1. Introduction

Innovation is an important driver of economic growth. There is then wide consensus among antitrust authorities that merger policy needs to move beyond its traditional focus on static efficiency to account for innovation. Katz and Shalenski (2006) note that “In order fully to assess the impact of a merger on market performance, merger authorities and courts must examine how a proposed transaction changes market participants’ incentives and abilities to undertake investments in innovation.”

However, there is not general agreement among economists on which market structure can better serve innovation and technological progress. Theoretical models have shown that both competition and monopoly power can foster innovation depending on the assumption made about the cost of innovation and imitation, the type of innovation (e.g., product vs. process), the technological advantages of incumbents, the size of the market, and the importance of the innovation (“drastic” vs. “nondrastic”).

Given the inconclusiveness of the theoretical analysis, analysing real world evidence is of paramount importance to understand how changes in market structure affect the incentives to innovation. In this context, it is vital for Antitrust Authorities to assess the impact of competition policy enforcement, such as merger control decisions, on innovation outcome. For this reason, the Directorate General for Competition (DG COMP) commissioned a team of academics from the Centre for Competition Policy, University of East Anglia, to do a feasibility study on the innovation impact of two mergers in the Hard-Disk Drive (HDD) market with the aim of defining a sound methodology that can be used to investigate the impact of specific antitrust decisions and, at the same time, understanding the challenges that may be encountered in doing such analysis.

The report “Feasibility Study on the microeconomic impact of the enforcement of competition policies on innovation” by Ormosi, Bennato, Davies and Mariuzzo contains a detailed description of the remarkable work done by this group of academics. The first part of the Feasibility Study (FS) includes a literature review on how innovation has been measured in

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previous empirical work followed by a brief survey of the literature on competition and innovation and a rather detailed analysis of different academic studies that have looked at the role played by different areas of competition policy (abuse of dominance and mergers) in innovative industries. The authors then propose a novel methodological framework that is used to investigate the effects on innovation of two mergers in the Hard-Disk Drive (HDD) market. The analysis is divided into three main parts. The first looks at the effects of the mergers on innovation input, measured by R&D expenditure. The second part investigates the impact on innovation output, as measured by the number of patents or citations, followed by an exploratory analysis on the effects of the mergers on product and technological diffusion.

The remainder of this appraisal of the FS is divided in three sections. In Section 2 I briefly describe the data and discuss the three different measures of innovation that have been used by the authors. In Section 3 I first discuss the methodology used to analyse the effect of mergers on R&D and then I comment on the analytical framework used to analyse the impact of mergers on patents and product characteristics. Finally, the last section contains a discussion of what general lessons can be learned from the study.

2. Overview of the Feasibility Study and Measures of Innovation

The FS looks at the effects on innovation of two acquisitions in the Hard-Disk Drive (HDD) market, Seagate’s acquisition of Samsung’s HDD division, and Western Digital’s (WD) acquisition of Hitachi Global Storage Technologies (HGST), both signed in 2012. DG COMP unconditionally approved the Seagate/Samsung merger, and approved the WD/HGST merger subject to the divestiture of HGST’s 3.5’ HDD operations to Toshiba. Both deals were also approved by the Chinese competition authority but MOFCOM imposed a number of remedies that were lifted only three years after the merger. The fact that three mergers were consumed at the same time and the delayed lifting of remedies imposed by competition authorities makes the identification of any causal effect of mergers on innovation particularly challenging.

The FS considers three different measures of innovation: R&D expenditures, patents (or patent citations) and product characteristics. The first two measures have been used in multiple previous academic studies on innovation. The third measure is a novel way of measuring innovation and it consists of constructing an index of the price per unit of storage. Information on the date a new product was launched on the market, the storage capacity of this new product and its price are retrieved from Amazon. These data are used to construct the price per gigabyte in 2016 for products of different “vintage”.

The use of different measures of innovation represents a practical solution to the problem that there is not a perfect measure. For instance, R&D expenditures may be subject to problems of measurement, partially because accountancy rules may create inconsistencies when comparing firms. Similarly, patents may fail to capture several aspects of firms’ innovative activities, in particular in those industries that rely more on trade secrecy to
protect their know-how. Price per unit of storage is a new interesting measure of innovation proposed by the authors of this study: compared to R&D and patents, it is closer to capturing the output of the innovation process. However, it also suffers from two important limitations. First, it might be difficult to define a control group that can mimic the counterfactual product market in the absence of the merger given that all the main players of the HDD market are involved in M&As. Second, the price index might combine the effect of an increase in productivity (reduction in costs) and an increase in market power (leading to higher prices).

A well-known measure of innovation that is not used in the FS is productivity. Productivity is broadly defined as quantity of output that can be produced using a given level of inputs. The advantage of productivity compared to the three measures above is that it can measure successful process and product innovation. Figure 1 in the FS shows that the drastic increase in Patents observed from 1983 has not been coupled with an equivalent increase in Total Factor Productivity, thus confirming that productivity provides a different and possibly, more comprehensive measure of technological advances. However, productivity also presents important challenges, most notably how to adjust prices of products to take into consideration quality improvements. Robert Solow, for instance, famously remarked that “we can see the computer age everywhere but in the productivity statistics”.

3. Methodology and Results

The methodology used to assess the impact of mergers on the three measures of innovation is the “Dif-in-Dif”. This approach requires the construction of a control group that can reproduce the (unobservable) dynamics of innovation if the treated firms had not merged. A valid control group needs to satisfy two conditions. First, it must not be affected by the treatment event. Second, the control group should capture approximately the counterfactual market dynamics of the merging firms in the absence of the merger. This second requirement is often tested by checking whether treated and control group show similar (parallel) dynamics in the pre-merger period.

The construction of a reliable control group is more challenging when it comes to assess innovation because of different reasons. First, innovation is global in nature. When a firm creates a new product, this is generally introduced in all its geographical markets. This hinders the possibility of using geographically separate control group, a practice often used when assessing the static effects of mergers on market power. Second, in some industries, innovation can have such a disruptive effect that it is difficult to find a control group that is not affected by the merger and, at the same time, can mimic the counterfactual in the absence of the merger. Finally, while prices can be adjusted in a relatively short period of time, the effects of innovation may take several years to materialize, thus making identification of causality more difficult.
The cases chosen for the FS presents further challenges because all the active firms in the HDD market are simultaneously involved in M&As in a very short period of time. It is then possible that this wave of consolidations was triggered by a negative outlook on future technological advances in HDD technology, a fact also acknowledge by the authors when they write that “HDDs always had mechanical limitations that meant that their growth would come to an end and the technology would be replaced by a different one”. If this were the case, control groups that include only producers of substitute or complementary products may not represent a good counterfactual as they are unlikely to experience similar technological dynamics.

To address the problems above, the authors adopt a pragmatic approach. They construct alternative control groups and they check the robustness of their results for each of the three innovation measures: R&D expenditures, patents and product characteristics. In the rest of this section I will comment on the strength and limitations of the methodology proposed by the authors for each of the three outcomes.

### 3.1 Effects on R&D Intensity

Following standard approach in the economics literature, the first outcome variable that is analysed by the author is R&D intensity, the ratio between R&D expenditure and total revenues. The main findings of the FS in this part of the analysis are the following: (i) a statistically significant increase in Seagate’s research intensity after 2012, (ii) no significant effects for WD and (iii) a drop in Toshiba’s R&D intensity following the 2012 events.

The authors note that R&D intensity in the post-merger period represents the sum of the merging parities’ R&D intensity and they make the methodological remark that “To eliminate biased impact estimates, one should (1) remove the period of the merger from the analysis, and (2) look at growth in R&D intensity rather than absolute figures.” I find that this approach is appropriate for this pilot study because the target companies in the Seagate-Samsung and WD-HGST mergers are subsidiaries of large diversified mother companies and it is often impossible to obtain precise information on the research expenditures for a particular business line. However, when mergers lead to a consolidation of all the business activities of acquirers and targets, it would be advisable first, to compute the aggregate R&D expenditure of the two companies in the pre-merger period and then, to evaluate the impact of the merger on both levels and changes of R&D intensity.

One of the most important contributions of the FS is that it compares the results obtained when constructing a control group using different approaches. The first control group constructed by the authors consists of producers of competing storage data technologies, namely SDD and Flash memories. The authors acknowledge that “by using SSD/Flash manufacturers as Control we would assume that these technologies were exposed to the same demand and supply side shocks, except for the effect of the merger”. While I agree with the fact that these markets may be similarly affected by changes in consumers’ preferences, the
assumption on the supply side is more questionable given that HDD is a more mature technology, which is likely to be superseded by SSD itself. The authors are also upfront in recognizing that the innovation strategies of the firms in this control group may change as a result of the mergers. Under the assumption that research expenditures of competing firms are strategic complements, the existence of spillovers across markets (where the effect of the treatment spills into the control group) can lead to a downward bias in estimating the impact of the mergers on the R&D intensity.

The second control group consists of a sample of firms classified in the “Information Technology” market. This control group offers two distinct advantages. First, the pool includes 1,701 companies, thus making it easier to find firms with a similar trend in R&D intensity for the pre-merger period. Second, IT firms are less likely to be affected by the treatment compared to the storage firms. However, one drawback in using this control group is that the assumption that IT firms and treated companies are exposed to the same demand and supply shocks becomes even more controversial. To partially address this limitation, the authors propose a refinement of this control group which consists in selecting a weighted sample of the IT firms using the Propensity Score method. The first step of this approach consists in estimating the probability of a merger (the treatment) as a function of a set of characteristics including the pre-merger means of R&D expenditure, revenue growth and total assets. For each treated firm, the authors select the 30 firms with the nearest propensity score and assign equals weight to each of them. Table 20 in the Appendix shows that the pre-merger characteristics of the weighted sample of IT firms are closer to the corresponding variables of the treated group, compared to the unweighted sample. One small criticism I have is that the table could be more informative if it showed the result of a test of difference in means between treated and control groups. I find that the propensity score method represents a solid and well-established methodology for the selection of the control group. However, researchers should check whether results are robust to changes in the variables included in the first-step and in the weights used to construct the control group. To this aim, statistical tests of the difference in means between treated and control groups can be used to select the most appropriate matching and weighting methods.

Finally, the last approach used consists in the construction of a synthetic control group, following the methodology described in Abadie and Gardeazabal (2003), and Abadie et al. (2010). Differently from the propensity score matching described above, this method consists in matching each treated firm to a “fictional” control firm whose R&D intensity is defined by a weighted average of the R&D intensity of a group of IT firms (with weights summing to 1). Graphical inspection of the R&D intensity growth reported in Figure 13, 14 and 15 of the FS shows that the Synthetic Control group performs best in terms of displaying parallel pre-merger trend in R&D intensity.

The authors put a remarkable effort in checking the quality of their identification strategy as well as the robustness of their results. First, they provide a formal test of the common trend assumption for the pre-merger period based on the joint significance of the annual difference in R&D intensity between treated and control group. Second, they provide compelling
evidence of the robustness of their results by estimating the treatment effect of a placebo treatment group (that is, a fictitious treatment where each of the 1,701 IT firms is assumed to be involved in a merger) and a placebo treatment time (where the mergers are assumed to take place in a period before 2012). I think that the placebo analysis should be part of the set of tools that DG COMP should use for retrospective merger analysis. Given that the synthetic control method is found to produce a more reliable control group in terms of pre-merger trend in R&D intensity, I think that it would be advisable to use the same methodology in doing the placebo analysis.  

3.2 Effects on Patents

To estimate the impact of the mergers on patenting activity the authors use the following three measures: patent counts, citation weighted patents, and a composite indicator obtained by way of factor analysis (based on seven original patent variables). The first two measures, number of patents and citations, have been largely used in the literature as measure of innovation output. The use of composite indicators is an effective way to aggregate the information content of different measures of innovation into a lower number of “factors”. In the specific case, the authors find that a single indicator is enough to capture most of the correlation in the original data. I have a couple of comments on the proposed measures of patent activity. First, it is often difficult to understand the economic meaning of this composite indicator and this may be particularly problematic in the present framework where it is used not as a regressor on the right-hand side of the empirical specification, but as a measure of innovation outcome on the left-hand side. A related point is that it is not clear how the analysis can be implemented and interpreted when there is more than one composite indicator. A second comment is on how the number of patents (or citations) has been computed. As I suggested in the previous section, the preferred approach would be to add the number of patents of target and acquirer in the pre-merger period. The authors seem to use only the data of the acquirer which may lead to problem of measurement errors.

As for R&D investments, the authors select different control groups, namely the (1) HDD patents of firms most active in patenting HDD-related innovations; (2) NAND Flash patents; and (3) patents of the top ten storage firms. The authors are upfront in recognizing that none of these control groups may satisfy the double requirements of being independent from the treatment and representing a good counterfactual of the innovation outcome of treated firms in the absence of the mergers. For instance, for the first control group, it may well be the case that patents on complementary products to HDD follow a similar patter to patents on HDDs

\[ \text{This should not be too demanding in terms of resources as it requires to apply the same methodology (i.e construction of a synthetic control group and estimation of “Dif-in-Dif” coefficients) to a random group of “fake” merging firms not directly or indirectly involved in the merger (placebo group) or to the real merging firms but assuming that the merger took place in a different year (placebo year).} \]

\[ \text{For instance, in the years following a merger, there can be a sudden increase in the number of patents of acquirers as they are assigned property rights on new inventions made by employees of the now consolidated target companies.} \]
themselves but it may be equally likely that mergers may trigger an increase in innovation in complementary goods. In this case, the analysis may lead to a downward bias in the estimates. In spite of these limitations, I am sympathetic with the idea of using different control groups and check the robustness of the results. If estimated coefficient tend do not vary when using different empirical strategies, then we can be more confident about the reliability of the findings.

Each of the three measures of patent activity (number of patents, citations and factor variable) can be computed in different ways, for instance, as simple count, as stock or as intensity (using revenues at the denominator). At the same time, each measure can be expressed in levels, logs and growth rates. The authors run a series of Dif-in-Dif regressions using all these measures of patent activity. Table 10 of the FS reports the weighted average of the Dif-in-Dif coefficients, after eliminating the ones that do not satisfy two assumptions for unbiased Dif-in-Dif estimates (parallel trends and no serial correlation). Table 10 shows that Seagate and WD increased their patent activity in comparison to all three control groups while Toshiba’s patent activity dropped after 2012 when compared to all the three groups.

The authors acknowledge that these results are preliminary and need further work. Yet, I am not totally convinced that running dozens of regressions and reporting the average of the resulting estimates represents a good way to analyse the impact of mergers on patent outcome, first and foremost because it is not clear to me how we can interpret results obtained by adding a point estimate of, let’s say, 0.1 in the patent-growth regression with a coefficient of 0.05 in the patent-intensity regression. I would rather suggest that the analysis is restricted to a limited number of outcome measures and control groups. For instance, if most of the companies in an industry are granted very few patents (or even zero patents), it would be better to use levels instead of logs or growth rates. At the same time, I would privilege the selection of a control group based on the propensity score method or the creation of a synthetic control group as for the R&D intensity. Check of robustness, including placebo treatment group and placebo treatment time, can then be performed to investigate the reliability of the results. This will also produce a more consistent analysis across the different parts of this pilot study (or any ex-post analysis of merger).

3.3 Effects on Product Characteristics

The study team acknowledge that, due to time and budget limitations, this part of the analysis is less well developed than the previous ones. Using information retrieved from Amazon, two different measures of product innovation in the HDD and the SDD markets are constructed: the number of new products launched, and the price per gigabyte of storage. The authors suggest that the number of new products is often the most easily available information that can be used to measure how innovation is diffused into the market. Still it may be challenging to discern products that offer major technological improvements from those that contain only small changes in existing product features. This is the same distinction that exists between a
simple patent count and a measure of patent quality, with the difference that the latter can be easily captured using statistics such as citations, number of claims or number of application states among others. In the case of new products, actual quality improvements can be captured by the prices but this would require that products are sold in competitive markets with perfectly informed consumers; assumptions that are unlikely to hold in the case of innovative industries. This may also undermine the use of price per gigabyte of storage as a good measure of technology improvements. Whereas I think that the idea of computing this price for storage devices of different “vintage” is very interesting and original, it is important to consider that prices reflect not only process and product improvements but also the changes in the competitive environment following the mergers. This means that this specific measure of product characteristic can confound changes in innovation with changes in market power.

The control group used to assess the impact of mergers on product characteristics includes SSD producers. The empirical strategy is again a Dif-in-Dif specification with the inclusion of firm and time fixed effect as well as different control variables (R&D expenditures, revenues and profits all in year t-1). As said, the authors acknowledge that this part of the report is still very preliminary and needs further work. Accordingly I will not make any specific comments on the actual estimates but only on the empirical framework used. While I am very supportive of the work done for R&D expenditures and patent activity, I am a bit sceptical about the reliability and usefulness of this part of the analysis for different reasons. First, I am not sure that SSD represent a good control group in terms of product characteristics. HDD is a more mature and established technology with probably less margin of technological improvements compared to SSD. My scepticism is reinforced by a graphical inspection of Figure 21 and 22 which do not seem to support the parallel trend assumption between treated and control group in the pre-merger period. Second, it may be difficult to establish a causal relationship using the number of new products introduced in the following years without having more information on the research projects currently developed by targets and acquirers. In this respect, my view is that the analysis of the impact of mergers on developments of “future products” requires the acquisition of proprietary (and often expensive) data from specialized companies, something that is beyond the remits of this FS.

I conclude this section by noticing that the aforementioned problem of not observing the product pipeline of merging firms is an example of a general concern that selection of a control group on the base of observable characteristics may not eliminate bias from unobserved controls. For instance, it is possible that firms with (unobserved to the econometricians) poor product pipelines may use a merger as a defensive move against expected negative performance. Recent works by Altonji et al. (2005) and Emily Oster (2017) suggest that observing coefficient movements and movements in R-squared value can be

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4 For instance, in the case of pharmaceutical industry, it is possible to acquire precise data on the number of new molecules (i.e. future drugs) that companies have in their pipelines.
useful in identifying omitted variable bias. This is a methodology that may be worth exploring in future studies of competition policy enforcement.

4. General Considerations and Conclusions

I think that there are at least four important lessons that can be learned from the FS for future research or future antitrust cases on the impact of mergers on innovation.

First, sound theoretical analysis and economic reasoning need to guide the empirical analysis. For instance, there seems to be an implicit assumption that a reduction in R&D investments (like an increase in price) is “bad” for consumers. But this assumption is not theoretically grounded as we do not know the socially optimal level of R&D investment. It is possible that the newly formed company reduces R&D to avoid useless duplication. Moreover, even if mergers may increase market power in future markets, there may be efficiency gains that can justify the increase in market power (a sort of “efficiency defence” for innovation).

Second, while one of the main goals of this FS is to establish a general methodology that can be used to investigate the impact of mergers on innovation in different sectors, it is vital for Antitrust Authorities to acknowledge and understand the differences in innovation dynamics across industries. For instance, Comanor and Scherer (2013) points out that technological progress in an industry like pharmaceutical is best achieved through the exploration of multiple technical paths. When a major merger occurs, the number of independent sources of technological initiative is reduced which may lead to fewer parallel paths pursued and slower rates of pharmaceutical innovation.

Third, it is important to take into consideration the fact that not all the mergers have the same effects. This pilot study finds that Seagate became more innovative in all the three stages of innovation (research effort, patent activity and product improvements); no statistically significant effect on research inputs and product characteristics were found for WD; and the evidence for Toshiba points to a reduction in all the three innovation outcomes. In a paper published in 2009, I noted that: “there is no such thing as an “average merger” and differences in post-merger outcomes are still left unexplained”. More work is needed to understand why some mergers are successful and others are not. Moreover, the empirical analysis should look at the reaction of competitors to the new competitive environment. For instance, growing R&D expenditures by merging firms may trigger more research efforts by competitors, making estimates downward biased if competitors are used as control. Gugler and Szucs (2016) note that: “Using synthetic control groups and difference in difference estimation, we find that the return on assets of rival firms increases significantly after a merger. The size of the effect varies strongly with market characteristics and the intensity of competition”.

Finally, in the two merger cases of this FS, MOFCOM decided to impose remedies which did not allow the full integration of the merging companies until 3 years after the merger. This
shows that, because of the objective difficulties in assessing the effects of mergers on innovation, Antitrust Authorities across the globe are more likely to arrive at different conclusions on whether to authorize a deal and what remedies to impose. The uncertainty of the outcome may be counterproductive if it discourages welfare increasing deals or if it prevents merging companies from realising all potential innovation synergies.

To conclude, I strongly support the effort of DG COMP to conduct ex-post analyses of the effects of mergers on innovation. This is a high-quality study that represents an important contribution towards a better understanding on what data, variables and methodology can be used to assess the effects of mergers on the incentives and abilities of merging companies and competitors to invest in innovation. I believe that retrospective analysis of other mergers and competition policy ruling in high tech industries, such as pharmaceuticals, would be of paramount importance to guide future decisions.

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