The impact of 3D printing on trade and FDI

Preliminary and incomplete

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Abstract

We analyze the effects of 3D printing technologies on the volume of trade and on the structure of FDI. A standard model with firm-specific heterogeneity predicts that i) the first introduction of 3D printers predominantly takes place in areas with high economic activity that are contemporaneously subject to high transport costs; ii) initially, technological progress with respect to 3D printing machines leads to a gradual replacement of FDI relying on traditional production structures with FDI relying on 3D printing techniques. At that stage, international trade stays unaffected; iii) in later stages, when 3D printing machines are already widely used, further technological progress with respect to 3D printers leads to a gradual replacement of international trade.

JEL classification: F10, F23, O33.
Keywords: 3D printing, FDI, trade, technological change.

> "Companies are re-imagining supply chains: a world of networked printers where logistics may be more about delivering digital design files- from one continent to printer farms in another- than about containers, ships and cargo planes"
>
> — PWC report (2014), *3D printing and the new shape of industrial manufacturing*

1 Introduction

Three dimensional or 3D printing is emerging as a world-shattering technology. With this new technology at hand ordinary citizens could present their ideas to designers (e.g. Freedom of Creation in Amsterdam) and easily turn them into real products using a 3D machine to manufacture small products that could cost around US$ 10,000. Large 3D printers, which are capable of making objects with 1m diameter and 3m in height (e.g. delta-style 3D printer developed by SeeMeCNC) have also been developed for industrial use. The main challenge faced by the developers is to improve the technology to create printers able to produce large objects in high speed that can be used for mass production. Among the industry leaders are Stratasys and MakerBot. The second firm even sells a kit for around US$ 1,000 for consumer use. The main difference with respect to previous manufacturing technologies is that 3D Printing is based on additive manufacturing (AM). AM consists on building products layer-by-layer instead of subtracting or cutting material from a large piece or a block (this is called "subtractive"manufacturing). This makes a substantial difference in many respects. First, production lines (assembly) could be reduced or even could disappear for many small manufactured products. Second, a regionalization process could emerge as production could be located close to the main markets without any need of transporting goods over long distances. Third, product variety could radically increase since it will be easy to customize products and adapt them to consumer tastes. Fourth, there will be not need to keep inventories, since design files can be sent instantly to any location in the world. Fifth, the technology is environmental friendly; it will definitely reduce emissions for two reasons: it employs a cleaner production process and it could potentially reduce emissions coming from the transport sector. Finally it allows the possibility to produce more with less labor units, increasing drastically labor productivity and reducing labor needs. This could off course generate disruptions in the labor market, but in aging societies like Western Europe this could be seen as an advantage. The cost effectiveness of AM manufacturing seems to be unbeatable in comparison to existent technologies and could challenge the actual competitive advantages of China and other low-wage countries as factories of the world. It will also reduce barriers of entry for potential manufacturers in many industries and will have important implications for national security and geopolitics.

The main aims of this paper are twofold. Firstly, a theoretical model that investigates the impact on international trade and global transmission of this path-breaking invention is presented. Secondly, the new developments in terms of production and trade of the 3D printing industry are empirically evaluated. To our knowledge this is the first paper that specifically analyses 3D printing in the context of the new-new theory of international trade and explores the consequences of introducing this technology in the production processes on the new economic developments of the global economy. The theoretical model predicts a product life-cycle-type development of production and trade, according to which in a first stage (introduction) 3D printers are introduced in areas with high economic activity subject to high transport costs; in a second stage (growth), technological progress in 3D printing machines leads to a gradual replacement of traditional production structures used in FDI with those relying on 3D printing techniques. At that stage, international trade stays unaffected; in a third stage (maturity), 3D printing machines are widely used and further technological progress in 3D printing leads to a gradual replacement of international trade by local production. The empirical results outline the main challenges faced concerning data collection in 3D printing concerning production, trade and investment and present current trends showing the impressive growth in terms of patenting and R&D investment in the leading countries (introduction) and in terms of international trade.

The paper is structured as follows. Section 2 presents the theoretical framework. Section 3 is dedicated to our empirical analysis and Section 4 concludes.

2 The impact of the 3D printer on international trade: theory

Consider a world comprised of $i \in [1, n+1]$ open economies that are populated by firms producing a continuum of manufactured goods $j \in (0,1)$. Following Helpman et al. (2004) these goods can be sold in the home country, they can be exported subject to iceberg transport costs $\tau > 1$ to other countries, or they can be produced directly in the destination country by subsidiaries established via greenfield foreign direct investment (FDI). Production for the home market is subject to the fixed costs cf_D, while production for the export market is subject to the fixed costs $cf_X > cf_D \cdot \tau^{1-\epsilon}$. In contrast to Helpman et al. (2004), FDI can occur in two different forms: a) a firm incurs a fixed investment of cost $cf_I > cf_X \cdot \tau^{\epsilon-1}$ to establish a subsidiary that replicates the parent's domestic production technology in the foreign country, b) a firm incurs a fixed investment of cost $cf_{3D} > cf_I$ to establish a foreign subsidiary based on the technology of 3D printing machines. The use of 3D printers implies that the subsidiary utilizes a superior production technology as compared to the parent in the domestic country. We conceptualize this by assuming that the factor input requirement for the production of each good in the subsidiary is reduced by the amount ξ in relation to the parent company. In line with the literature on trade with firm-specific heterogeneity[1], we assume that the only variable production factor of firms is labor, which earns the wage rate w, and that, upon entering the industry, a firm draws its productivity level $\theta(j)$ from the distribution $G(\theta)$, which implies that its variable cost is given by $w/\theta(j)$.

At the consumption side, we assume that households are identical across economies

[1] See for example Eaton and Kortum (2002), Melitz (2003), Bernard et al. (2003), Helpman et al. (2004), and Helpman (2006) for different approaches.

and have utility functions with a constant elasticity of substitution $\epsilon = 1/(1-\alpha) > 1$ across the different varieties. Following the notation of Helpman (2006), the demand for each variety is given by $x(j) = Ap(j)^{-\epsilon}$ with $x(j)$ being the quantity of good j, $p(j)$ its price, and A denoting the demand level as determined by household's income. The standard profit maximization problem in this setting leads to the familiar outcome that the profit-maximizing pricing strategy for firms is to charge a mark-up over marginal cost (cf. Dixit and Stiglitz, 1977; Melitz, 2003). This implies that firms charge the price $p(j)_D = w/[\alpha\theta(j)]$ on the domestic market, the price $p(j)_X = w\tau/[\alpha\theta(j)]$ in the destination country in case that they choose to export, the price $p(j)_I = w/[\alpha\theta(j)]$ in the destination country in case that they choose to open a subsidiary there that is based on the traditional production technology, and the price $p(j)_{3D} = w/[(1+\xi)\alpha\theta(j)]$ in the destination country in case that they choose to open a subsidiary there that is based upon the superior 3D printing technology.

For the sake of exposition, we suppress the index j from now on. In our setting, a partitioning of firms occurs as follows: very unproductive firms that do not expect to recover the fixed costs of production, choose to exit immediately. Firms that are so productive that they can be profitably run by supplying to the home market but not to the foreign market via exports, earn profits

$$\begin{aligned} \pi_D &= \theta^{\epsilon-1}(1-\alpha)A\left(\frac{w}{\alpha}\right)^{1-\epsilon} - cf_D \\ &\equiv \Theta B - cf_D, \end{aligned} \tag{1}$$

where we follow the notation of Helpman (2006) and denote $\Theta = \theta^{\epsilon-1}$ and $B = (1-\alpha)A\left(w/\alpha\right)^{1-\epsilon}$. Let the threshold level of productivity below which the firm would choose to exit be given by Θ_D, then there exists a productivity level $\Theta_X > \Theta_D$ above which firms are so productive that they can even recover the additional fixed costs of exporting to the destination i. These firms earn profits as given by

$$\begin{aligned} \pi_D + \pi_X &= \theta^{\epsilon-1}(1-\alpha)A\left(\frac{w}{\alpha}\right)^{1-\epsilon} - cf_D + \tau^{1-\epsilon}\theta^{\epsilon-1}(1-\alpha)A^i\left(\frac{w}{\alpha}\right)^{1-\epsilon} - cf_X \\ &\equiv \Theta B - cf_D + \tau^{1-\epsilon}\Theta B^i - cf_X, \end{aligned} \tag{2}$$

where $B^i = (1-\alpha)A^i\left(w/\alpha\right)^{1-\epsilon}$. Greenfield FDI has the advantage that goods can be sold in the destination country without the need to incur transport costs. The disadvantage of FDI is mainly the higher fixed cost as compared to exporting because a new plant has to be established in the destination country. Consequently, more productive firms with a productivity level above $\Theta_I > \Theta_X$ find it profitable to exit the export business to country i and instead to open a subsidiary there. These firms earn profits

$$\begin{aligned} \pi_D + \pi_I &= \theta^{\epsilon-1}(1-\alpha)A\left(\frac{w}{\alpha}\right)^{1-\epsilon} - cf_D + \theta^{\epsilon-1}(1-\alpha)A^i\left(\frac{w}{\alpha}\right)^{1-\epsilon} - cf_I \\ &\equiv \Theta B - cf_D + \Theta B^i - cf_I \end{aligned} \tag{3}$$

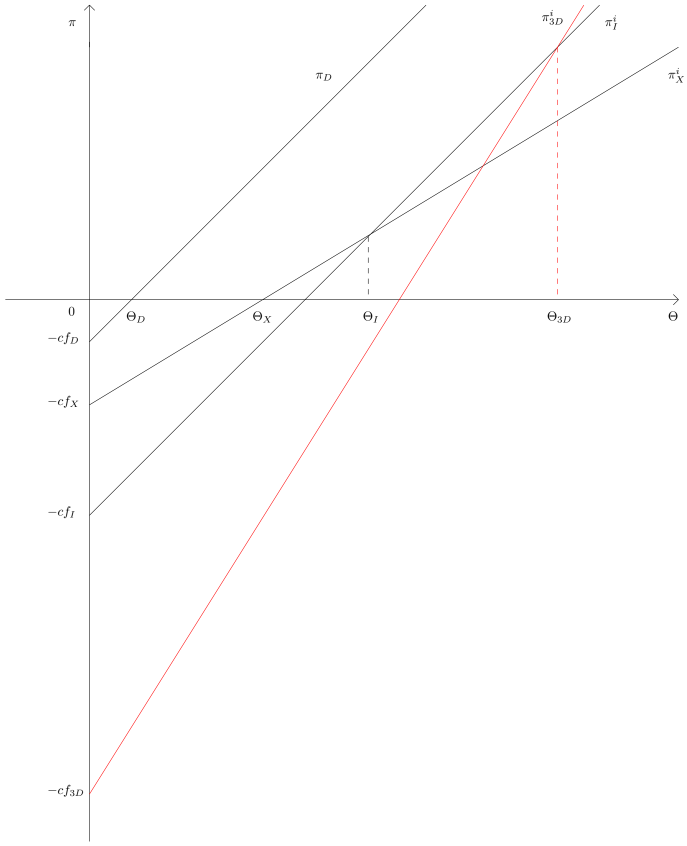

Figure 1: The effect of 3D printing technology on FDI and trade

but they still do not invest in the new technology of 3D printing machines, when establishing their subsidiaries. The reason is that 3D printing facilities, while leading to lower variable production costs, come with a higher fixed cost. Only the firms with productivity levels above Θ_{3D} will choose to base their subsidiary in the foreign economy on the superior 3D printing technology. Initially, Θ_{3D} will be very high because the 3D printing technology is new and its fixed cost are high. In this case we will for sure have that $\Theta_{3D} > \Theta_I$. Over time, however, technological progress with respect to 3D printing technologies will lead to falling fixed costs, such that other situations become possible as we will see below. Firms pursuing FDI via advanced 3D printing technologies earn profits

$$\begin{aligned}\pi_D + \pi_{3D} &= \theta^{\epsilon-1}(1-\alpha)A\left(\frac{w}{\alpha}\right)^{1-\epsilon} - cf_D + \theta^{\epsilon-1}(1-\alpha)A^i\left[\frac{w}{(1+\xi)\alpha}\right]^{1-\epsilon} - cf_{3D} \\ &\equiv \Theta B - cf_D + \Theta(1+\xi)^{\epsilon-1}B^i - cf_{3D}. \qquad (4)\end{aligned}$$

For the purpose of graphical illustration, we follow Helpman (2006) and restrict our attention to the case of equally-sized countries, which implies that $A^i = A$ for all i. The initial situation is depicted in Figure 1 that shows the profit components due to domestic sales (π_D), due to exports (π_X), due to FDI relying on traditional production technologies (π_I), and due to FDI relying on advanced 3D printing technologies (π_{3D}) for the case of high fixed costs of 3D printing machines. The fixed costs are depicted on the negative part

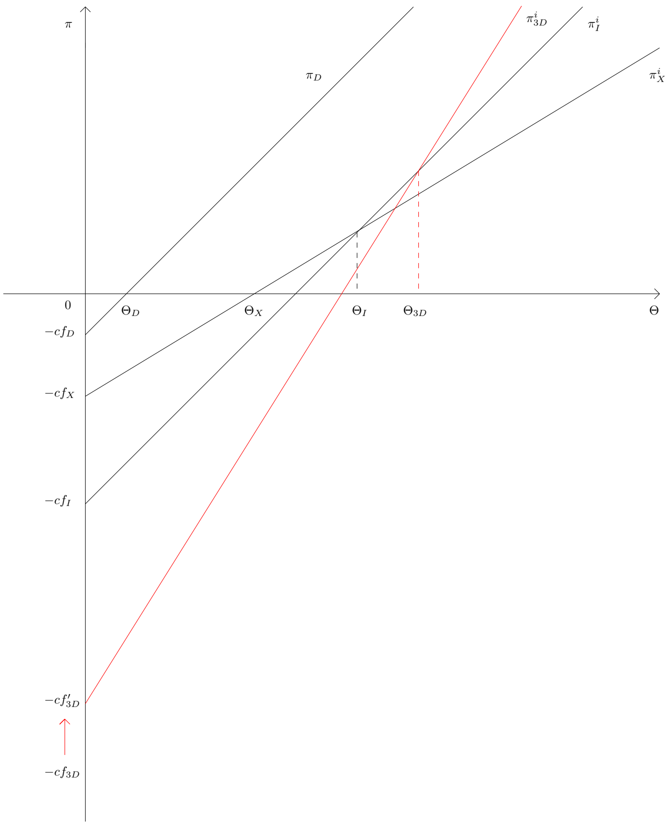

Figure 2: The effect of 3D printing technology on FDI and trade

of the y-axis, while productivity $\Theta = \theta^{\epsilon-1}$ is depicted on the x-axis. Similar to Helpman et al. (2004) and Helpman (2006), firms with a productivity level below Θ_D exit, firms with productivity $\Theta_D < \Theta < \Theta_X$ produce for the home market only, firms with productivity $\Theta_X < \Theta < \Theta_I$ produce for the home market and export, and firms with productivity $\Theta_I < \Theta < \Theta_{3D}$ pursue FDI relying on the traditional production techniques. Note that the slopes of the lines π_D and π_I are the same because this type of FDI just replicates the home market technology in the foreign economy, while the slope of the line π_X is lower because the iceberg transport costs reduce profits per unit shipped. The new element is the red line that refers to the additional profits due to FDI via 3D printing technologies. This line is steeper than all the other lines because the use of 3D printers reduces the variable costs by the amount ξ. At the stage depicted in the figure, the fixed costs of 3D printing technologies are still very high such that the productivity level necessary for a firm to invest in this technology is large ($> \Theta_{3D}$). In this situation, only the most productive firms choose to establish subsidiaries based upon 3D printing technologies.

Now suppose that technological progress reduces the fixed cost of 3D printing technologies. This situation is depicted in Figure 2 where cf_{3D} is reduced such that the red line of additional profits due to FDI via 3D printing technologies shifts upward. This implies that FDI relying on traditional technologies decreases and is gradually replaced by FDI relying on 3D printing technologies. In this situation, international trade still remains

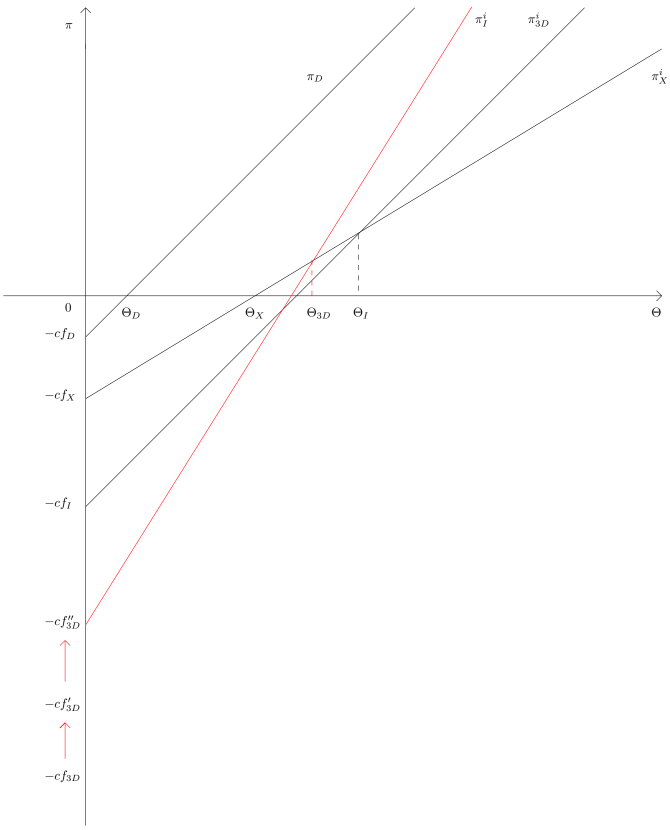

Figure 3: The effect of 3D printing technology on FDI and trade

unaffected by technological progress with respect to 3D printing machines. The reason is that the variable cost savings of 3D printing technologies are large enough to compete with traditional FDI, whose fixed cost is larger than the fixed cost of exporting, while the variable cost savings of 3D printing technologies are still not large enough to compete with the firms that only face the lower fixed cost of exporting.

Finally, suppose that technological progress reduces the fixed cost of 3D printing technologies further as shown in Figure 3. In this case the variable cost savings of 3D printing technologies are large enough that these firms start competing with the exporters. This implies that a situation has occurred with $\Theta_I > \Theta_{3D}$ implying that all FDI is based upon advanced 3D printing technologies. In case that technological progress with respect to 3D printing techniques reduces its fixed cost further, then exports will be replaced and international trade will necessarily decrease.

Our framework implies the following testable predictions: i) the first introduction of 3D printers predominantly takes place in areas with high economic activity that are contemporaneously subject to high transport costs; ii) initially, technological progress with respect to 3D printing machines leads to a gradual replacement of FDI relying on traditional production structures with FDI relying on 3D printing techniques. At that stage, international trade stays unaffected; iii) in later stages, when 3D printing machines are already widely used, further technological progress with respect to 3D printers leads to a gradual replacement of international trade.

3 The 3D printing Industry

Additive manufacturing, commonly known as *3D printing*, is a technology that allows the creation of objects by printing successive layers, either of plastic or metal. It can be considered a disruptive technology, since the use of a printer of this kind to create objects completely changes the production process in several ways. Firstly, there are no inventory costs since an order is placed, and it can shortly be printed [2] exactly as wished by the client. Related to this, one can perfectly customize the product with no extra effort or cost. For example, in the case of shoes, they can be printed in the size and color desired by the client decreasing the inventory costs (no more need to hold stocks of shoes of all of the different sizes and colors) besides being able to customize the shoes as specifically requested by the client. Moreover, this technology consumes much less energy and the waste of the production process is also significantly reduced. An article in *USA Today*[3] cite an example of Audiovox as a supplier for BMW. Since the initial order of control buttons was initially small, the 3D printer saves the company of incurring into the tooling expenses and also to deliver the pieces much faster. Another example that they provide is the production of infrared cameras for housing. Given that the supplier had to go through several design changes, the 3D printer served as an excellent production technology in order to cope efficiently with these kind of requests. Garrett (2014) also adds further benefits such as the elimination of supply chains and assembly lines, production of the same item can accrue at the same time in several parts of the world and the boost in innovation from design to materials.

Of course, there are also drawbacks. On the one hand, printing times are still substantial and particularly restrictive if thousands of pieces are requested within a short time frame. Moreover, some of the materials used are still not resistant enough (and therefore the final product) and still have to go through severe testing in order to meet the standards required by each governmental organization. Finally, the costs of the printers - though they have been reduced across time - are still high enough to be prohibitive for some small companies, especially the bigger and more expensive printers that are able to make products out of metal powder. Though the most affordable printers could be accessible to the consumer that would like to start designing its own small scale production (some printers can be bought for around US$2,000), bigger printers like the ones required by Airbus or General Electric could cost at least 2,000 times that price. Another final issue worth to mention is that the the environmental conditions of different countries could alter the characteristics of the powders used in the production process, altering the final product and prohibiting replicability.

[2]Depending of the 3D printing technology and what has exactly to be printed the times could be not so negligible

[3]http://usatoday30.usatoday.com/money/industries/manufacturing/story/2012-07-10/digital-manufacturing/56135298/1 , accessed 14th January 2015

A bit of history This technology was created by Chuck Hull and was patented in 1986. The class of technology created at the time is called *stereolithography*, that basically consists on solidifying very thin layers of a special polymer using a laser. Though Hull founded 3D Systems, one of the main market players in the business, he could not restrict competition and soon other technologies also developed. Two researchers at the University of Texas at Austin patented the *Selective Laser Sintering* in 1987, while Scott Crump patented the *Fused Deposition Modeling* in 1989. Briefly after the *Three Dimensional Printing (3DP)* was created in 1993 in MIT. More methods have also been developed and are also still in the process (Zhang (2014)). The next charts shows the evolution of the patent production in the United States as an illustration. Though it does not show the whole spectrum of patents, it is indicative of the evolution of the sector since it is the main producer of printers and related.

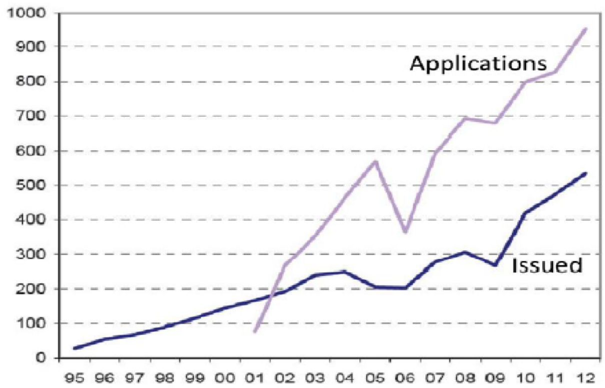

Figure 4: 3D Printing Patents in the US

Source: Zhang (2014) from Wohlers report (2013) and Castle Island

3.1 3D Printers' Production and Trade

Data on production and trade of 3D printers is scarce. Though the industry has been existing for over two decades, it not only till recently that it started to gain importance, specially since the initial patents just expired. In terms of production of the printers, data is not easily accessible for the public since not all of the companies that produce the printers are traded in the stock market and therefore the data is mostly confidential. Therefore, one has to rely on information from newspaper articles, reports from consulting firms or independent organizations. As we can see from 5, the number of industrial 3D printers sold has been increasing over time, especially since the mid 90's for the United States of America (USA), while for the other countries the jump can be seen from the mid 00's, except for Japan. Germany has had a steady increase thas has been closely followed by Israel. Interesting is the jump that can be observed with Israel in 2013 and its decrease in the USA. This is due to the fact that Stratasys Ltd. was created as a merger of Stratasys Inc. and Object Ltd. from Israel and with the merger the new company is

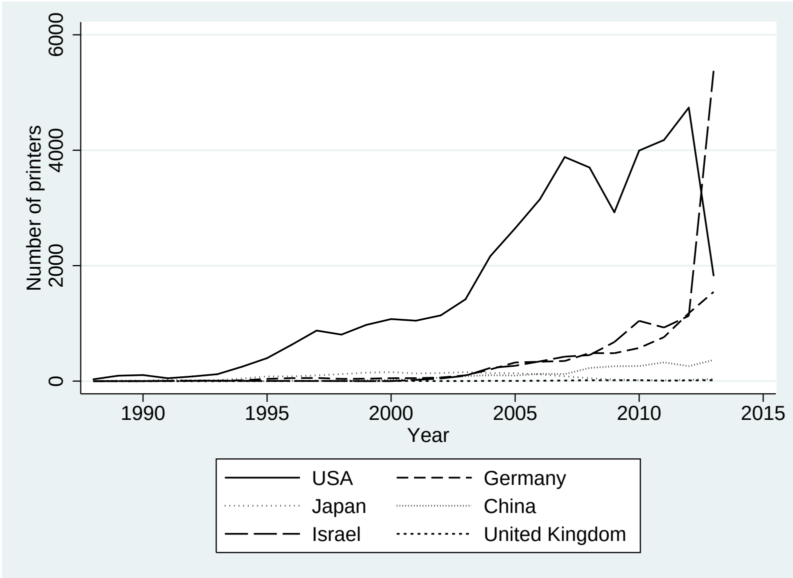

Figure 5: Printers sold in a selected group of countries

Own elaboration using data from Wohlers Report (2014)

now registered in Israel (Wohlers (2014)).

It is interesting to see that the main producers of industrial 3D printers are closely related to the Figure6, where we can observe the amount of patents per country. The USA is the leader, followed by China and then by Japan and Germany. Most of their Governments are financing research centers and initiatives in order to give an extra impulse to the sector and because they believe on its potential to benefit the economy in a variety of sectors - from medicine to the aeropace industry.

The industry is comprised of the production of services, inputs and materials for the industry itself, software development, printers, parts for final products, production of prototypes. In Figure7 we can observe the increase of parts for final products, as a participation in the whole market of 3D printing and AM Wohlers (2014). We can clearly see how the production of parts has been increasing steadily over time and this can be an indication that more companies have started to include 3D printed parts in their final goods.

The analysis of international trade is even more challenging. Since the printers are nowhere to be found in the harmonized system, being able to uniquely identify the exports and imports of these items is a challenging task. As Hodes and Mohseni (2014, p. 46) remarks, "neither the importer nor the government may be entirely certain of the correct classification", after analyzing a legal case related to 3D printers' classification. We have conducted some research on the classification of the printers and we have encountered inconsistencies about how different countries classify them. Table 1 provides an illustration. Nevertheless, we should also state that one of the roots of the problems with the classification is the materials with which the printers work.

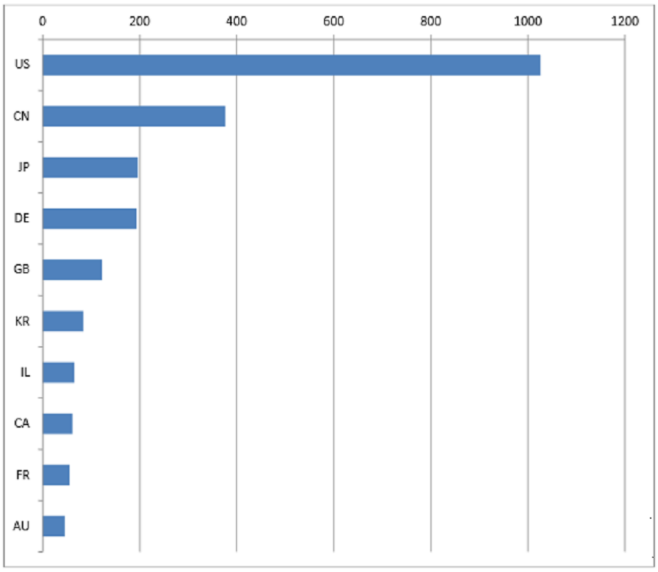

Figure 6: Amount of Patents related to Additive Manufacturing (selected countries)

Source: Office (2013)

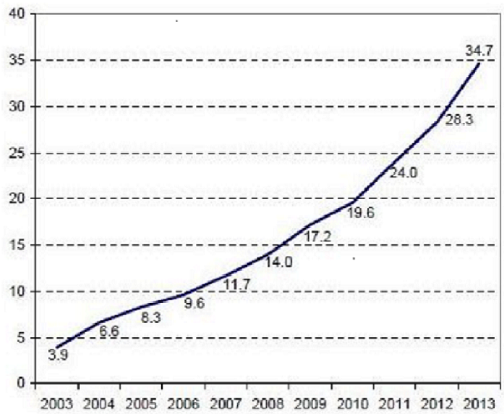

Figure 7: Participation of the production of parts for final products in total revenues

Source: Wohlers (2014), retrieved from Press Release Nr.68

From here we can see that the most common 6-digits codes are 8477.80 and 8443.32 from the Harmonized System (2007). The first code would comprise the trading of 3D printers that work with plastic or rubber for Germany, the United States and Argentina. On the other hand, Spain (who belongs to the same custom union as Germany) trades this printers with a different tariff line (8443.32). This tariff also coincides with the line that is suggested by a broker agency from the United States that provides advisory services on importing, besides being the suggested tariff line in the popular website "'Duty Calculator" and looking for "3D Printers"[4]. This category (refer to Table2 for the definitions of the different tariff lines) is more general and could include printers working with metal

[4]http://www.dutycalculator.com/hs-lookup/423051/hs-tariff-code-for-3d-printer/

Country	Code	Source
Argentina	3909.50.19.000A	Trimaker
United States	8443.32.1090	Flexport (http://learn.flexport.com/import-3d-printers
Spain	8443.32.10.90	SICNOVA3D and Valencia Port authority
United States	8443.99.5050	Flexport (http://learn.flexport.com/import-3d-printers
Argentina	8477.20.10	Kikai Labs
United States	8477.59.01.00	U.S. Census Bureau - Foreign Trade Schedule B (2015) (https://uscensus.prod.3ceonline.com/)
Hong Kong	8477.59.10	Trade and Industry Department of Hong Kong (http://www.tid.gov.hk/english/cepa/tradegoods/files/mainland_2014.pdf)
United States	8477.80.00	Hodes and Mohseni (2014)
Germany	8474.80.90	German Federal Statistical Office
Argentina	8477.80.90.000W	Trimaker
Germany	8477.80.99	German Federal Statistical Office
United States	8479.89.98	Hodes and Mohseni (2014)

Table 1: Collected information on tariff lines considered for the trade of 3D printers

or plastic powder, though the other tariff line is more straightforward meaning that it explicitly says that it works with plastics or rubber. Another company in Argentina also trades the product under a different tariff line, though close to the most popular one. Given the description of the tariff line, this could be because they deal with printers that can print small objects. Finally, we have fewer data for the machines that work with metal powder but we find again inconsistencies - the tariff line reported by Germany is 8474.80.90 while the one of the United States is 8479.89.98. Another inconsistency that we also found was within the United States, as the table recalls. Of course, our sample is reduced but we believe that it portrays some inconsistencies in classifications that deserve a closer attention and also implies that when looking at trade data of these items, numbers should be read with certain skepticism. Just of note, we also included the data that we got for a tariff line for parts of printers and the rubber input that one of the consulted companies reported.

In an attempt to look at the export data, we had to make some concessions and we decided to consider the product 847780 from the harmonized system (this category has remained the same throughout the different changes). Given the classification issues described above, these results are only illustrative. We can observe that Germany is the main exporter, followed by China (whose exports started increasing at a high speed since the beginning of the 00's, United States (who had the most stable exports), Japan, the Republic of Korea and finally Israel. It was puzzling not to find the USA as the main exporter. This could be due to the fact that the trade is misreported under different classifications as Hodes and Mohseni (2014) remark and as it can be seen from Table1.

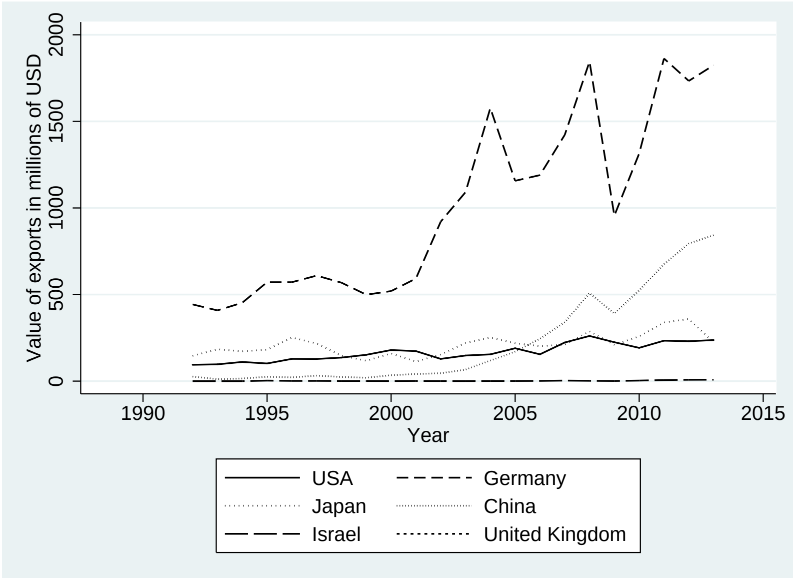

Figure 8: Exports of 3D printers, considered under Tariff Line 8477.80

Source: Own elaboration using data from UN-Comtrade

4 Conclusions

This paper is a first attempt to pu the 3D printers into the agenda of globalization. 3D printing is still in its infancy and a high degree of uncertainty is going to shape the future impact of this path-breaking technology on production rellocation and trade. The life-cycle-type theory presented in this paper indicates that the wider adoption of 3D printing in industrial processes around the world could eventually lead to glo-calization (shipping parts and components internationally becoming obsolete). Although the time frame in which these changes will evolve is uncertain, there is surely going to be a progressive change in the way in which some products (e.g. automobiles, airplanes and electrical equipment) are manufactured and the economic, social, environmental and security implications deserve to be investigated by economist, social scientists, lawyers and the like.

The stylized facts presented outline the main challenges faced concerning data collection in 3D printing for production, trade and investment. Using the available data we present current trends showing the impressive growth in terms of patenting and R&D investment and production in the leading countries and in terms of international trade. We aim at extending the empirical analysis by testing the theoretical predictions.

The pending challenges for the economic profession are to investigate how AM will transform the production processes and in turn influence the location of economic activity and international trade and the ongoing globalization process.

5 Appendix

Country	Code	Description
Most common 6 digits	8443.32	Other printers, copying machines and facsimile machines, whether/not combined , excluding the ones which perform two/more of the functions of printing, copying/facsimile transmission; capable of connecting to an automatic data processing machine to a network
Most common 6 digits	8477.80	Machinery for working rubber/plastics/for the manufacture of products from these materials, not specified /incld. elsewhere in this Ch., Other machinery, n.e.s. in 84.77
Argentina	3909.50.19.000A	Amino-resins, phenolic resins and polyurethanes, in primary forms. Plastics and articles of plastic; Polyurethanes; others
United States	8443.32.1090	Other, capable of connecting to an automatic data
Spain	8443.32.1090	Other, capable of connecting to an automatic data; Printer units; Other
United States	8443.99.5050	Printing machinery used for printing by means of plates, cylinders and other printing components of heading 8442; other printers, copying machines and facsimile machines, whether or not combined; parts and accessories thereof; Parts and accessories;other;other;other
Argentina	8477.20.10	Machinery for working rubber or plastics or for the manufacture of products from these materials, not specified or included elsewhere in this Chapter; Extruders; for thermoplastics, with a screw diameter not exceeding 300 mm
United States	8477.59.01.00	Machinery for working rubber or plastics or for the manufacture of products from these materials, not specified or included elsewhere in this chapter, parts thereof; other machinery for molding or otherwise forming; other
Hong Kong	84775910	Three-dimensional printer (3D printer)
United States	8477.80.00	Machinery for working rubber or plastics or for the manufacture of products from these materials, not specified or included elsewhere in this chapter, parts thereof; Other machinery
Germany	8474.80.90	Machinery for sorting, screening, separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances, in solid (including powder or paste) form; machinery for agglomerating, shaping moulding solid mineral fuels, ceramic paste,unhardened cements, plastering materials or other mineral products or in powder or paste moulds of sand;other form; machines for forming foundry machinery; other
Argentina	8477.80.90.000W	Machinery for working rubber or plastics or for the manufacture of products from these materials, not specified or included elsewhere in this Chapter;other machinery; other
Germany	8477.80.99	Machinery for working rubber or plastics or for the manufacture of products from these materials, not specified or included elsewhere in this chapter;other machinery;other
United States	8479.89.98	Machines and mechanical appliances having individual functions, not specified or included elsewhere in this chapter; parts thereof; Other: Electromechanical appliances with self-contained electric motor;Other

Table 2: Collected information on tariff lines considered for the trade of 3D printers with description

References

Bernard, A. B., Eaton, J., Jensen, J. B., and Kortum, S. (2003). Plants and Productivity in International Trade. *American Economic Review*, Vol. 93(No. 4):1268–1290.

Campbell, T., Williams, C., Ivanova, O., and Garrett, B. (2011). Could 3D printing change the world. *Technologies, Potential, and Implications of Additive Manufacturing, Atlantic Council, Washington, DC.*

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic Competition and Optimum Product Diversity. *American Economic Review*, Vol. 67(No. 3):297–308.

Eaton, J. and Kortum, S. (2002). Technology, Geography, and Trade. *Econometrica*, Vol. 70(No. 5):1741–1779.

Economist, T. (2010). Printing Body Parts: Making a Bit of Me. [Online; posted 18-February-2010].

Garrett, B. (2014). 3D Printing: New Economic Paradigms and Strategic Shifts. *Global Policy*, 5(1):70–74.

Helpman, E. (2006). Trade, FDI, and the Organization of Firms. *Journal of Economic Literature*, pages 589–630.

Helpman, E., Melitz, M. J., and Yeaple, S. R. (2004). Exports vs. FDI With Heterogeneous Firms. *American Economic Review*, Vol. 94:300–316.

Hodes, M. G. and Mohseni, N. C. (2014). Classifications Determinations in the United States Court of International Trade Brought under 28 U.S.C. 1581(a). *Georgetown Journal of International Law*, 46:27–56.

Ivanova, O., Williams, C., and Campbell, T. (2013). Additive manufacturing (AM) and nanotechnology: promises and challenges. *Rapid Prototyping Journal*, 19(5):353–364.

Lind, M. and Freedman, J. (2012). *Value Added: America's Manufacturing Future.*

Melitz, M. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica*, Vol. 71:1695–1725.

Office, I. P. (2013). 3D Industry. A patent Overview. *Report*, pages 1–48.

Wohlers, T. (2014). Additive Manufacturing and 3D Printing, State of the Industry. *Wohlers Report 2014*, pages 1–277.

Zhang, S. (2014). Location Analysis of 3D Printer Manufacturing Industry. Master's thesis, Columbia University.