destination is unknown 	
		<i>Perform:</i>	
		(1) Did you perform contract manufacturing services for foreign persons in fiscal year 2011?	
		(2) Are you able to report the fee you received for performing contract manufacturing services? NOTE: This may include the cost of the materials you purchased to perform this service. If yes – Enter the amount received from foreign persons for contract manufacturing <u>services</u> you performed on goods owned by foreign persons and go to questions 3 and 4.	
		(3) The receipts for manufacturing in question 2 were (check the appropriate box): <ul style="list-style-type: none"> • Based on accounting records. • Estimated by persons knowledgeable regarding these transactions. 	
		(4) Destination of goods produced after you performed contract manufacturing (check appropriate box): <ul style="list-style-type: none"> • Goods remain in the United States • Goods are exported from the United States • A portion of the goods remain in the United States and a portion are exported from the United States • Destination is unknown 	
Census Bureau	Company Organization Survey (NC-99001)*	In 2011, did your company do any of the following activities related to manufacturing?	2011
		1. Operate manufacturing facilities (such as a factory, plant, or mill) where products are completed or partially produced? <ul style="list-style-type: none"> • Yes - Go to line 2 • No - Go to line 3 	

		<p>2. Provide contract manufacturing services to other companies incorporating their patents, trade secrets, or proprietary technology?</p> <ul style="list-style-type: none"> • Yes • No - Go to line 3 <p>Estimate the percent of operating revenues and net sales, as reported in Section 3B, from contract manufacturing services.</p> <ul style="list-style-type: none"> • Less than 25% • 25 to 49% • 50 to 74% • 75 to 99% • 100% 	
		<p>3. Purchase contract manufacturing services from other companies or foreign subsidiaries of your company incorporating your company's patents, trade secrets, or proprietary technology?</p> <ul style="list-style-type: none"> • Yes • No - Go to Section 4 on CERTIFICATION <p>a. Use 3rd party contract manufacturing services inside the U.S.?</p> <ul style="list-style-type: none"> • Yes • No <p>b. Use 3rd party contract manufacturing services outside the U.S.?</p> <ul style="list-style-type: none"> • Yes • No <p>c. Use your company's foreign subsidiaries' or affiliates' contract manufacturing services at locations outside the U.S.?</p> <ul style="list-style-type: none"> • Yes • No <p>d. Estimate the percent of the cost of sales from expenses for contract manufacturing services.</p> <ul style="list-style-type: none"> • Less than 25% • 25 to 49% • 50 to 74% • 75 to 99% • 100% 	
Census Bureau	Census of Wholesale Trade (WH42101–WH42237)	<p>1. Product design/engineering</p> <ul style="list-style-type: none"> • This activity was performed by this establishment • This activity was performed for this establishment by another company • This activity was not provided by this establishment 	2002
		<p>2. Materials fabrication/processing/assembly/blending</p> <ul style="list-style-type: none"> • This activity was performed by this establishment • This activity was performed for this establishment by another company • This activity was not provided by this establishment) 	
		<p>1. Did this establishment design, engineer, or formulate the manufactured product that it sold, produced, or shipped?</p> <ul style="list-style-type: none"> • Yes • No 	2007
		<p>2. Which of the following best describes this establishment's primary activity? (Mark only one box)</p> <ul style="list-style-type: none"> • Providing contract manufacturing services for others • Transforming raw materials or components into new products that this establishment owns or controls • Reselling goods manufactured by others [with or without minor final assembly] • Other – Specify below 	
		<p>3. Did this establishment purchase contract manufacturing services from other companies or other establishments of your company to process materials or components that this establishment owns or controls?</p> <ul style="list-style-type: none"> • Yes, primarily with establishments WITHIN the 50 states and the District of Columbia 	

		<ul style="list-style-type: none"> • Yes, primarily with establishments OUTSIDE of the 50 states and the District of Columbia • No 	
		<i>Add remarks that are essential in understanding your reported data.</i>	
		Purchase of contract manufacturing	
		<p>1. Did this establishment purchase contract manufacturing services from other companies or foreign plants of your company in 2012?</p> <p>Include: Products for which the manufacturing (i.e. transforming or otherwise processing materials or components based on specifications provided by your company) was outsourced to other companies. Products for which the manufacturing was performed by our company's foreign plants.</p> <p>Exclude: Services for packaging and assembling. Purchases of merchandise for resale (sales of products bought and sold without further processing or transformation).</p> <ul style="list-style-type: none"> • Yes – Go to line 2 • No – Go to Question 30 	2012
		2. Report the costs incurred by this establishment for using contract manufacturing purchases in 2012	
		3. Report the value of sales, shipments, receipts, revenues generated in 2012 from products whose purchases were reported as contract manufacturing costs in line 2.	
		<i>Add remarks that are essential in understanding your reported data.</i>	
Census Bureau	Census of Manufactures (MC31101–MC33975)	No details available. Likely to be similar to Census of Wholesale Trade.	2007, 2012
<p>Notes: * Only covers all multi-unit companies with 250 or more employees and a selection of smaller companies to support other Census Bureau surveys. Conducted annually in the four years between economic censuses.</p>			

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