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Comment Eleanor Wiske Dillon

Many conditions must come together for someone to develop a successful innovation. She, or he, must understand the current base of knowledge in her area to build on it; she must have the spark of a new idea; and she must have the inclination and security to take a risk in developing her idea. Both the content and the structure of educational institutions can be designed to foster these conditions.

In chapter 12, Biasi, Deming, and Moser focus largely on the role of education in providing for the first condition: a base of knowledge from which to innovate. In particular, they emphasize that incomplete and unequal access to quality education leaves some potential entrepreneurs without the base of knowledge they need to develop new ideas. Providing this base of knowledge

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is undoubtedly the most important role of education in supporting innovation. Failure to provide quality education to all young people will lead to missed opportunities and will lower the overall pace of innovation in the economy. In education systems like that of the US, where access to education varies systematically with parents' income and with race, this failure also reinforces existing inequalities by shutting down a path for economic mobility.

Democratizing access to general education, while valuable for many reasons, is a broad policy and may have limited direct effects on the rates of invention. I focus my discussion on whether the existing economic literature can suggest more targeted interventions that would particularly spark innovation. I follow the authors on focusing mainly on the US context. Universities with strong track records of producing successful innovators share a focus on building mentor relationships, exposing students to real-world open questions, and training in STEM (Science, Technology, Engineering, and Math) fields. Providing curricula with these themes in high school, which nearly all young people now complete in the US, could be another powerful policy for increasing both the representativeness and total level of innovative entrepreneurship.

Access to Training for Innovation

Attendees of a small set of US colleges account for an outsized share of US patents (Bell et al. 2019). Not all innovations generate patents, and not all patents are innovative, but this tight concentration of patenting suggests some colleges and universities are creating environments that nurture invention, beyond simply catching students up to the frontier of knowledge. Biasi, Deming, and Moser emphasize that these most innovative colleges are often small and private (Cal Tech and MIT top the rankings by rates of patenting)[1] and admit relatively few low-income students. Increasing access to these colleges could create more equitable opportunities and reduce the strong relationship between parental income and future innovation in the US.

However, these current centers of innovation make up a tiny fraction of college seats in the United States. Democratizing access to these schools will do little to increase overall innovation unless capacity is simultaneously increased without affecting the quality of instruction. In Bell et al.'s sample, the 10 colleges with the highest rates of patenting among their students produce 90 patent holders per 1,000 attendees, in contrast to 7 per 1,000 in the remaining sample. These 10 colleges had a combined enrollment of

1. As part of a larger project using Census data, Bell et al. (2019) match US citizens born between 1980 and 1984 to the college they attended for the longest time and also to US patent records. They then report the share of attendees matched to each college who hold at least one patent.

just over 30,000 undergraduate students in 2018—about the same size as Purdue University.[2]

Policymakers and educators could do more to spur innovation by bringing successful elements of entrepreneurial instruction into more colleges and high schools, reaching a wider audience. Pinpointing what these institutions do to promote invention is difficult to do using observational data, and I have not found any economic studies that attempt it, but profiles of programs like those at Stanford (Read 2019) and Technion (Solomon 2019) suggest a few common practices. Both programs put students in contact with successful entrepreneurs, creating mentorship opportunities. Both also set students to work on current open problems suggested by businesses through class projects and hackathons. Finally, both programs place a specific emphasis on training in STEM fields.

Ingredients of Education for Innovation

Each of these ingredients in training for innovation has at least suggestive support in existing economic studies of innovation and entrepreneurship. Bell et al. (2019) find that young people who grow up in a neighborhood with more inventors are more likely to later become inventors themselves, and they are more likely to innovate in the same fields represented by inventors in their early neighborhoods. Girls are more likely to go on to innovate in the same fields as female inventors in their neighborhoods, but not more likely to follow in the fields of local male inventors. Bell et al. interpret these findings as evidence that neighbors are not just affecting general human capital accumulation (through, for example, higher quality schools), but also sharing specific knowledge and mentorship. Lerner and Malmendier (2013) find that Harvard Business School graduates who interacted with more former entrepreneurs during school were more likely to succeed if they started businesses in the future, providing further support for the importance of learning some soft skills directly from active entrepreneurs.

There is also outside evidence on the importance of exposure to open questions. Chatterji (2009) and many others document that past experience in incumbent firms in the same industry improves entrepreneurial success. While industry experience provides specific skills, helping would-be innovators reach the current frontier of knowledge, it may also surface the kinds of open questions that successful innovations can answer. Koning, Samila, and Ferguson (2020) find that female medical researchers are significantly more likely than male researchers to patent innovative treatments for female diseases and conditions, which may reflect different priorities but

2. Top colleges are from the data that Bell et al. (2019) released with their paper. Counts are full-time undergraduate enrollment in Fall 2018, from the Integrated Postsecondary Education Data System (US Department of Education, National Center for Education Statistics 2018).

again reinforces that innovators must identify an open problem before they can solve it.

As the authors discuss in their chapter, several studies find persuasive evidence that increases in STEM training, such as increased vocational and technical secondary education in Italy (Bianchi and Giorcelli 2020) and expanded engineering training in Finland (Toivanen and Väänänen 2016), generate increases in patenting. The current patent system is better designed to protect innovations in the sciences than in, for example, business operations. These studies may therefore partially capture a transfer of talent and energy from fields where innovations are not captured by patents to fields where they are. However, these are also fields where computerization has rapidly expanded the frontier of what is possible and created entire new fields, with well-documented increases in the demand for workers trained in these areas by incumbent firms. It is reasonable to believe that this training is also particularly valuable for entrepreneurs in this era.

A Role for Vocational Training

Bringing curricula that develop entrepreneurial skills to more colleges, and particularly to secondary schools, would do at least as much to capture more would-be innovators as improving equitable access to the elite, but small, institutions that already target these skills. Technical and vocational curricula, which have declined recently in the US but remain common in many European countries, would seem to be a good environment for this training. Most US high school students follow an academic curriculum, which emphasizes abstract thinking and general knowledge, such as mathematics and writing in preparation for college course work. In contrast, vocational tracks teach applied and often technical skills, providing applied, subject-specific knowledge that is otherwise not available until post-secondary schooling (figure 12.C.1). Increasingly, European vocational tracks emphasize apprenticeships and direct links with active businesses (Hampf and Woessmann 2016). These kinds of curricula could provide all three ingredients for innovation: a focus on technical STEM subjects, mentorship from innovators, and exposure to open questions.

Vocational training lost popularity in the US partially from a perception that multiple tracks would tend to segregate low-income, non-white, and lower-performing students into applied curricula without strong earning prospects while preserving the path to affluence through academic training and college for more privileged students. However, there is growing interest among policymakers, academics, and the public for thoughtfully designed, high-quality technical training in secondary school.[3] Renewal of these pro-

3. See Jacob (2017) for a survey of recent academic work, and a cry for more attention, or Belkin's (2018) *Wall Street Journal* article for an example of public interest.

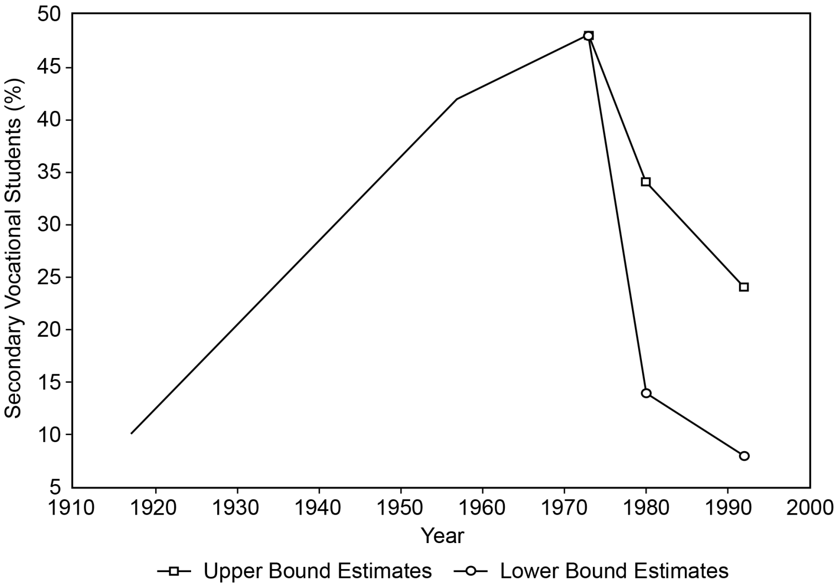

Fig. 12.C.1 Share of US secondary school students in vocational tracks
Source: Alon (2018) "Earning More by Doing Less: Human Capital Specialization and the College Wage Premium." Lower and upper bounds indicate more or less restrictive definitions of vocational curriculums.

grams could include opportunities to switch tracks, commitment to high-quality training, and an awareness of the potential of these programs to reinforce inequalities rather than mitigating them.

I know of no research that estimates the effects of vocational secondary school curricula on business starts or innovation, but several papers find generally positive effects on labor market outcomes (Jacob 2017). In one recent example, Bertrand, Mogstad, and Mountjoy (2019) study a reform in Norway that improved that country's vocational secondary school track, including adding apprenticeships, and led to increased enrollment. They estimate that entering vocational training generates a noticeable increase in post-school earnings, particularly for men, who were more likely to choose the more technical fields of that training. One aspect of the reform allowed students to convert from a vocational track to an academic one, which enabled them to go on to college, but the earnings gains are not a result of men taking this opportunity. This result suggests that vocational training teaches skills that are distinct from those learned in college but still valuable in the labor market.

Bertrand, Mogstad, and Mountjoy (2019) also find that enrollment in Norway's vocational secondary school track reduced criminal charges during students' teenage years, presumably because they were more occupied with school, and modestly increased secondary school completion. Creating strong vocational secondary school options appears to engage students who are otherwise on the margin of dropping out or engaging in illegal activities that would hamper future work. Potential innovators may particularly benefit from these alternative paths through secondary school. Levine and Rubinstein (2017) find that the most successful entrepreneurs have both high cognitive skills and a higher likelihood of having engaged in petty criminal behaviors (i.e., vandalism) in high school. Providing opportunities for creative thinking and applied problem solving early could generate the extra benefit of catching outside-the-box thinkers before they drift out of the system. Exploring the potential for well-designed vocational training to increase innovation would be a valuable area for future research.

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