Home Economics and Women's gateway to science

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Abstract

Women are underrepresented in STEM overall, but they have fair representations in many fields such as chemistry, biology, psychology, and public health. We propose that women came to dominate these fields because they were exposed to these subjects in large numbers through collegiate home economics in the early twentieth century. Home economics was developed in the context of the prevailing germ theory and was designed as a feminine parallel to agriculture studies at land-grant universities. The unique historical circumstances and institutional setup tied home economic curricula closely to chemistry and biological sciences. Using college-level data from the Commissioners of Education reports, we establish a causal relationship between home economics and women's enrollment in science majors in the cross-section. We further compiled a panel of student majors from 1910-1940 with data collected from various college yearbooks. In a DID framework, we test the effect of opening a home economics major. Compared to when home economics was not available, the presence of home economics led to a higher proportion of women choosing a major in science and a substantial reduction in the science gender gap. To shed light on occupational outcomes, we compared the labor force participation rate across college counties using the 1910 census. While a larger Home Ec program negatively correlates with the female labor force participation rate, it positively correlates with the female labor force participation rate in technical occupations.

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1 Introduction

In the past century, the gender gap in overall college enrollment and enrollment in each STEM major (with one notable exception of computer science) has reversed or narrowed (Goldin, 2014; Goldin and Kuziemko, 2006). However, the speed of convergence varied very much across fields (Kahn and Ginther, 2017). Within STEM, the share of women in life sciences and chemistry grew faster than other physical sciences and engineering. This pattern of preferences has been documented for women from different samples and periods (Lubinski and Benbow, 1992; Xie and Shauman, 2003). Because physical sciences and engineering are more math-intensive, the existing literature has been primarily concerned with gendered differences in math ability and whether the differences are caused by nature or culture. Kahn and Ginther (2017) thoroughly surveyed the literature on women's under-representation in the math-intensive fields. So far, scholars seem to take for granted that women are well-represented in life sciences. The literature has vaguely attributed it to preferences (Wiswall and Zafar, 2015) and psychological explanations (Ceci et al., 2014) without addressing where the preferences or mentality come from.

Our paper explores the higher education history in the U.S. and looks at the initial condition for women to enter into science. Specifically, we look at collegiate Home Economics (Home Ec), a women's field developed around the Progressive Era. It was the only professional major designed to be pursued by women at the time, and although closely tied to the homemaking tradition, incorporated many science courses. We document the science courses that frequented the Home Ec curriculum and establish a short-run relationship between Home Ec and women's enrollment in science. Given that gendered attitude, particularly in academic stereotypes, may be transmitted across generations (Alesina et al., 2013; Eccles and Jacobs, 1986), the development of women's curricula in the early twentieth century may have long term influence on observed academic preferences today.

The early twentieth century saw the increasing specialization of academic disciplines and, with it, gendered enrollment across majors. For most of the nineteenth century, classical curricula dominated U.S. higher education for both men and women and was gender-balanced.[1] Among the newer majors, agriculture and engineering were almost exclusively male. General Science, although exclusively male in most places, began to see positive share of women at some colleges, especially at land grant institutions. The timing and location where women were likely to enroll in science coincided with the roll out of Home Ec programs.

[1] According to the Report of the commissioner of education in 1910, 34,492 women and 36,077 men enrolled in classics.

To test the hypothetical link from Home Ec to science, we collected college level data from the Report of the Commissioner of Education in 1910, which recorded enrollment by major and gender. For each institution, we also document the land-grant status, endowment by private and public source, value of scientific apparatus, teaching disbursement, etc. The first part of our empirical analysis reveals a positive significant relationship between Home Ec and women's science enrollment in cross section. The spill-over rate from Home Ec to science is approximately 10:1. The estimated spill-over rate is robust to controlling for various sets of confounding factors.

A key concern with the cross-section analysis is that colleges with Home Ec programs vary in unobserved characteristics, such as their acceptance of highly educated women. In that case, colleges with larger Home Ec programs had more women in all majors. To address this, we conduct falsification checks. Placebo analysis shows that no other major that women were likely to choose had a positive relationship with women in science. Home Ec had singular importance in driving up women's enrollment in science. To exclude the possibility that colleges with Home Ec had a higher demand for science, we show that Home Ec does not predict men's enrollment in science.

To identify the causal effect of Home Ec, we adopt an instrumental strategy that exploits the institutional setup of Home Ec at land-grant universities: it was coded as an agricultural subject. Home Ec was entitled to funding from the Hatch Act of 1887 and the Smith-Lever Act of 1914, both agricultural grants from the federal government. Building on this insight, we instrument for Home Ec using the size of enrollment in agriculture. We confirm that the land-grant with higher agricultural demand had larger Home Ec programs, translating into more women in science.

Home Ec's association with agriculture also influenced the type of science courses included in the curriculum. Many Home Ec departments started as a part of agricultural colleges and adopted the core courses from agriculture programs.[2] Since agriculture is a multidisciplinary field of biology, students who enrolled in Home Ec programs were fully exposed to the foundation of biological sciences. Before taking specialized courses in Home Ec, they have typically completed courses in chemistry, physiology, and bacteriology.

To show that biological sciences constituted an integral part of Home Ec education, we compile a novel dataset using annual university catalogs. For each catalog, we transcribe the college where the Home Ec department locates, the different concentrations offered, the required

[2]For example, when Iowa State University inaugurated the Home Ec program, the freshmen year courses for Home Ec were identical with that in agriculture. The sophomore year courses continued to include courses in chemistry and botany (Eppright and Ferguson, 1971).

courses and their credit hours. We have currently transcribed 104 catalogs from 15 universities spanning from 1910 to 1950. We document that when the Home Ec department is a part of agriculture college, the share of chemistry and biology courses required is larger. On average, a Home Ec degree requires approximately 30 credit hours in chemistry and biology. Math and physics play a relatively smaller role, adding up to 5 hours on average.

We plan to merge the course catalog data with a panel dataset of student enrollment assembled from college yearbooks. We have collected yearbooks for 21 colleges spanning from 1910 to 1940. A college yearbook typically contain full student names and declared majors. We infer a student's gender by matching the first name to the 100% U.S decennial population census in the closest decade and compute the probability that the first name is male. We then aggregate the gender ratio for science majors for each college-year. Using a generalized difference-in-differences model, we show that the gender gap in science became smaller in the presence of Home Ec. Since the yearbooks report college majors in granular definitions, we can often categorize a science major into physical science or life science. We further show that Home Ec's effect is primarily driven by a smaller gender gap in biological sciences and chemistry rather than math, physics and geology.

Why does it matter what these women majored in if they all became housewives anyway? Despite a modern curriculum, women who selected into Home Ec were supposedly more conservative. Without matching names to the full census, we compared labor force participation rate for college counties using the 1910 census. While larger Home Ec program negatively correlate with female labor force participation rate, it positively predicts the share of women in technical occupations.

Today, the Home Ec program is arguably irrelevant in the academic domain. In rare cases where this program continued, they are rephrased as either Human Ecology or Family and Consumer Science. The Home Ec legacy is easy to overlook. Our paper examines the unique circumstances that gave rise to Home Ec, and highlights its relation to physical and biological sciences. This short-lived college program may have a long term consequence in womens fair representation in science today.

The rest of the paper is organized as follows: Section 2 provides a brief history on the founding of Home Ec. Section 3 explains the sources of our datasets. Section 4 describes our empirical specifications for cross section, describes the instrument, and shows the results. Section 5 presents the panel analyses on the opening of new Home Ec program, utilizing a novel dataset in student yearbooks. Section 6 describes potential mechanisms. Section 7 concludes.

2 Historical Background

The history of Home Ec education intertwined with that of the land-grant universities. Land-grant universities are higher education institutions tasked with teaching agriculture, military tactics, and the mechanical arts as well as classical studies to that members of the working classes by the Morrill Acts of 1862. [3] This mission contrasted with the historical practice of a liberal arts curriculum provided by private institutions.

Home Ec developed as a feminine parallel to agricultural education, a key component among the land-grant missions. Agriculture studies rarely existed among other state universities and were the primary target for federal financial support. The Hatch Act of 1887 provided federal funds to states to establish a series of agricultural experiment stations under the direction of each state's land grant college. The act also granted annual appropriations for research on the condition that state funds matched those funds. Besides agricultural research, the experiment stations were responsible for extension work: bringing new information and the results of agricultural research into rural areas. The outreach mission was further expanded by the Smith-Lever Act of 1914. Andrews (2019) discusses the causal effect of land grant colleges on local agricultural output.

Since agriculture and mechanics were supposedly practical fields for men, only a small number of women attended land grant universities (25.1% of student population in 1910) in comparison to private colleges (47.8%) or other state universities (34.3%).[4] Some advocated to enroll more women in land-grant universities. For example, trustees at Iowa State College declared in 1869, "if young men are to be educated to fit them for successful, intelligent and practical farmers and mechanics, is it not as essential that young women should be educated in a manner that will qualify them to properly understand and discharge their duties as wives of farmers and mechanics? (Eppright and Ferguson, 1971)" In order to increase women's enrollment at land-grant universities, they created a practical field for women, Home Ec.

The U.S. Department of Agriculture (USDA) was a significant impetus to the development of Home Ec. Through coding Home Ec as a subject under the broad umbrella of agriculture, it enabled Home Ec related research and outreach programs to unlock funding from both the Hatch Act and the Smith-Lever Act. As we will demonstrate, federal financial support significantly increased program sizes of Home Ec. Besides providing funding to Home Ec programs, the USDA provided employment opportunities for Home Ec graduates. It opened the Office of

[3]Land-grant universities were designated by states to receive the benefits of the Morrill Acts of 1862 and 1890.The first Morrill Act granted federally controlled land, hence land-grant, to the states to sell and raise funds.

[4]The percentages are derived from Table 16 of the Report of the commissioner of education in 1910.

Home Economics in 1915, where home economists were hired to work with agricultural experts (Elias, 2008).

Home Ec's association with agriculture also influenced its curriculum. Many Home Ec departments started as a part of agricultural colleges and adopted the core courses from agriculture programs.[5] Since agriculture is a multidisciplinary field of biology, students who enrolled in Home Ec programs were fully exposed to the foundation of biological sciences. Before taking specialized courses in Home Ec, they have typically completed courses in chemistry, physiology, and bacteriology.

While agriculture played an important role, the Home Ec curriculum was equally a product of its time. The late nineteenth century and early twentieth century witnessed scientific discoveries and culture shifts that directly shaped homemaking (Mokyr, 2000). Home Ec began to take shape as an academic field around 1900, when the first Home Ec subject, Hygiene and Sanitation, emerged (Elias, 2008). The timing coincides with the breakthrough in bacteriology. Scientists came to understand that germs caused disease and infection, and they are preventable through hygiene and sanitation. The second Home Ec subject, Food and Nutrition, formed in the late 1910s and integrally linked to the discovery of vitamins and minerals. In the 1930s, Home Ec training added another component in developmental psychology, possibly in response to the cultural shift in the belief that children deserved protection, nurture, and education.

The Home Ec movement was most relevant in the first half of the twentieth century. The number of degrees conferred in Home Ec grew substantially until the 1950s (see figure 2).[6] This period concurred with women's increasing productivity in the labor market and at home. This was when high school attendance increased significantly (Claudia Goldin, 1999), and electrification brought household labor-saving technologies (Cowan, 1985) and skill-biased job opportunities (Gray, 2013; Vidart, 2020) in the service sector (Goldin, 2006). However, women's increasing labor supply did not correlate with a decline in the time spent on housework (Cowan, 1985; Ramey and Francis, 2009). Mokyr (2000) reconciled the paradox by accounting for the growing domestic knowledge of hygiene, nutrition, and child development. The information was transmitted to households via home economics, more specifically, women who became high school teachers and extension workers in home economics (Stage and Vincenti, 1997).

[5] For example, when Iowa State University inaugurated the Home Ec program, the freshmen year courses for Home Ec were identical with that in agriculture. The sophomore year courses continued to include courses in chemistry and botany (Eppright and Ferguson, 1971).

[6] The ratio of conferred degrees on enrollment is approximately 1:10 for women, based on 1910 statistics.

3 Data

The *Report of the Commissioner of Education* provided data on enrollment by major and sex at the college level in 1910. The information was self-reported. A total of 583 institutions completed the survey, and nine majors were classified: classical & general culture, general science, agriculture, household economy (Home Ec), engineering, education, commerce, music, and fine art. Figure 1 shows the distribution of majors at different types of institutions. Classical education dominated the higher education landscape at private colleges for both men and women. At land-grant universities, roughly 20% of men enrolled in agriculture, and 20% of women enrolled in home economics. While agriculture was supposedly a men's field and home economics, a women's, there were a few exceptions. Women constituted 1.7% of agricultural students in 1910, and although home economics was exclusively female in 1910, some men studied home economics in later years.[7]

General Science was not a popular major for either gender. However, the share of women in general science (women in general science/total female students) was slightly larger at land-grant colleges (5.4%). The percentage was 1.5% and 3.8% at state colleges and private colleges, respectively. Men were more likely to major in science in private college (11.4% of men) compare to state (3.5%) or land-grant (4.3%) colleges.

Besides enrollment, the commissioners collected information on many college characteristics, including location, the number of faculty, founding date, funding sources, values of various assets, library volumes, tuition costs. For land-grant universities, in particular, teaching expenses on different subjects were reported.

Unfortunately, the commissioners only collected data on Home Ec and science degrees jointly in 1910, and the series of *Annual Report of the Commissioner of Education* ended in 1915. The follow-up series of *Biennial Survey of Education* collected data on enrollment for professional majors and arts & sciences majors, but not on science majors separately. Therefore, we cannot observe changes in the women's science enrollment over time at a national scale.

To overcome this challenge, we resort to the historical student yearbooks that are available through ancestry.com. The college yearbooks include full student names and hometown, which can be used to infer gender and to match students from yearbooks to other data sources such as

[7] Elias (2008) suggested that when men enrolled in home economics courses, these were most often institutional management classes, a group of topics that later became the core of hotel management. Using Cornell University's yearbooks from 1919 to 1936, we estimate that 95 percent of male students in Home Ec indeed majored in Hotel Management. However, data from the 1958 *Biennial Survey of Education* did not show a specific concentration. Among the 36 bachelor's degrees in home economics conferred to men, there were 2 in general curriculums, 2 in child development and family relations, 3 in clothing and textile, 11 in foods and nutrition, 6 in institution management, and 12 in other unspecified home economics fields.

the patent record. Instead of categorical disciplines, we observe enrollment in specific majors and double majors, if any.

We collected yearbooks from 21 different land-grant colleges, covering 305 yearbooks from 1879 to 1940 and including records for 83,448 undergraduate seniors. Summary statistics of all colleges appearing in the sample are provided in Table 7. In our sample, 7 colleges had no Home Ec enrollments at all, 5 colleges had positive Home Ec enrollment for all transcribed years, 9 colleges went from no enrollment to positive enrollment in Home Ec. Figure 3 (a) (b) show the increase in the number of Home Ec programs and total Home Ec enrollment.

We use first names from the US decennial censuses to infer the gender of each student. For each state and each census, we calculate the probability of being male for each first name, and then impute the inferred gender of the student. Similar technique has been used in (Andrews, 2019) to infer gender and race of patentees, (Cook et al., 2014) to identify race, and (Jones, 2009) to infer age.

We grouped home economics majors and science majors to the best of our ability to account for differences in the granularity of major names and formats. We excluded majors in Arts & Sciences since we cannot identify whether they are science majors or not. For this reason, the enrollment in sciences is under-counted, and more so in recent years than earlier years due to the increasing number of Arts & Sciences major reported. Therefore, we focus on gender ratio in science, an alternative measure to the number of women in science that is less sensitive to under-counting. Figure 6 shows the gender ratio in science over time for three college groups: colleges that never had Home Ec enrollment (the "never" group), colleges that had Home Ec enrollment throughout the years (the "always" group), and colleges that switched from zero to positive Home Ec enrollment (the switching group). The fraction of women in science is consistently higher in the "always" group than colleges in the "never" group. The trend in the switching group follows the "never" group in earlier years and converges to the "always" group in recent years.

We show the share of women in science (number of women in science/ total women) for a cross-sectional comparison in figure 4. Even though this measure loses precision over time, it offers a more direct interpretation of women's participation in science. As we have expected, the share of women in science is consistently higher in colleges with Home Ec than colleges without Home Ec.

4 Cross Section Analysis

This section presents the empirical exploration of the relationship between Home Ec and women's in science through OLS estimation. A discussion of endogeneity concerns and corresponding instrumental variable solution is presented in the next section. We focus on land-grant universities because of their comparable institutional setup and academic standards for Home Ec programs. We include the regression for the full sample in the appendix.

4.1 Land Grant Sample

The cross section estimating equation is:

$$number\ of\ women\ in\ science_c = \beta \cdot number\ of\ women\ in\ home\ ec_c + \theta X_c + \epsilon_c \qquad (1)$$

where the outcome is the number of degrees in general science conferred to women in 1910 at college c and the variable of interest is the number of degrees in home economics conferred to women in 1910 at college c. X_c is a vector of control variables, and ϵ_c is an error term.

The coefficient of interest, β, captures the relationship between home economics and women in science. A positive β provides evidence that women who enrolled in home economics courses spilled over into science majors.

We consider four subcategories of controls to capture the differences across colleges that might affect the number of women in science: the size and breadth of academic offerings, the types of funding received, the overall resources available, and the emphasis on science education. The baseline controls consist of the number of women graduating in classics, the number of majors available, and the size of the student body. Column 1 in table 1 shows this baseline estimate. As predicted, the number of women in home ec strongly predicts that in general science: an increase of 10 women in home ec is correlated with 1 more woman in general science. Since classics was still the most popular major for women at land-grant, the number of women in classics serves as a natural comparison group. In contrast to home ec, classics show no signs of spill-over to women in general science.

Even though land grant universities provided similar education to each other, they still could have varied in their commitment to science depending on the geographic location or the attitude of the university administration. Therefore, we quantify the supply and demand for science education. We control the sunk investment in scientific instruction by the value of scientific apparatus and machinery as of 1910 and the marginal spending on science education by the disbursement of funds towards the teaching of natural sciences in 1910. Additionally, we control for the overall demand for science education through the number of men in general science. Column 2 in table 1 show estimates after controlling for the popularity of the science major in different ways. The controls, especially the number of men in science, positively correlate with the number of women in science. Reassuringly, they hardly affect the coefficient of interest.

We further test robustness on university resources to account for the overall quality of education: the number of faculty, the volume of library books, and total endowment. Column 3 in table 1 shows that estimates are robust to controlling for the university resources.

Controls on funding include funds received from government sources and funds collected from private sources. Funds from government sources, in particular the Hatch Act funds, were directed to agricultural, home economics, and biological research. The spill-over effect may be caused directly via the Hatch Act spending. Table 2 shows the direct effects of public and private funding on various subjects. While public financing positively predicts the size of agriculture and home economics programs, it has no direct impact on the size of the science program. Consistent with this result, column 4 in table 1 shows that estimates are robust to controlling for types of funding.

4.2 Robustness Checks

The size of a Home Ec program may have indicated the degree to which women receive higher education was accepted. To account for this possibility, we replicate our regression for all other majors which women were likely to take. Columns 1-6 of table 3 show that no major other than Home Ec had a positive and significant impact on women's enrollment in science. This evidence supports the singular importance of Home Ec in driving women to science.

To further demonstrate that the relevance of Home Ec is not driven by demand for science in general, we run a placebo regression on men in science. We show in Column 7 of table 3 that no significant relationship exists between Home Ec and men's enrollment in science.

4.3 Agriculture Instrument

What drives the underlying cross-sectional variation in Home Ec program sizes? Understanding the driving force will allow us to interpret whether our estimates are causal or merely correlational. Even though all land-grant universities were encouraged to establish the Home Ec program, not every institution opened a Home Ec major, and sizes of the program varied significantly.

As discussed in the historical background, the U.S. Department of Agriculture contributed to Home Ec development by including it as an agricultural subject. Thus, the in-state demand for agricultural education likely correlated with the offering for Home Ec. Specifically, a higher in-state demand for agricultural education led to a larger agriculture program; since Home Ec shared the same funding sources with agriculture, a larger agriculture program meant a lower marginal cost to invest in a Home Ec program. Home Ec programs were often part of schools of agriculture, Home Ec research were conducted at the Agricultural Experiment Stations, and collaborations between Home Ec faculty and agriculture faculty were common (Smith, 1933). Building off from this observation, we use the number of men in agriculture program as an instrument for the number of women in Home Ec.

Before turning to the 2SLS results, we will examine the first stage relationship in our land-grant sample. Columns 1&2 of table 4 show the coefficient on the instruments in predicting the Home Ec program size in 1910. The relevance assumption is satisfied as colleges with larger agricultural programs had larger Home Ec programs. Figure 8 visualizes the relationship. Unfortunately, 1910 was still early for some colleges to establish a Home Ec program. For instance, Cornell University's large Home Ec school that pioneered the Hotel Management program, didnt begin until 1919.[8] Hence, our instrument worked better at the intensive margin than the extensive margin. Because sizes of the agriculture program only explain a proportion of variation in sizes of the Home Ec program (when Home Ec program had been established), the F-stat is small and our 2SLS estimates would be biased towards OLS estimates given the small sample (Bound et al., 1995).

Obviously, states with high demand for agricultural education were not randomly chosen. The states with the largest agriculture program in 1910: New York, Pennsylvania, and Illinois, were among the states with the highest value of farm building and equipment, an indicator for the mechanization of agriculture.[9] The adoption of new farming technology likely incentivized potential farmers to attend college and learn about the latest science and techniques in agriculture. To confirm that farm mechanization is the primary channel to agriculture enrollment, we compare the relative predictive power of other major aspects of agriculture: employment, output, livestock, size of farms, and the abundance of farms. Since the set of agricultural variables available from the 1910 Census of Agriculture is quite large, we use the Least Absolute Shrinkage and Selection Operator (LASSO) technique (Tibshirani, 1996) to select the predictors in

[8]Home economics began as a department in the College of Agriculture at Cornell. In 1919, Cornells trustees made it the School of Home Economics (Engst and Friedlander, 2014). From Cornell's yearbooks, we first observe seniors majoring in Home Ec in 1919.

[9]Figure 7 shows the relationship between the enrollment in agriculture at land-grant college and the value of farm machinery of that state.

forwarding steps. Table 11 in the Appendix shows the variable selection procedure. Indeed, the value of farm equipment stands out as the most correlated agriculture predictor, and its combination with state population and student population gives the optimal Lasso solution.

The credibility of our research design hinges on the assumption that demand for agriculture did not affect women in science directly or indirectly for reasons other than Home Ec. The exclusion restriction is challenged if the relevance of agricultural education, whose variation could be attributed to the adoption of agricultural technology, increases the demand for science education. To rule out this possibility, we regress agricultural program sizes on different science measures: the number of men in general science, teaching expenses on science, and the value of scientific apparatus. Table 5 presents the results and shows that no strong correlation existed. In contrast, we found a significant reduced-form relationship between sizes of the agricultural program and the number of women in general science (table 4 columns 3&4).

IV results:

Now we turn to quantify the marginal effect of Home Ec program size on womens enrollments in general science in the second stage. Table 6 presents the estimates in 2SLS (columns 1-2). The results are robust to controlling for university scale measures and science-related conditions. Our instrument proved to be relevant, and the second-stage results are larger than the cross-sectional estimates: the spill-over ratio from Home Ec to general science is approximately 10: 1 according to the OLS estimation and 6.5: 1 according to the 2SLS estimates.

The discrepancy between IV and OLS estimates point to the fact that Home Ec program sizes could be correlated with omitted variables that are negatively associated with womens enrollment in general science, resulting in a downward bias in the OLS estimates. This suggests that if anything there is a negative bias in the selection of Home Ec programs with respect to womens scientific pursuit. This accords with the narrative evidence which indicates that the design for Home Ec was motivated by ideas about traditional gender roles and targeted women from rural areas (Schwieder, 1986). The bias could occur, for instance, if prior to the college entrance, a woman (or her parents) who chose the Home Ec major had a lower level of interest in science than another woman who chose the major in music or classics.

The analysis in this section offers two distinct advantages. First, although Home Ec education was a signature of land-grant universities, the instrument explains the variation in sizes of the Home Ec program within the land-grant sample. Second, the empirical design allows us to assess the plausibility of the identification strategy more easily. Since agricultural education was almost exclusively male[10] and has specific motivated origins that are bound to geological conditions and factor prices,[11] it should have little organic connection with women in higher education other than the arbitrary Home Ec-Agriculture bundle assigned by the USDA. Altogether, this allows us to make progress toward actual causal estimation of the effect of Home Ec education on bringing women into science majors.

5 Panel Analysis with Student yearbooks

In this section, we expand the time horizon from 1910 to 1940 and test the hypothesis in the panel framework. We compile measures in enrollment by major and gender at the college level by using student data from the yearbooks. This dataset was first deployed in (Andrews, 2019). We introduce time variation and exploit both the establishment of new Home Ec programs and the relative sizes of the program at different points in time. In contrast to the previous analysis, here our estimates are identified not by variation across colleges, but variation across time in a given college. Due to the under-counting problem discussed in the data section, we modify our specification as follows:

$$frac.\ of\ women\ in\ science_{c,t} = \beta \cdot home\ ec\ dummy_{c,t} + \delta_c + \theta X_{c,t} + \epsilon_{c,t} \tag{2}$$

$$frac.\ of\ women\ in\ science_{c,t} = \beta \cdot share\ of\ women\ in\ home\ ec_{c,t} + \delta_c + \theta X_{c,t} + \epsilon_{c,t} \tag{3}$$

where outcome of is the fraction of women in science (number of women in science/total science enrollment), $home\ ec\ dummy_{c,t}$ is a dummy variable that equals 1 if Home Ec had positive enrollment at college c in year t, $share\ of\ women\ in\ home\ ec_{c,t}$ is the share of women in Home Ec (number of women in Home Ec/ total female students) at college c in year t. The inclusion of college fixed effect, δ_c, allows us to flexibly address any time invariant characteristics which may differentially affect demand for practical or scientific education. Factors may include geological conditions, distance to metropolitan areas, founding philosophy of a institution, etc.

Since our sample is small and unbalanced, we control for year intervals instead of year fixed effects. Based on the trend in figure 6, we divide the thirty years into 3 intervals: 1910-1915; 1915-1933; 1933-1940. In addition, we control for the total enrollment in science as it is the denominator of our outcome variable. As in the cross-section specifications, we include sizes of the student body as a control.

[10] 98.3% of agriculture degrees were awarded to men in 1910.

[11] For example, Manuelli and Seshadri (2014) attributed the variation in horse prices for the case of tractor adoption.

Columns 1 & 2 of table 8 show the results of the panel regression (2) & (3), respectively. Home Ec increases the fraction of women in science both on the extensive and intensive margins. The magnitude of the impact is substantial. After a Home Ec program opens, the fraction of women in science is expected to increase by 13.57 percentage points. A 4 percentage points increase in the Home Ec program's size is associated with a 1 percentage point increase in the fraction of women in science.

Columns 3 & 4 show estimates on a different outcome: the share of women in science. Because the reporting in the Arts & Sciences major increased over time, the number of students in science suffers under-counting more severely when the Home Ec dummy goes from 0 to 1. Thus, the estimates will understate the impact of having Home Ec programs. Even though the magnitude is not interpretable, the estimated coefficient of interests are positive and significant, indicating a positive spilled-over effect from Home Ec to science.

The above analysis excluded Cornell University. Although Home Ec was primarily a women's field, the gender reversed at Cornell University after 1930, thanks to the inauguration of the Hotel Management Program under the College of Home Economics. Even though hotel management was seen as a male occupation (Elias, 2008), the freshmen year curriculum required the typical science courses in Home Ec: hygiene, inorganic chemistry, and chemistry of food. Advised elective courses include general biology and physics (See figure 9). Could there be a parallel spilled-over to science for men? We regress the share of men in Home Ec on the fraction of men in science for all Cornell observations. Interestingly, the share of men in HE is positively correlated with the fraction of men in science. (See table 9)

The nature of compiling a dataset from numerous decentralized sources, where data content and format vary enormously even within the same source, means noisy measurement. We introduced several rounds of noises in preparing the yearbook data. We lost observations when students left the major field as blank or left their names in initials. We lost precision when the gender is inferred based on first names, and when the major field is too broad. Nevertheless, this data source has provided us with valuable evidence concerning women's dynamic enrollment in science in the early twentieth century. In future work, we plan to extend the data collection to private colleges and the period after 1940.

6 Mechanism

Why did Home Ec, a discipline closely tied to domesticity, increase women's enrollment in science? In this section, we provide some evidence on the potential mechanisms which underlie this finding.

Fundamentally, the spill-over effect was caused by overlapping in content, especially in the distribution requirements. In many ways, Home Ec studies developed as a feminine parallel to agricultural studies, so the requirements for domestic sciences around 1910 overlapped with those of farm sciences (chemistry and biological sciences).[12] For example, the 1919 Cornell Catalog shows that women who wished to specialize in Home Ec must complete the same core courses as men in agriculture, covering biology, chemistry, physics, physiology, and bacteriology. At Iowa State University, the first year courses for Home Ec were also identical with courses in agriculture (Eppright and Ferguson, 1971). Similarly, in the 1911 course catalog at Utah State University, students in domestic science must complete courses in general chemistry and plant physiology in freshman year. They must also take classes in bacteriology, advanced physiology and chemistry in sophomore year.

Through heavy exposure to sciences, Home Ec could lead women to a science degree in multiple ways. It reduced the amount of additional work to complete a double major in science. It could also inspire women to switch their majors entirely into sciences.[13] Moreover, it prepared women with all that was necessary to go to medical school or graduate school in science. There were plenty of anecdotes to support each channel. For example, Cassandra Wanzo went to Northwestern University in 1969 and majored in nutrition, a degree offered through the Department of Home Economics. She met all the requirements for a pre-med track and went on to medical school at the University of Wisconsin and became a psychiatrist in Atlanta (Blackwell, 2017). In another case, Reatha Clark King initially chose Home Ec major when she attended Clark College in Atlanta, considering a career in teaching Home Ec in high school. She fell in love with chemistry and switched her major to chemistry. She continued her education at the University of Chicago and completed her Ph.D. in thermochemistry (Spangenburg and Moser, 2003).

Data digitized from Student yearbooks helped us identify a pattern in the types of majors that were likely to pair with Home Ec. In all senses, double majors were rare. We observe a total of 56,314 undergraduates' declaration of majors, and only 648 (1.15%) of the undergraduates enrolled in more than one major. The percentage (2.7%) is higher for students in Home Ec: out of 5,179 students in Home Ec, 140 had a second major. Among the double-majors, 29 (20%) paired with education, and 45 (32%) paired with sciences.[14] In comparison, 171 out of

[12] Although life sciences dominated Home Ec science requirements, there was an exception. When household equipment inaugurated as a Home Ec field in parallel to agricultural engineering, courses in physics and electric circuits were required (Bix, 2002).

[13] As long as the switching rate from Home Ec to science is less than 100%, switching will result in a positive correlation.

[14] 35 general science, 3 industrial science, 1 science, 5 chemistry, and 1 zoology.

5,633 (3%) students who majored in education had a second major. Only 6 students had a double-major in science. [15]

7 Conclusion

In this paper, we study a historical pattern on American women's participation in science. Specifically, we argue that Home Ec programs expanded women's enrollment in science. We first present cross-sectional evidence between the size of Home Ec program and women's general science enrollment in 1910. We focused on the sample of land-grant universities because of their comparable institutional setup and academic standards. To generate exogenous variation in Home Ec enrollment, we use the demand for agricultural education as a source of identification. The empirical evidence supports the idea that exposure to the Home Ec curriculum increased women's participation in science.

The snapshot in 1910 captured a point in time when hygiene and sanitation was the central theme in Home Ec. This theme developed in the context of the prevailing germ theory and incorporated science courses such as bacteriology as its theoretical foundation. There was no evidence to suggest that women in Home Ec took a watered-down version of the science courses. Since Home Ec departments borrowed physical science courses from natural science departments or agricultural schools, Home Ec students were taught and evaluated in the same standard as their male classmates. Moreover, there was an incentive in the founding days to establish a rigorous scientific standard, as Home Ec strove for academic legitimacy.

We complement the cross-section analysis with a short run panel study on the opening of new Home Ec programs. Compared to when Home Ec was not available, the presence of Home Ec led to a higher proportion of women choosing a major in science and a substantial reduction in the science gender gap. Given that the Home Ec movement quickly spread to other private colleges and state universities, [16] extrapolating the panel estimates would imply a reasonably broad impact on women's entry into science.

Besides serving as a back door to science, Home Ec also invented important subfields in science. The first subfield is nutrition (or food science), the study of chemical substances relating to food. Students who graduate from food science can find employment as dietetics or food technologist. The second subfield is developmental science, the study of child behaviors and development. As Home Ec gradually phased out, developmental science became an integral branch in psychology.

[15] 1 botany, 2 chemistry, 1 medicine, 1 physiology, 1 pharmacy.

[16] The number of Home Ec programs increased from merely 68 in 1910 to 340 by 1970.

Today, the Home Ec program is arguably irrelevant in the academic domain. In rare cases where this program continued, they are rephrased as either "Human Ecology" or "Family and Consumer Science." The Home Ec legacy is easy to overlook. Our paper examines the unique circumstances that gave rise to Home Ec, and highlights its relation to physical and biological sciences. This short-lived college program may have a long term consequence in women's fair representation in science today.

Table 1 – Spill over to science : land grant universities

Women in general science

	(1)	(2)	(3)	(4)
Women in home ec	0.0993***	0.0808***	0.0986***	0.0996***
	(0.0205)	(0.0196)	(0.0216)	(0.0218)
Women in classics	-0.0095	-0.0164	-0.0072	-0.0099
	(0.0128)	(0.0121)	(0.0138)	(0.0132)
Number of majors	2.8443***	2.6917***	2.6224**	2.8599**
	(1.0317)	(0.9848)	(1.1604)	(1.0580)
Total students	-0.0024	-0.0053	-0.0037	-0.0022
	(0.0025)	(0.0035)	(0.0041)	(0.0027)
Scientific apparatus		4.1025		
		(3.1748)		
Teaching expenses on science		28.5038		
		(25.4913)		
Men in science		0.1042***		
		(0.0346)		
Total faculty			1.8801	
			(3.3518)	
Total books			-0.3537	
			(2.9093)	
Total endowment			-0.1536	
			(0.6598)	
Funds from public sources				-0.2365
				(1.0022)
Funds from private sources				-0.0520
				(0.3969)
Observations	47	47	47	47
R^2	.48	.61	.49	.48

Notes: The table reports OLS estimates. An observation is a land grant college in 1910. The dependent variable is the number of degrees in general science conferred to women. Women in home ec/classics is the number of degrees in general science conferred to women in home economics/classics. Number of majors is the total number of majors offered at the college. Scientific apparatus measures the value of scientific apparatus and teaching expenses on sciences measures the disbursement of funds on the teaching of natural sciences. Men in science equals to the number of degrees in general science conferred to men. Total faculty/books/endowment are measured in logarithm. Funds from public sources equals the amount of funds from state, federal government in logarithm. Funds from private sourses is measured in logarithm. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 2 – The effect of funding sources on program sizes

Dependent Variable: # graduates in	Agriculture	HomeEc	Science	Engineering	Classical	Education
land grant	95.7574***	2.4963	-6.3288	195.7200***	-235.5455***	-13.2711
	(12.1969)	(9.1385)	(14.0454)	(31.6270)	(40.6233)	(24.9810)
land grant X public funds	0.0027***	0.0020***	-0.0003	-0.0010	-0.0004	-0.0014*
	(0.0004)	(0.0003)	(0.0005)	(0.0011)	(0.0014)	(0.0009)
landgrant X private funds	0.0012***	-0.0002***	-0.0003***	0.0025***	-0.0019***	-0.0005**
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0004)	(0.0002)
size	Yes	Yes	Yes	Yes	Yes	Yes
state fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	573	573	573	573	573	573
R^2	.66	.28	.32	.59	.65	.26

Notes: The table reports OLS estimates. An observation is a college in 1910. The dependent variable is the number of degrees conferred in various major. land grant is a dummy if a college is a land grant university. Funds from public sources equals the amount of funds from state, federal government in logarithm. Size equals to the total number of degrees conferred at a college in 1910. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 3 – Testing spill-over effect of other majors on science

#graduates in:	Women in science						Men in science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Classics	-0.0282**						
	(0.0116)						
Music		-0.1097*					
		(0.0569)					
Education			-0.0389*				
			(0.0224)				
Fine Art				-0.0725			
				(0.0579)			
Commerce					0.1368		
					(0.2938)		
Household Economy						0.0896***	-0.0126
						(0.0203)	(0.0993)
Fundings	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Men in science	Yes	Yes	Yes	Yes	Yes	Yes	No
Women in science	No	No	No	No	No	No	Yes
Number of majors	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	48	48	48	48	48	48	48
R^2	.39	.36	.35	.53	.31	.33	.28

Table 4 – Spill over to science : First Stage & Reduced Form

	Women in home ec	Women in home ec	Women in general science	Women in general science
Men in Agriculture	0.1687*	0.1906**	0.0336**	0.0294*
	(0.0943)	(0.0934)	(0.0155)	(0.0146)
University Size Controls	Yes	Yes	Yes	Yes
Science related Controls	No	Yes	No	Yes
Observations	48	48	48	48
R^2	.24	.36	.23	.4

Notes: The table reports OLS estimates. An observation is a land grant college in 1910. The dependent variables in columns 1&2 are the number of degrees in home economics conferred to women. The dependent variables in columns 3&4 are the number of degrees in general science conferred to women. University size controls include the total number of majors offered and the total number of degrees conferred at the college. Science related measures include the value of scientific apparatus, teaching expenses on natural sciences, and the number of degrees in general science conferred to men. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 5 – Placebo Test of Instrumental Variable on Various Outcomes

	Men in science	Teaching expenses on science	Scientific apparatus
Men in Agriculture	0.0322	1.0531	252.3759
	(0.0554)	(5.2379)	(174.4870)
University Size Controls	Yes	Yes	Yes
Funding Controls	Yes	Yes	Yes
Observations	48	48	48
R^2	.17	.11	.8

Notes: The table reports OLS estimates. An observation is a land grant college in 1910. The dependent variable in column1 is the number of degrees in general science conferred to men. The dependent variable in column2 is the teaching expenses on natural sciences. The dependent variable in column3 is the value of scientific apparatus. University size controls include the total number of majors offered and the total number of degrees conferred at the college. Funding controls include the amount of money received from public and private sources. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 6 – Spill over to science : Second Stage

Women in general science

	(2SLS)	(2SLS)	(OLS)	(OLS)
Women in home ec	0.1993**	0.1544**	0.1035***	0.0957***
	(0.0897)	(0.0652)	(0.0197)	(0.0194)
University Size Controls	Yes	Yes	Yes	Yes
Science related Controls	No	Yes	No	Yes
Observations	48	48	48	48
R^2	.19	.5	.48	.59

Notes: The table reports 2SLS and OLS estimates. An observation is a land grant college in 1910. The dependent variable is the number of degrees in general science conferred to women. Women in home ec is the number of degrees conferred to women in home economics. University size controls include the total number of majors offered and the total number of degrees conferred at the college. Science related measures include the value of scientific apparatus, teaching expenses on natural sciences, and the number of degrees in general science conferred to men. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 7 – Yearbook Data Summary Statistics

College	Students Mean	Women Mean	Students in HomeEc Mean	Women in Science Mean	Yearbooks Num.	Yearbooks First	Yearbooks Last
Auburn University	343.88	66.13	25.25	0.63	8	1916	1940
Clemson University	238	23.6	0	1.8	5	1915	1940
Cornell University	732.53	260.79	20.5	11.74	38	1897	1936
Georgia School of Technology	274	44.18	0	0.53	17	1917	1940
Iowa State University	372.1	169.52	91.03	9.62	29	1905	1940
Louisiana State University	675.29	234	12.86	2.86	7	1927	1940
Missouri University of Science and Technology	74.42	27.08	0	0	12	1911	1940
North Carolina Agriculture and Technology	100	32	4	5	1	1939	1939
North Dakota State University	239	95.53	25.29	1.94	17	1908	1940
Texas Tech	378.5	163.5	50	2.5	2	1937	1940
University of Arizona	213.67	95.56	0	0	9	1913	1940
University of Colorado	218.93	100.78	0	0	27	1893	1939
University of Maine	208.76	83.88	8.12	5.36	25	1904	1940
University of Missouri	457.27	220.77	0.5	0.37	30	1905	1940
University of Nevada	74	28.57	3.71	2.86	7	1901	1940
University of New Hampshire	292.85	97.77	2.46	0	13	1909	1940
University of North Dakota	203.4	69.2	0	0	5	1906	1940
University of Washington	553	171	70	8	1	1940	1940
Utah State University	181.6	52.8	22.6	0.2	5	1911	1939
Virginia Tech	133.33	23.39	0	0.22	18	1898	1939
Washington State University	346.64	112.36	43.27	4	11	1903	1939

Notes: This is a list of colleges for which yearbooks are transcribed. For each college, we list the average number of students, average number of women, average number of students in Home Ec, average number of women in science with matched first names. Also listed is the total number of yearbooks transcribed, the earliest and the most recent transcribed yearbook

Table 8 – Panel Estimates from Yearbooks Sample

	Frac. Women in science		Share Women in science	
	(1)	(2)	(3)	(4)
HE Exists	0.1357**		0.0242**	
	(0.0670)		(0.0105)	
Share of Women in HE		0.2584*		0.0523*
		(0.1364)		(0.0302)
Num. Women Students	No	No	Yes	Yes
Num. Science Students	Yes	Yes	No	No
Num. Total Students	Yes	Yes	No	No
Time intervals	Yes	Yes	Yes	Yes
Observations	122	122	217	217
R^2	.75	.74	.43	.43

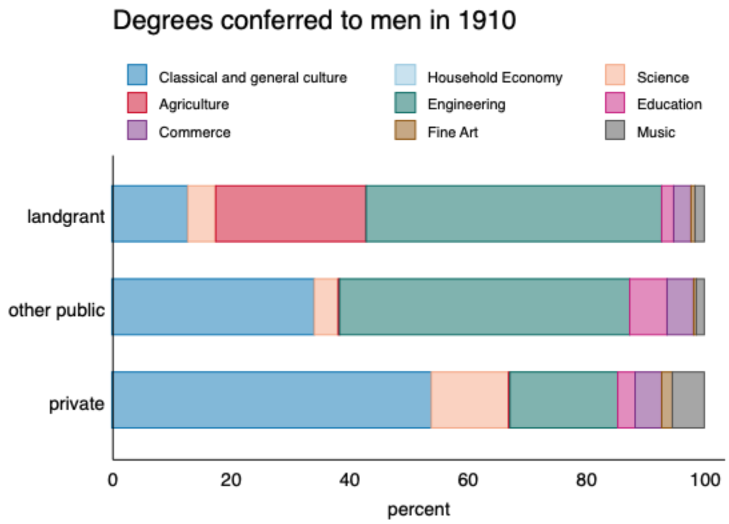
Notes: The table reports OLS estimates. An observation is a college-year. The dependent variables in columns 1&2 are the estimated fraction of women science (women in science/total students in science). The dependent variables in columns 3&4 are the share of women in science (women in science/total women). Time intervals are dummy variables for years before 1915 and for years after 1933. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 9 – Cornell University: Men in Home Ec and Science

	Frac. men in science	
	(1)	(2)
HE Exist	0.0821	
	(0.0481)	
Share of Men in HE		1.2012*
		(0.6190)
Num. Science Students	Yes	Yes
Num. Total Students	Yes	Yes
Time Intervals	Yes	Yes
Observations	23	23
R^2	.86	.87

Notes: The table reports OLS estimates. An observation is a year at Cornell University. The dependent variable is the estimated fraction of men science (men in science/total students in science). Time intervals are dummy variables for years before 1915 and for years after 1933. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Figure 1 – Distribution of majors by institution type



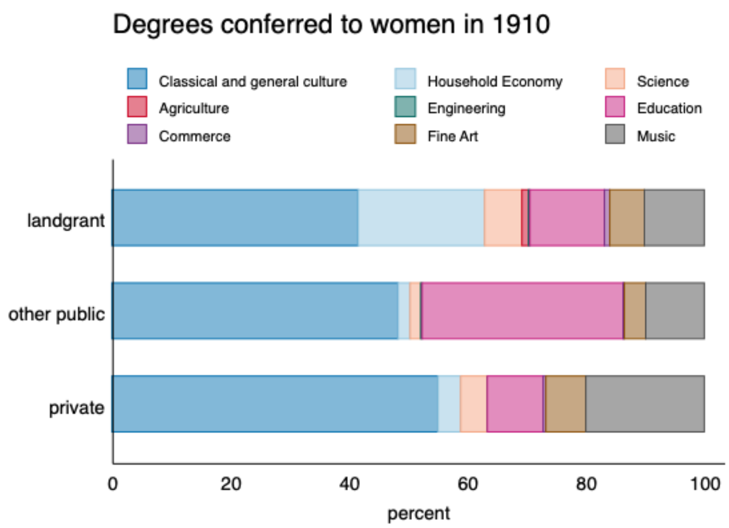
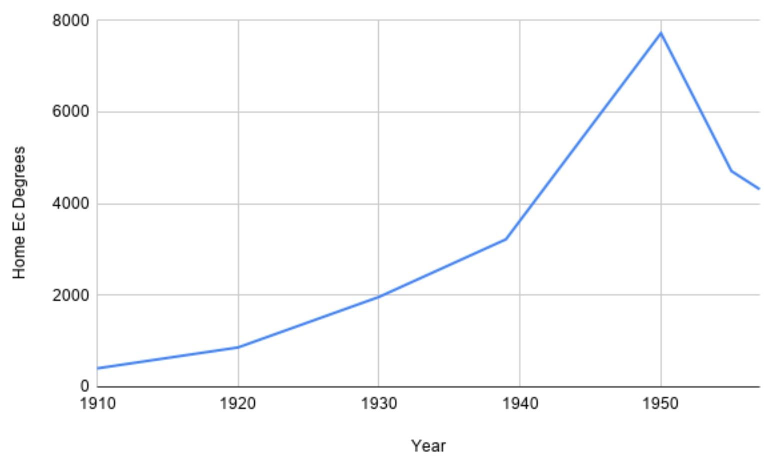


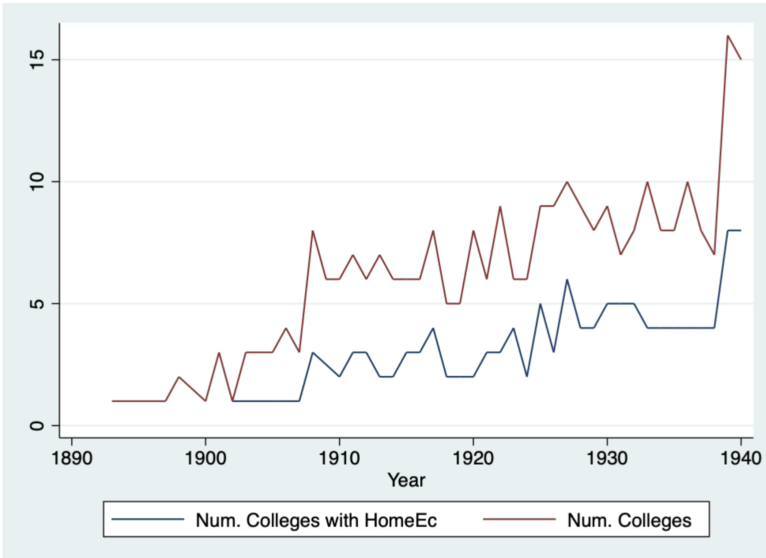
Figure 2 – Number of Degrees in Home Ec conferred



Notes: Number of degrees in Home Ec conferred. Data source: Annual Report of the Commissioner of Education 1910; Biennial Survey of Education 1920, 1930, 1939, 1950, 1955, 1957.

Figure 3 – Home Ec Trends from the yearbooks sample

(a) The number of colleges offering Home Ec



(b) Declared majors in Home Ec

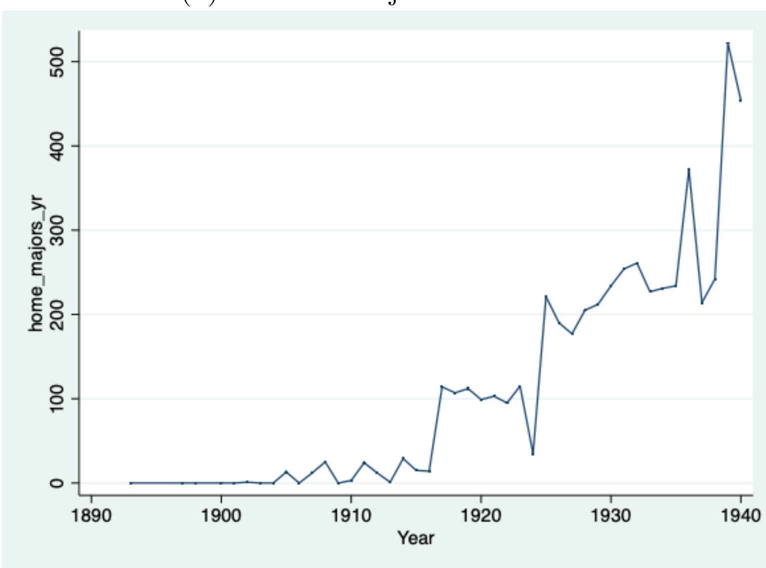
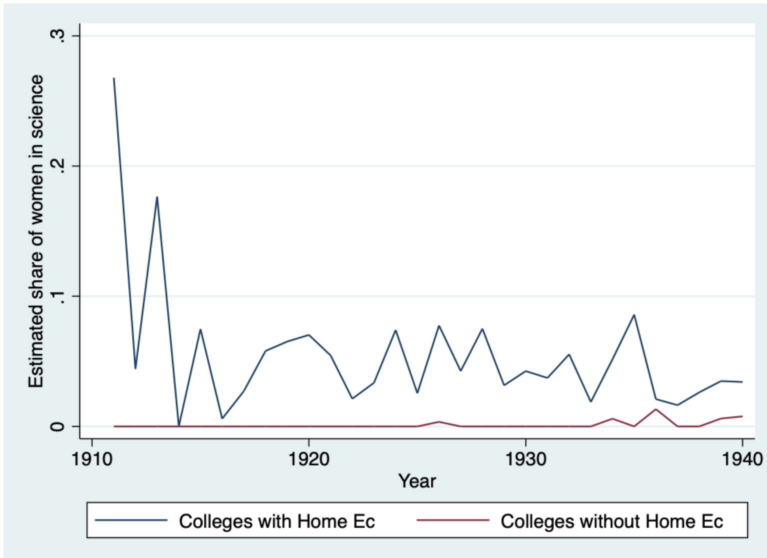
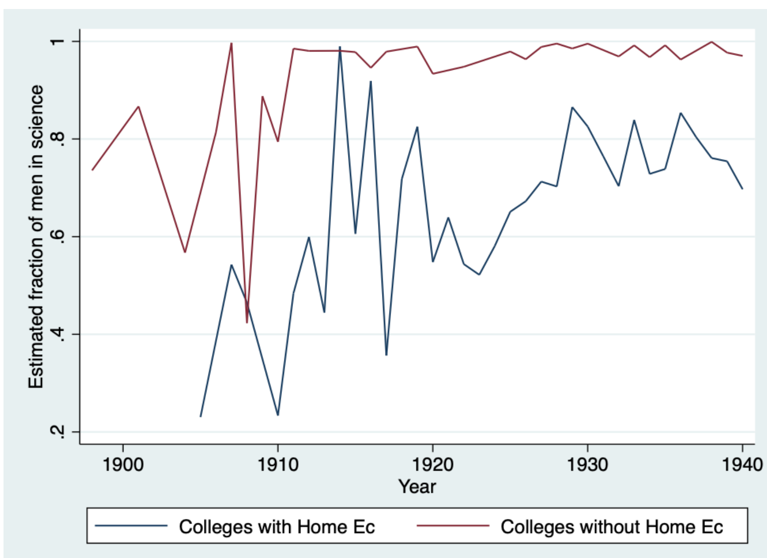


Figure 4 – Share of women in science



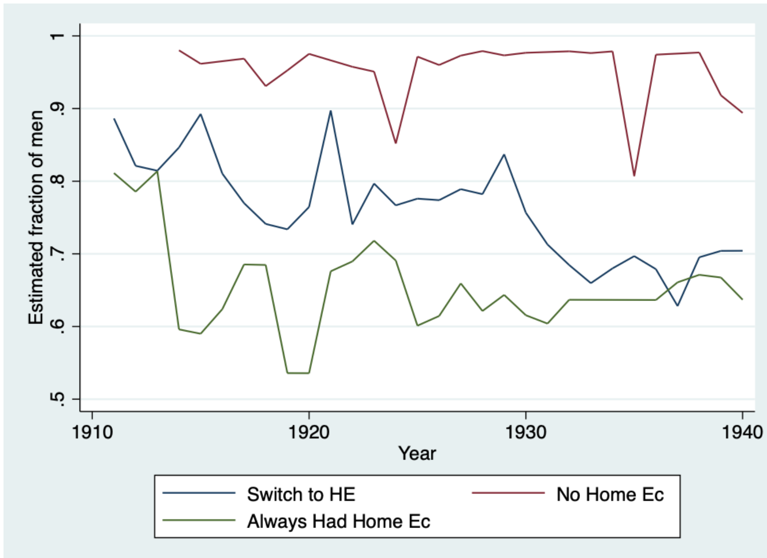
Notes: Unconditional mean share of women in science majors (women in science majors/total women) for colleges with Home Ec and colleges without Home Ec in each year. A student is counted as women if the first name has a probability of male less than 50% Data source:the student yearbooks sample.

Figure 5 – Gender ratio in science



Notes: Unconditional mean fraction of women in science majors (men in science majors/ total science majors) for colleges with Home Ec and colleges without Home Ec in each year. Data source:the student yearbooks sample.

Figure 6 – Gender ratio in science



Notes: Unconditional mean fraction of women in science majors (men in science majors/ total science majors) for colleges that always had Home Ec, colleges that never had Home Ec, and colleges that switched to offering Home Ec. Data source:the student yearbooks sample.

Figure 7 – Value of farm equipment and agriculture program size, 1910

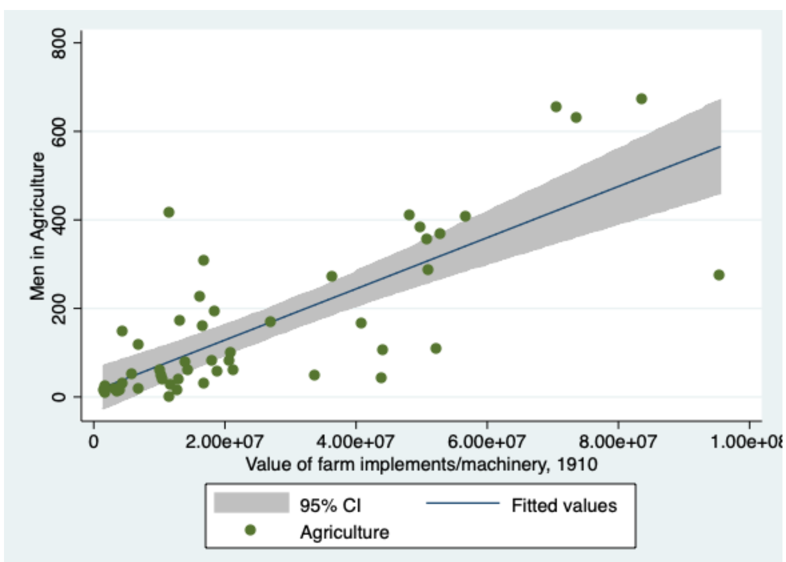


Figure 8 – Home Ec and agriculture program sizes, 1910

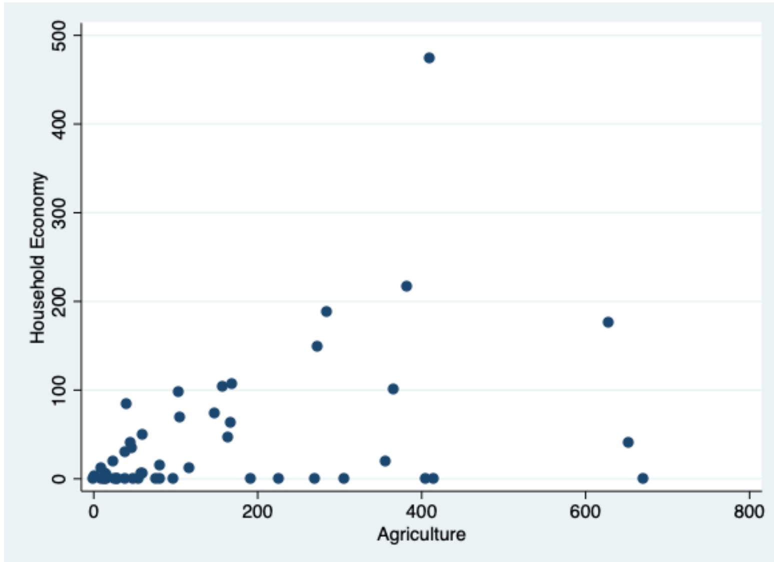


Figure 9 – Cornell University Hotel Management first year courses

THE HOTEL ADMINISTRATION CURRICULUM†

(Grouped according to years)

THE FRESHMAN YEAR

SPECIFICALLY REQUIRED

Course	Credit in hours
Orientation (Including *Elementary Hotel Organization*)	1
Accounting (*Hotel Accounting 81 and 82*)	6
Elementary Composition and Literature (*English 1*)	6
Introductory Inorganic Chemistry (*Chemistry 101 and 105*)	6
Elementary Chemistry of Food Products (*Chemistry 830*)	2
Food Preparation (*Food Preparation 15*)	3
Food Preparation (*Food Preparation 17*)	3
Mechanical Drawing (*Drawing 2*)	3
Hygiene	2
	32

ADVISED ELECTIVES

*General Hotel Lectures (*Hotel Administration 155*)	1
*Hotel Textiles (*Textiles 51*)	2
General Biology (*Biology 1*)	6
Introductory Experimental Physics (*Physics 3 and 4*)	6
French according to preparation	

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Appendix

Table 10 – Spill over to science: full sample

Women in Science	Full Sample	Full Sample	Full Sample	Land grant Sample
Women in HomeEc	0.0444**			0.0928***
	(0.0211)			(0.0220)
Women in Classics		-0.0019		-0.0090
		(0.0068)		(0.0130)
Women in Education			-0.0020	-0.0181
			(0.0098)	(0.0260)
Land grant status	Y	Y	Y	N
public funds	Y	Y	Y	Y
private funds	Y	Y	Y	Y
Size	Y	Y	Y	Y
Men in Science	Y	Y	Y	Y
Female College	Y	Y	Y	Y
State fixed effects	Y	Y	Y	N
Observations	578	578	578	42
R^2	.1	.1	.1	.42

Notes: The table reports OLS estimates. An observation is a college in 1910. The dependent variable is the number of degrees in general science conferred to women. Women in home ec/classics is the number of degrees in general science conferred to women in home economics/classics. Number of majors is the total number of majors offered at the college. Scientific apparatus measures the value of scientific apparatus and teaching expenses on sciences measures the disbursement of funds on the teaching of natural sciences. Men in science equals to the number of degrees in general science conferred to men. Total faculty/books/endowment are measured in logarithm. Funds from public sources equals the amount of funds from state, federal government in logarithm. Funds from private sourses is measured in logarithm. *** Significant at the 1% level; ** Significant at the 5% level; * Significant at the 10% level.

Table 11 – Cp, R-squared and Actions along the sequence of Lasso Algorithm

Step	Cp	R^2	Action
1	74.8429	0	
2	41.6181	0.2891	+value of farm implements/machinery
3	11.7252	0.5509	+state population
4	2.4243 *	0.6436	+total enrollment at landgrant
5	3.3911	0.6521	+improved acres
6	4.7873	0.657	+agriculture population
7	5.3482	0.6689	-agriculture population +no. farms
8	5.5579	0.6835	
9	7.0676	0.6876	+value of livstock
10	9.0135	0.688	+value of farmland
11	11	0.6881	+agriculture population

Notes: This table reports the lasso solution in a linear regression where the dependent variable is total enrollment in agriculture. The computation algorithm follows a modified least angle regression (Efron et al., 2004), and the Stata code is implemented by Mander (2006). An observation is a land-grant university in 1910. The lasso algorithm selects among land-grant enrollment and the following agricultural variables in the corresponding state: value of farm implements/machinery, state population, improved acres, population in agriculture, number of farms, value of livestock, and value of farmland. * indicates the smallest value for Cp statistic.