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FIRE & MICE: THE EFFECT OF SUPPLY SHOCKS ON BASIC SCIENCE

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INTRODUCTION

The availability of highly specialized material and equipment is increasingly crucial for the creation of scientific knowledge (Stephan, 1996). As the production of research-related assets is costly, researchers often rely on external suppliers. While an increasing number of scholars have devoted their attention to the role of physical assets for knowledge production (Baruffaldi and Gaessler, 2018; Murray et al., 2016; Waldinger, 2016), there is still a limited understanding of how the reliance on external supply affects the rate and direction of scientific knowledge production.

In this study, we seek to understand how negative supply shocks affect the production of scientific knowledge in research fields relying on specific tools and materials. To this end, we exploit the 1989 Morrell Park fire that destroyed a considerable share of the world's largest mice breeding facility, the Jackson Laboratory (JAX). This fire led to an unforeseen and substantial supply shortage of distinct mice strains for the North American biomedical research community. The blaze destroyed more than half of the rearing rooms and killed approximately 400,000 mice in the process. It took more than two years until JAX returned to pre-fire capacity. Case studies and surveys provide abundant qualitative evidence that affected customers from academia and industry faced delays in and premature terminations of research projects. Having access to fire recovery files, price lists, and personal memorabilia from the JAX archive, we identified mice strains in good and short supply, as well as a non-exhaustive list of researchers who had outstanding mice orders.

To study the effects of supply shocks on basic science, we link data from the archived documents with state-of-the-art databases on scientific publications both at the mice strain level and the individual scientist level. First, we select mice strains mentioned in the historical fire documents from the entire population of research mice cataloged in the Mouse Genome Database. Each of them is connected to scientific publications that use the respective strain, which in turn can be linked to Scopus and Pubmed to add bibliometric data. Unaffected mice strains can either be JAX mice that remained unscathed by the fire or mice strains available from other suppliers. Second, we identify individual scientists from customer lists that were presumably affected by the unavailability of certain strains. We construct a matched control group of scientists from out-

side North America based on author characteristics like age, number of co-authors/number of publications before the fire and the usage of mice in their research. We complement this with disambiguated bibliometric data from Scopus including proxies for the direction of the scientists' research.

Our empirical strategy follows earlier empirical studies on productivity in basic science (e.g., Azoulay et al., 2010; Baruffaldi and Gaessler, 2018). We use a difference-in-differences approach exploiting the plausibly exogenous supply shock on mice strains by JAX before and after the 1989 fire. We quantify research output by counting publications linked to affected and unaffected mice strains, respectively scientists. Furthermore, we measure changes in research trajectories of scientists through a decline in self-citations and new keywords listed in their published work.

At the mice strain level, we find that the temporary unavailability of certain mice led to fewer scientific publications related to these strains. Interestingly, the usage of affected laboratory mice did not recover after JAX returned to full capacity. At the scientist level, we find preliminary evidence that research output decreased substantially for scientists that were unable to obtain the necessary mice compared to control scientists. This effect is particularly pronounced for affected scientists that had no substitutes available. Moreover, affected scientists published more explorative research on topics that were new to them and relied less on their previous body of work.

This paper contributes to the literature on the production of scientific knowledge. So far, previous studies have focused on the importance of access to prior knowledge (e.g., Biasi and Moser, 2020; Furman and Stern, 2011; Iaria et al., 2018; Murray et al., 2016) as well as on the allocation of human capital for the creation of new scientific knowledge (e.g., Agrawal et al., 2017; Azoulay et al., 2010). In contrast, few contributions have focused on the importance of physical capital for the productivity of scientists (Baruffaldi and Gaessler, 2018; Waldinger, 2016). These studies suggest that negative shocks to research-related assets held by the scientist impede her productivity and influences the direction of her research. We further contribute to the literature on the strategic organization of scientific activities. Our findings align well with the previous literature that studies the strategic responses of scientists when gaining access to research-related tools (Furman and Teodoridis, 2020; Teodoridis, 2017; Zyontz, 2019).

Our research contributes to the literature on knowledge production and has implications for science-funding policies. Understanding the determinants of scientific productivity, e.g., the accessibility of research resources like laboratory mice, is important from an economic perspective since scientific and technological knowledge is a key source of economic growth (Stephan, 1996). An increasing share of research-related material and equipment is purchased from specialized suppliers and research facilities rather than produced in-house (e.g., the NIH founded the Office of Research Infrastructure Programs in 2012, which designates an increasing share of its grants to support purchases of state-of-the-art commercially available instruments). This requires investments from governments, often in coordination with private investors and the international scientific community. A better understanding of the importance of the supply of research-related assets for the rate and direction of knowledge production is likely to bring insights on the policy and strategic relevance of such investments.

EMPIRICAL SETTING

In 1909, Clarence Cook Little established continued sibling mating as a method to eliminate genetic diversity in laboratory mice. He then founded the Jackson Laboratory (JAX) in 1918 as a research institute and a supplier for high-quality inbred mice. Given that the self-breeding of mice is fairly cumbersome, researchers typically prefer to purchase established strains. By 1989, JAX had become the supplier of over two million genetically defined inbred and mutant mice annually to over 11,000 scientists. Mice reared at JAX were used for research on a variety of diseases and by a wide number of institutions in North America.

On May 10, 1989, a fire destroyed the JAX main production facilities in Bar Harbor, Maine. The fire “resulted from the ignition of flammable vapors from the methanol and construction adhesive being used in the room of origin.” The destruction encompassed eleven breeding and production rooms. Adjoining rooms were not destroyed but experienced smoke damage. An appendix building remained unaffected. The fire killed 400,000 mice and reduced the breeding capacity by at least 50%. Since foundation stocks of the inbred strains were kept at a different location, no mice strain was permanently lost.

The fire led to a supply shortage of particular mice strains in two ways: first, the physical capacity to rear mice was largely compromised and, second, the stocks of several mice strains intended for shipment and breeding were severely reduced. Although inbred and mutant mice strains were most affected, there was considerable heterogeneity among those mice strains depending on the exact location of their cages in the main production building.

The animal resource production dropped to 40.9% of the capacity right after the Morrell Park fire. Within six months, it steadily increased to 57.4%. Likewise, the shipment rate increased to 70% in March 1990 and 74% in June 1990. Only by mid-1991, JAX returned to full capacity. In total, sales dropped from 475,016 in the first quarter of 1989 (directly before the fire) to 220,988 mice in the first quarter of 1990. The projected unit sales dropped by 55% for inbred strains and by 83% for hybrid and mutant strains. As a result, many inbred and mutant strains were subject to a substantial supply shortage.

DATA

We collected fire recovery files, price lists, and personal memorabilia from JAX. A full inventory list of the documents available can be found in The Jackson Laboratory Archives. Based on these files, we identified mice strains in good and short supply in the post-fire period, as well as a non-exhaustive list of researchers who were presumably affected by the shortage of particular mice strains. To determine which mice strains were subject to the fire, we use archival JAX documents such as waiting lists, internal correspondence as well as public communiqués. Ultimately, we identified 95 distinct mice strains. Among these, 43 strains can be classified as affected and 44 as unaffected.

To link mice strains to scientific publications, we make use of the Mouse Genome Database (MGD), which is freely accessible and administered by JAX. MGD links more than 60,000 distinct mice strains to more than 250,000 scientific references. We collect all references in MGD for each mice strain over time including related genes and disease information. We assemble additional bibliometric data on the scientific publications from Scopus, e.g., citations.

We identified scientists presumed to be affected by the supply shortage with the help of two JAX mice order lists from April/May 1989. These lists include customers that ordered strains still unavailable in the beginning of 1990. We digitalized the pre-fire order lists and retrieved the following information: order number, mice strain, recipient name, and shipping address. The recipient names and shipping addresses listed in the orders were assumed to correspond to the scientists ordering the mice, along with their respective affiliations. We collected the identities of 148 individual scientists at this stage. We then searched these scientists by name and affiliation in Scopus. Ultimately, we identified a total of 105 authors, of which 96 have explicitly published on mice before 1992.

We then construct a matched control group of scientists that share particular pre-fire characteristics with the affected scientists, such as age, number of co-authors, number of publications, number of citations, similarly ranked affiliations, and the usage of mice in their research. Potentially, every U.S. biomedical scientist could have been a JAX customer for different but unmentioned laboratory mice strains, while – according to official JAX documents – European and Japanese scientists could rely on domestic mice suppliers. We therefore select scientists with a primary affiliation outside the U.S. in order to prevent contamination of the matched control group. To find control scientists that meet the above criteria, we make use of a newly developed software program, *sosia* (Baruffaldi and Rose, 2019).

ANALYSIS AND RESULTS

For the main part of our empirical analysis, we rely on difference-in-differences models, exploiting the plausibly exogenous supply shock of certain mice strains at JAX due to the 1989 Morrell Park fire. At the mice strain level, we compare the number of (citation-weighted) publications linked to affected mice strains (in short supply) before and after the fire to the number of (citation-weighted) publications linked to the control group of spared mice strains (in good supply). Since laboratory mice became an increasingly popular research tool over time, we control for time trends using calendar year effects. Furthermore, the effect of the supply shock might be correlated with the experience of the scientific community with a particular strain. Hence, we include strain “age” effects (years from the first publication on a particular strain) into our specification. Given the differences in importance and applicability (e.g., number and strength of gene-phenotype links), we also include strain fixed effects. We cluster errors at the mice strain and year level.

At the scientist level, we compare research activities conducted by potentially affected customers to our matched control group, both before and after the fire. As the effect of the supply shock is by definition correlated with time and the scientists’ career progress, we include calendar year effects and scientist age effects. We cluster errors at the scientist and year level.

Our analysis at the mice strain level reveals a negative effect on research output linked to affected strains. The negative effect of the supply shortage of laboratory mice on publications is persistent over several years after the fire. At the individual scientist level, we find a detrimental productivity effect on scientists that previously relied on unavailable strains. This effect becomes stronger in the absence of a suitable substitute. Moreover, affected scientists start working in fields less related to their previous research. Finally, affected scientists also tend to publish less first-authored papers, which implies that they are forced to drop projects where they have execut-

ing functions. Hence, we find suggestive evidence that access to research tools has implications for the organization of science.

The fact that researchers tend to work more in new fields after such a supply shock suggests some degree of flexibility in research trajectories (e.g., Myers, 2020). However, this comes at the cost of lower productivity, especially in terms of the quantity of scientific output. This finding complements the previous literature on the importance of physical capital by providing first evidence on how the supply of physical capital affects the rate and direction of scientific knowledge production.

At this stage, our findings imply that the supply of research-related material bears important implications for the production of scientific knowledge. Public support appears justified to guarantee the stability and reliability of the upstream sector devoted to the production of these assets. The Jackson Laboratory was rebuilt with the financial assistance of the NIH based on an extramural grant. Case studies, survey results and our empirical analysis suggest that this fast response from the scientific community as well as from the government may have prevented more detrimental consequences for basic science.

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