

Gender-biased technological change: Milking machines and the exodus of women from farming

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Appendix Material – For On-line Publication

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A.1 Appendix for short-term estimates

Table A.1 reports estimates for the short-term effect of the roll-out of milking machines in 1960 using household-level data from the 1960 Census. Estimates are based on:

$$Y_{i,j,b} = \beta_b + \gamma M_{j,1960} + \sum_t \mathbf{1}[b = t] \times \mathbf{X}'_{j,b} \theta_t + \epsilon_{ijb} \quad (\text{A.1})$$

where i indexes households, j municipalities, and b the birth cohort of the woman aged 16-25 in 1960. The outcome variable Y is the share of individuals employed in each household on an indicator of student activity in the household (1 = yes; 0 otherwise). The variable $M_{j,1960}$ is the number of milking machines per farm in 1960 in municipality j . The estimation sample is a cross-section of households in rural municipalities with at least one farm in 1929 and at least one woman aged 16–25 in 1960.

Table A.1: Short-run effects of the diffusion of milking machines on households, using 1960 Census data

	(1)	(2)	(3)	(4)
	Household members in employment (share)	Household members in employment (share)	Student activity in household (0/1)	Student activity in household (0/1)
Milking machines per farm	-0.026* (0.015)	-0.030* (0.017)	0.078* (0.040)	0.132*** (0.040)
Observations	73,064	73,064	76,850	76,850
Birth year FE	Y	Y	Y	Y
Flexible trends Lasso)	.	Y	.	Y
County-by-byear FE	.	Y	.	Y
Mean dep. variable	0.466	0.466	0.155	0.155

NOTE.— This table shows the short-run effect of the roll-out of milking machines in 1960 on two household-level outcomes measured in the 1960 Census: the share of individuals employed in the household (Cols. 1-2), and an indicator of student activity in the household (1 = yes; 0 otherwise) (Cols. 3-4). The sample is a cross-section of households in rural municipalities with at least one farm in 1929, with at least one women aged 16–25 in 1960. Estimates are based on equation (A.1). The vector of flexible trends $\mathbf{X}$ is defined as in Table 2. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Figure A.1 shows estimates for the short-term effects of milking machines on income under alternative specifications of equation (11). In Panel (a), we follow the recommendations of Chen and Roth (2024) to obtain an approximate percentage interpretation when the outcome variable takes zero values. In detail, Chen and Roth (2024) show that the log- or arcsinh-transformations, $\log(1 + y)$ or $\text{arcsinh}(y)$, are not unit-invariant when outcome y is zero-valued, and hence, should not be interpreted as percentage effects. Instead, to obtain an approximate percentage, they recommend using Poisson quasi-maximum likelihood (QMLE) regressions, which in our setting take the form:

$$Y_{i,j,t} = \exp \left(\sum_{s \in (wom, men)} \mathbf{1}[g_i = s] \times \{ \alpha_0^s + \alpha_j^s + \alpha_t^s + \sum_{k \neq 12} \gamma_k^s \mathbf{1}[t - 1970 = k] \times M_{j,1970} \} \right) u_{i,j,t}, \quad (\text{A.2})$$

where $Y_{i,j,t}$ is the (untransformed) income in year $t \in \{1970, \dots, 1995\}$ of individual i who was born in rural municipality j and who turned 16 in 1970. α_j and α_t are fixed effects for municipalities and years. The main variable of interest is the interaction between $M_{j,1970}$, the number of milking machines per farm in municipality j in 1970, and $\mathbf{1}[t - 1970 = k]$, a set of dummy variables for the number of years since 1970—when the relevant uptake of milking machines took place for this sample. The γ_t coefficients capture the differential evolution of incomes in municipalities where milking machines were adopted at different rates, relative to the differences 12 years after the 1970s rollout.¹ The implied estimate of the proportional treatment effects is $\exp(\hat{\gamma}_t) - 1$, which has an approximate percentage interpretation (Chen and Roth, 2024). As in Section IV.A, we capture gender effects by pooling together women and men and interacting all right-hand-side variables with gender dummies $g_i \in (wom, men)$.

In Panel (b), we show log effects with calibrated extensive-margin values. Chen and Roth (2024) suggest this exercise as an alternative to the average proportional treatment effects explained above. The main advantage is that log effects with calibrated extensive-margin values are not influenced by observations in the tail of the income distribution. To estimate them, we first normalize the dependent variable so that 1 corresponds to the value of the minimum nonzero income in the data. That is, we divide $Y_{i,j,t}$ by $Y_{min} = \min(Y_{i,j,t} | Y_{i,j,t} > 0) = 100 \text{ NOK}$.

We then estimate a modified version of Equation (A.2) by OLS:

¹In detail, we choose 1982 as the omitted category to capture short-term effects relative to income differences in the medium term. In addition, estimating a cell means model without omitted category and no constant yields a zero-effect for γ_{1982}^{wom} and for $\gamma_{1982}^{wom} - \gamma_{1982}^{men}$.

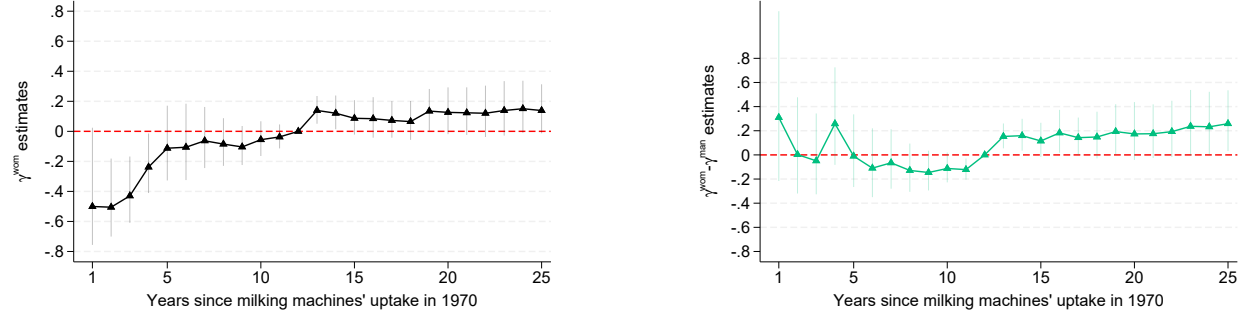
$$m(Y_{i,j,t}) = \sum_{s \in (wom, men)} \mathbf{1}[g_i = s] \times \{\alpha_0^s + \alpha_j^s + \alpha_t^s + \sum_{k \neq 1995} \gamma_k^s \mathbf{1}[t - 1970 = k] \times M_{j,1970}\} + u_{i,j,t} , \quad (\text{A.3})$$

In Panels (c) and (d), we show log effects on the intensive margin and effects on the extensive margin, respectively. Specifically, in Panel (b) we estimate Equation (A.3) using $\log(Y_{i,j,t})$ as the dependent variable, and restricting the sample to observations with positive incomes, $Y_{i,j,t} > 0$. In Panel (c), we estimate Equation (A.3) using an indicator variable equal to one if $Y_{i,j,t} = 0$ and zero otherwise as the dependent variable. To capture the potential effects of displacement from milkmaid employment, we restrict the sample to women (and men) employed at age 16; i.e., with $Y_{i,j,1} > 0$.

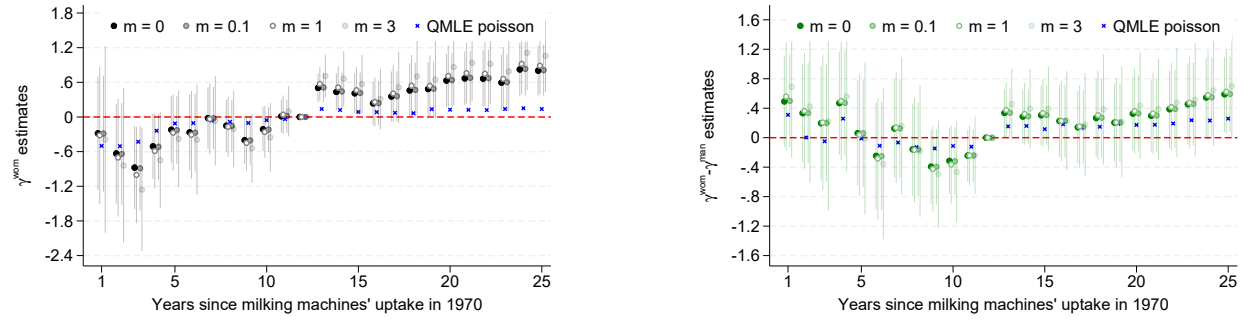
As in the main text, Appendix Figure A.1 shows estimates for the short-term effects on women (black) alongside estimates for the differential effect on women vs. men (green). These correspond to $\exp(\hat{\gamma}^{wom}) - 1$ (black) and for $\exp(\hat{\gamma}^{wom} - \hat{\gamma}^{men}) - 1$ in Panel (a) and to $\hat{\gamma}^{wom}$ and $\hat{\gamma}^{wom} - \hat{\gamma}^{men}$ in Panels (b) to (d).

Figure A.1: Robustness checks for contemporaneous effects

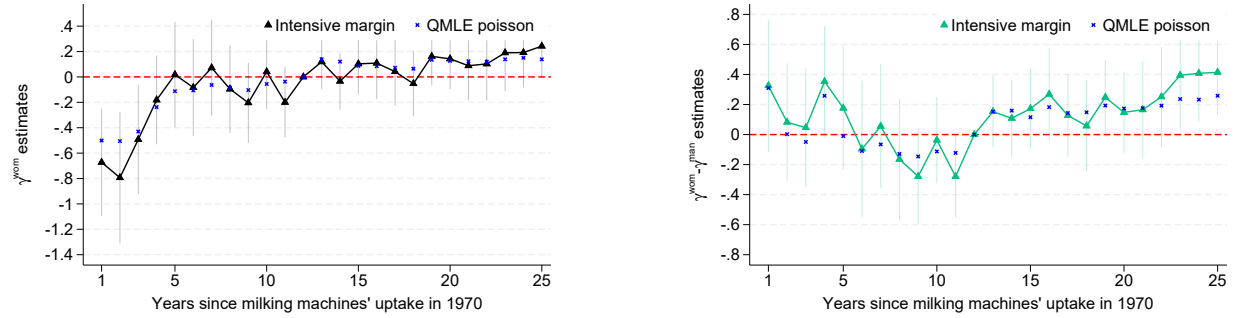
(a) QMLE estimates



(b) Calibrated extensive margin values



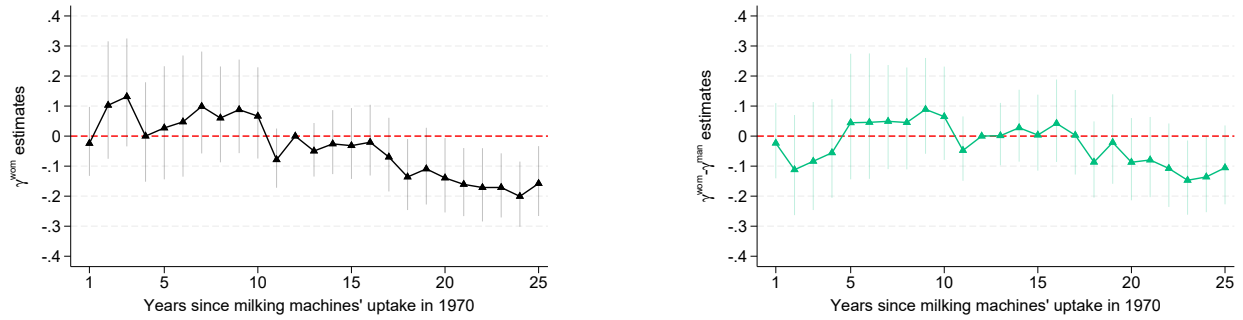
(c) Intensive margin effect



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Figure A.1: Robustness checks for contemporaneous effects (continued)

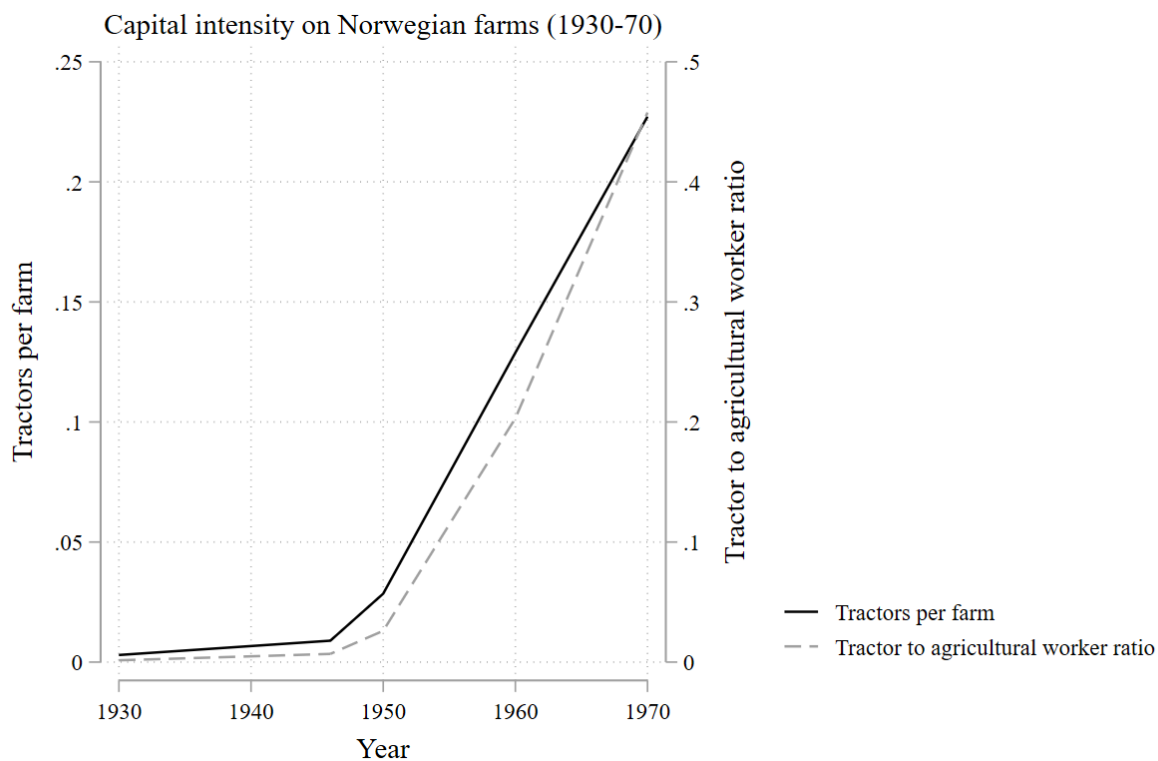
(d) Extensive margin effect (zero incomes)



NOTE.— This figure plots estimates for the short-term effects of milking machines from the specifications described in the text above. Black is for the effect on women, and green is for the differential effect on women vs. men. The sample is a panel of 18,014 women and men born in rural municipalities who turned 16 in 1970 and their incomes over 25 years, from 1970 to 1995 ($N=450,350$). In Panels (c) and (d), the sample is restricted to positive incomes and to individuals employed at age 16, respectively. Standard errors are clustered by municipality; 95% confidence intervals.

A.2 Appendix figures and tables

Figure A.2: Capital intensity in agriculture (1930–1970)



NOTE.— This figure shows the evolution of tractors per farm (left vertical axis) and the ratio of tractor to agricultural worker (right vertical axis) in Norway between 1930 and 1970. Source: Census of Agriculture (own calculations).

Figure A.3: Milk yields per cow (1927/28–1969)

Tabell 8. Mjølkekemengd pr. ku og egg pr. høne. Kilo. Heile landet *Milk yield per cow and eggs per hen. Kilos. The whole country*

Husdyrprodukt <i>Livestock product</i>	1927-28	1930	1935	1939-40	1949-50	1954-55	1959-60	1964	1969
Mjølk pr. ku <i>Milk per cow ..</i>	1 534 ¹⁾	1 620	1 698	1 761	2 092	2 314	2 681	3 139	4 027
Egg pr. høne <i>Eggs per hen ..</i>	6,3	..	..	..	7,3	8,1	9,0	9,2	9,9

1) 1925.

NOTE.— This figure shows the evolution of milk yields per cow from 1927–28 to 1969.
Source: Central Bureau of Statistics of Norway (1974, Table 8).

Figure A.4: Labor input on agricultural holdings (1928–29 to 1965–66)

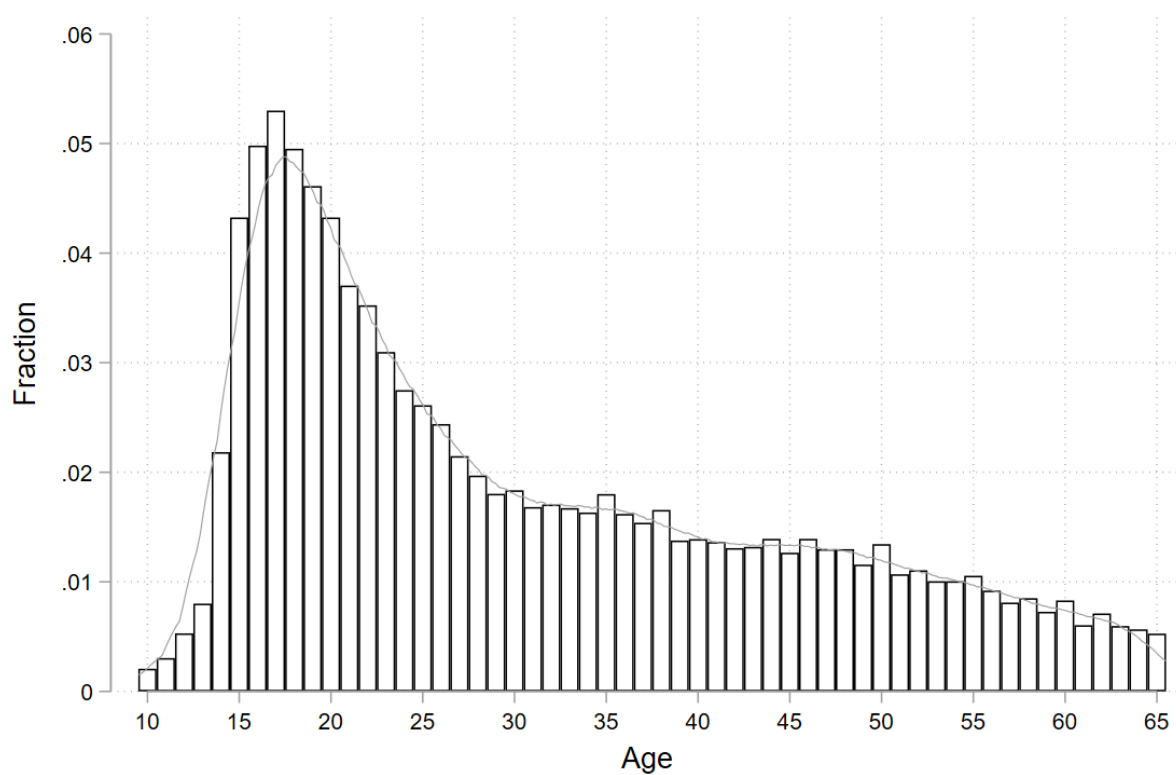
Tabell 78. Arbeidskraft på brukene. Årsverk.
Labour input on holdings. Man-years.

År Year	I alt Total		Brukere og ektemaker Holders and their spouses		Andre familiemedlemmer Other family members		Fremmed arbeidshjelp Hired workers	
	Menn Males	Kvinner Females	Menn Males	Kvinner Females	Menn Males	Kvinner Females	Menn Males	Kvinner Females
	Årsverk i alt ¹ Total man-years ¹							
1928—29	257 513	311 742	124 390	172 265	86 945	92 872	46 178	46 605
1938—39	276 266	313 037	131 151	174 301	91 134	92 745	53 981	45 991
1948—49	236 959	277 001	132 950	177 600	67 729	75 791	36 280	23 610
1951—52	213 200	258 800	131 600	179 100	55 000	62 900	26 600	16 800
1953—54	195 400	241 800	125 600	175 200	48 400	53 300	21 400	13 300
1955—56	191 100	232 300	123 400	170 800	47 900	49 400	19 800	12 100
1958—59	178 621	205 850	117 295	159 437	38 694	36 612	22 632	9 801
1961—62	164 031	196 925	108 126	158 541	37 456	31 142	18 449	7 242
1965—66	141 787	169 764	99 383	142 516	28 718	22 304	13 686	4 944
	Av dette i jordbruket ² Of which in agriculture ²							
1958—59	159 522	69 808	106 420	45 254	36 291	18 765	16 811	5 789
1961—62	147 714	66 224	98 599	45 804	35 285	16 118	13 830	4 302

Noter ¹ Medregnet arbeid i egen skog og husarbeid. ² Ikke medregnet skogs- og husarbeid.
Notes ¹ Including forestry and household work. ² Excluding forestry and household work.

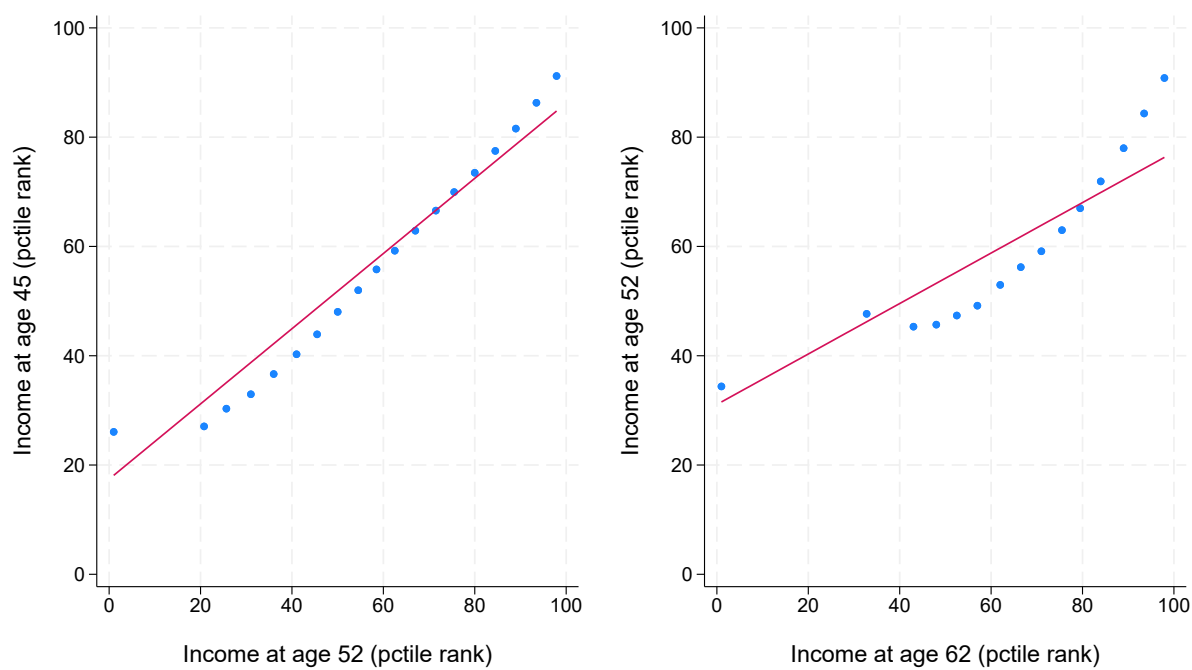
NOTE.— This figure shows the labor input on farms by gender and by type of worker (holders and spouses, other family members, and hired workers) for the years 1928-29 to 1965-66. Source: Central Bureau of Statistics of Norway (1968, Table 78).

Figure A.5: Distribution of milkmaids by age in 1910



NOTE.— This figure shows the distribution of milkmaids (livestock and dairy farm workers identified by variable ISCO68A code 624 and 625 in IPUMS-I ([Minnesota Population Center, 2020](#))) in 1910 by age. Source: Census of Norway in 1910.

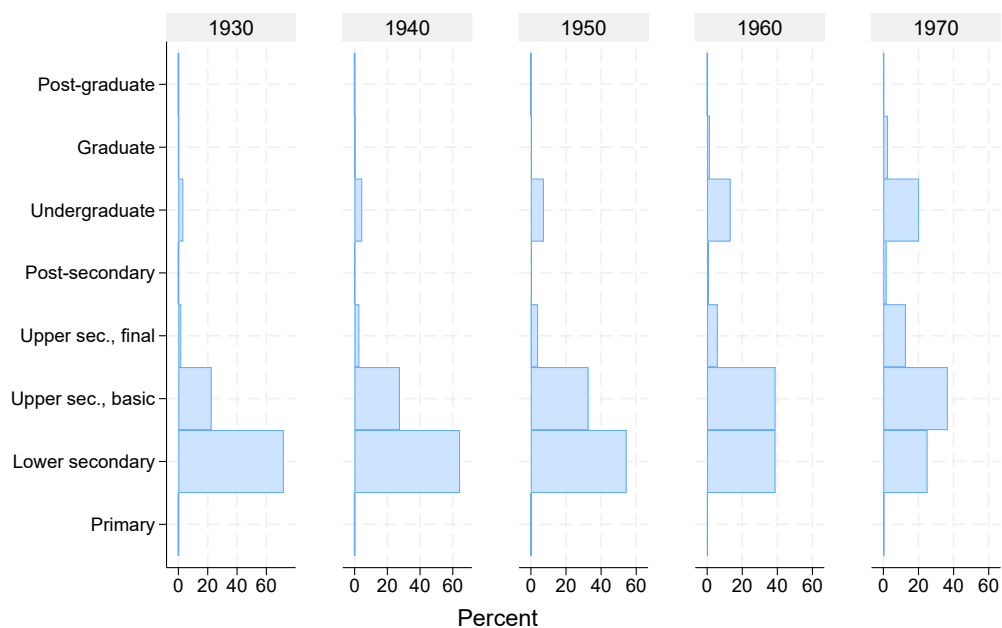
Figure A.6: Comparison of income ranks based on income at ages 45, 52, and 62



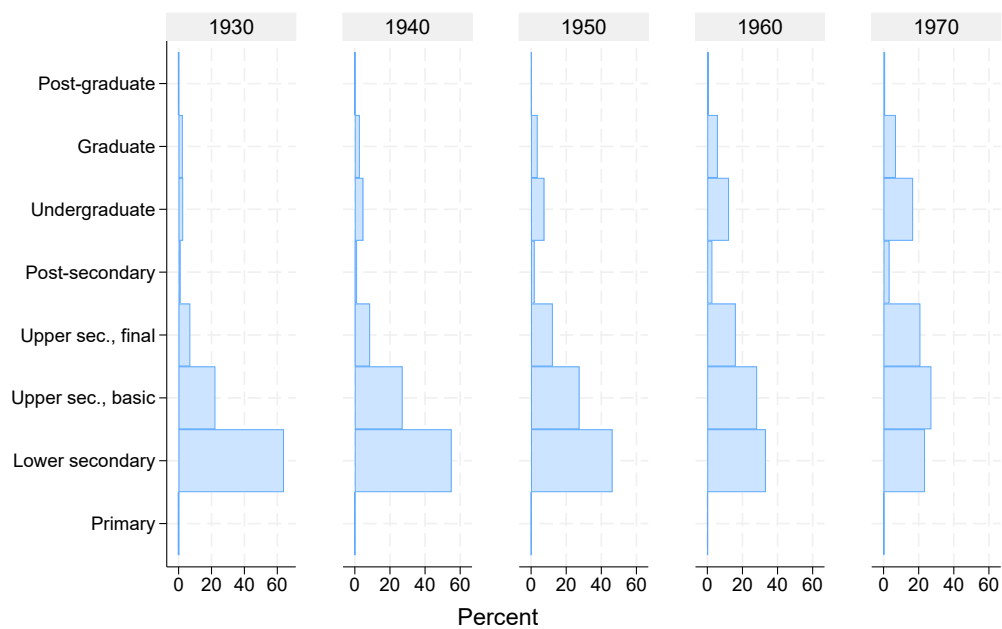
Note: Income ranks calculated over birth-year cohorts for all women in our baseline sample with income data at ages 45, 52, and 62.

Figure A.7: Education distribution over time (1930–1970)

(a) Women



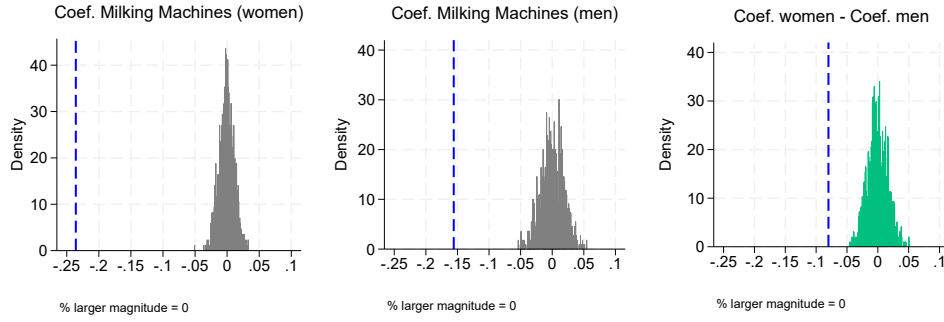
(b) Men



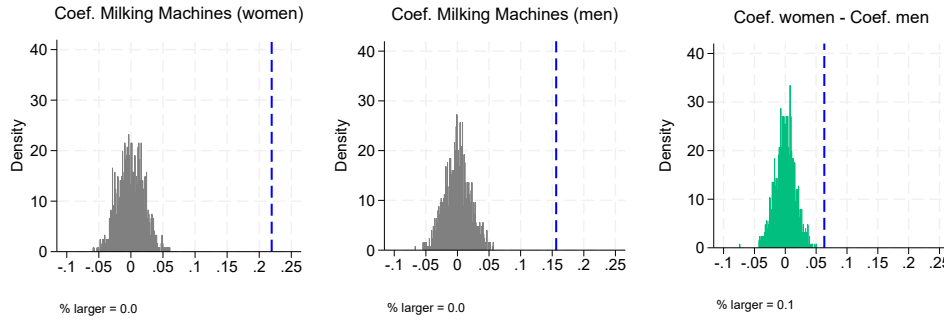
NOTE.— This figure plots the education distribution of rural women and men aged 16–25 in 1930, 1940, 1950, 1960, and 1970.

Figure A.8: Permutation tests

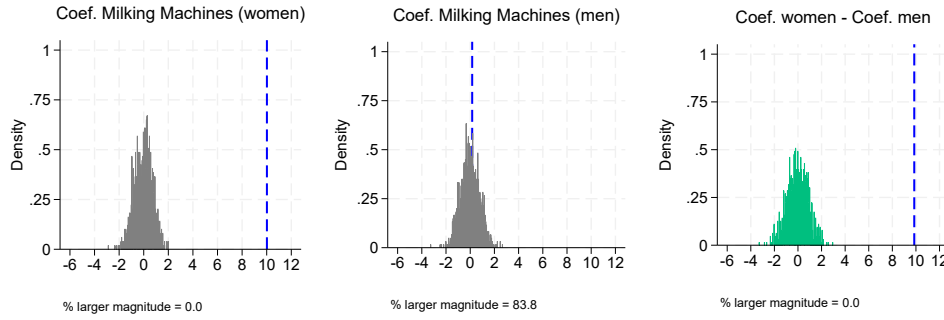
(a) Dep. Var.: Employment in agriculture



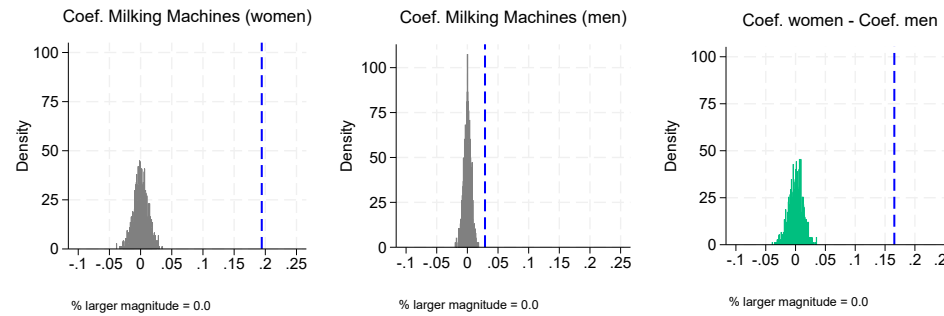
(b) Dep. Var.: Migration



(c) Dep. Var.: Income pctl rank



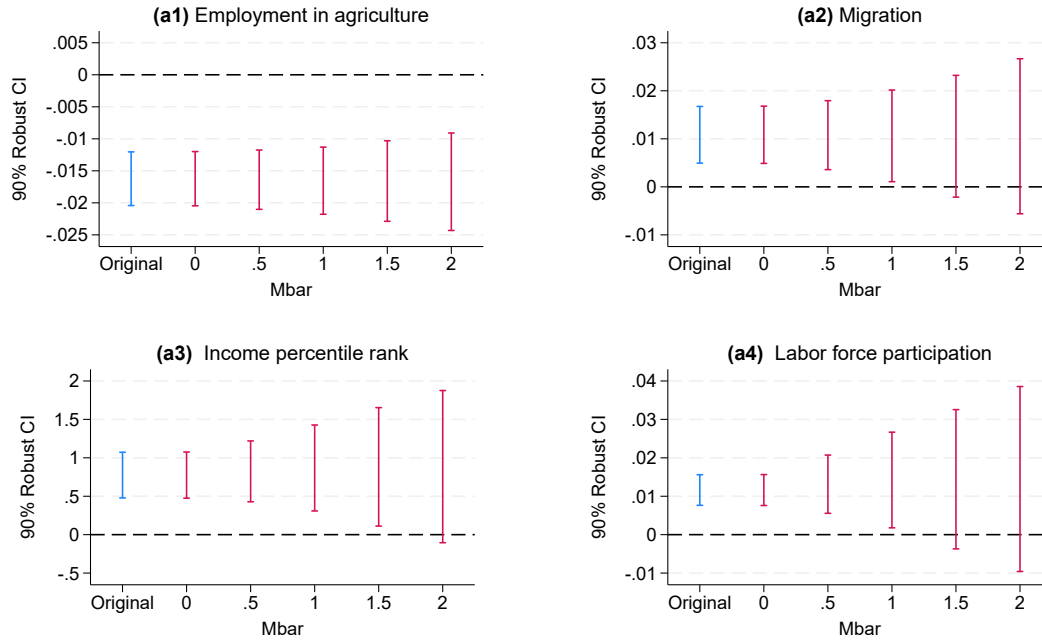
(d) Dep. Var.: Labor force participation



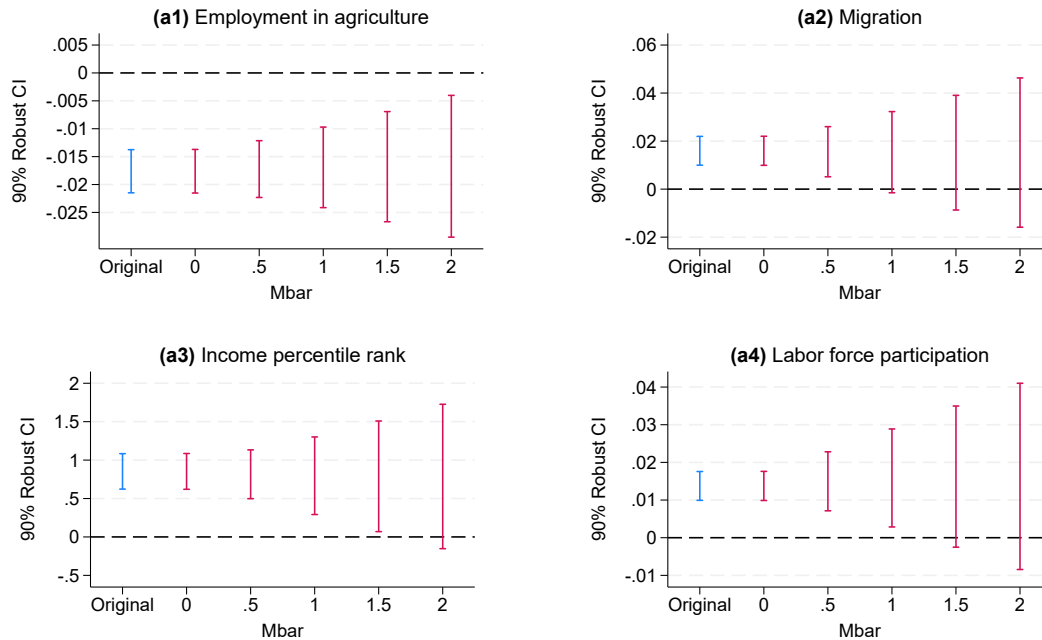
NOTE.— This figure plots 1,000 coefficients from the reduced-form version of equation (3), where we reshuffle the number of milkcows per farm. The left column displays the results for women, the middle column for men, and the last column refers to women-men differences. Dependent variables, samples, and flexible trends are defined as in Tables 2 and 3. Vertical dashed lines indicate baseline (non-permuted) coefficients.

Figure A.9: Rambachan and Roth’s “Honest DiD” sensitivity analysis

(a) Difference-in-difference specification



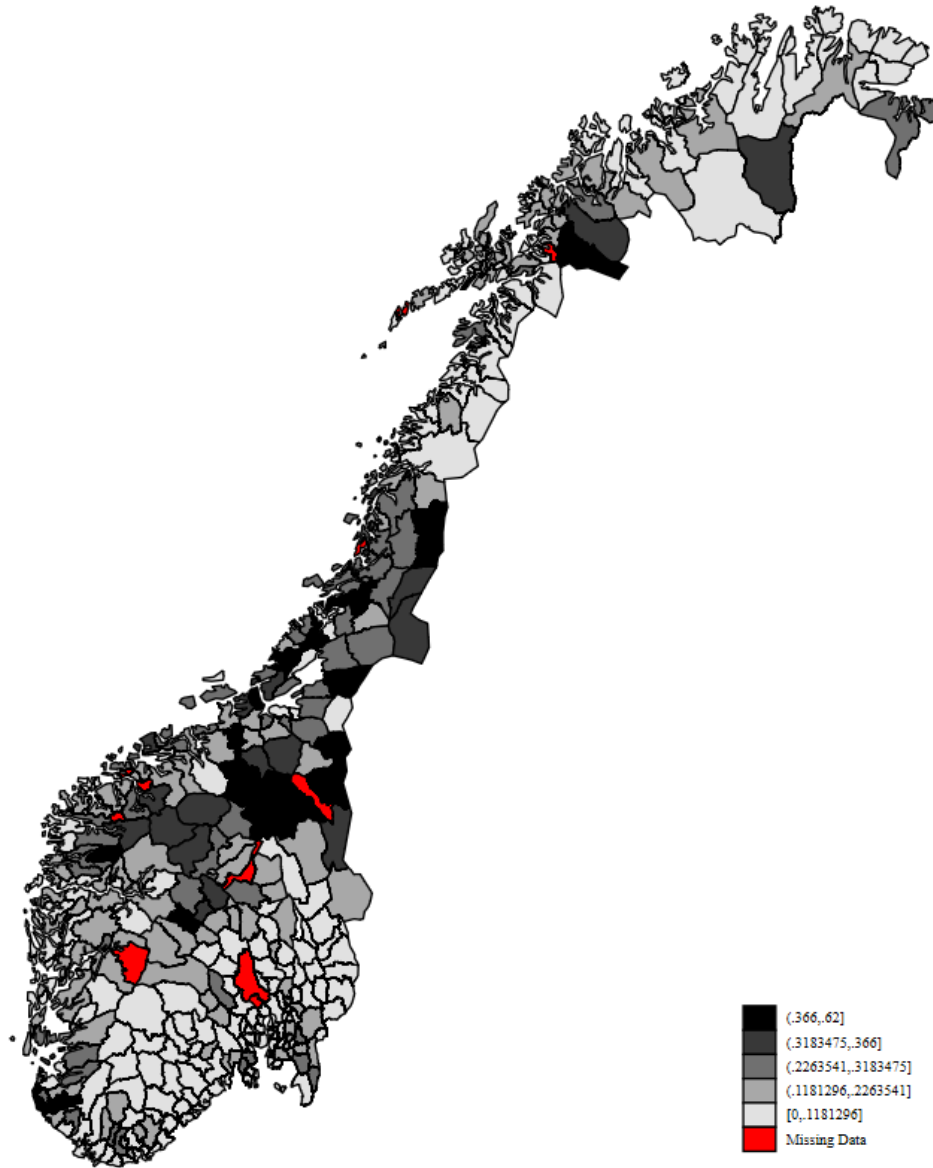
(b) Difference-in-difference specification with flexible trends and county-by-cohort FE



NOTE.— This figure performs the “Honest DiD” sensitivity analysis by [Rambachan and Roth \(2023\)](#). It plots estimates and 90% robust confidence sets for the treatment effect of milking machines for cohorts age 16–25 in 1950–70, assuming that the violation of parallel trends is equal to some constant $\hat{M}$ times the maximum violation of parallel trends in the pre-treatment period, i.e., for cohorts age 16–25 in 1930–1940.

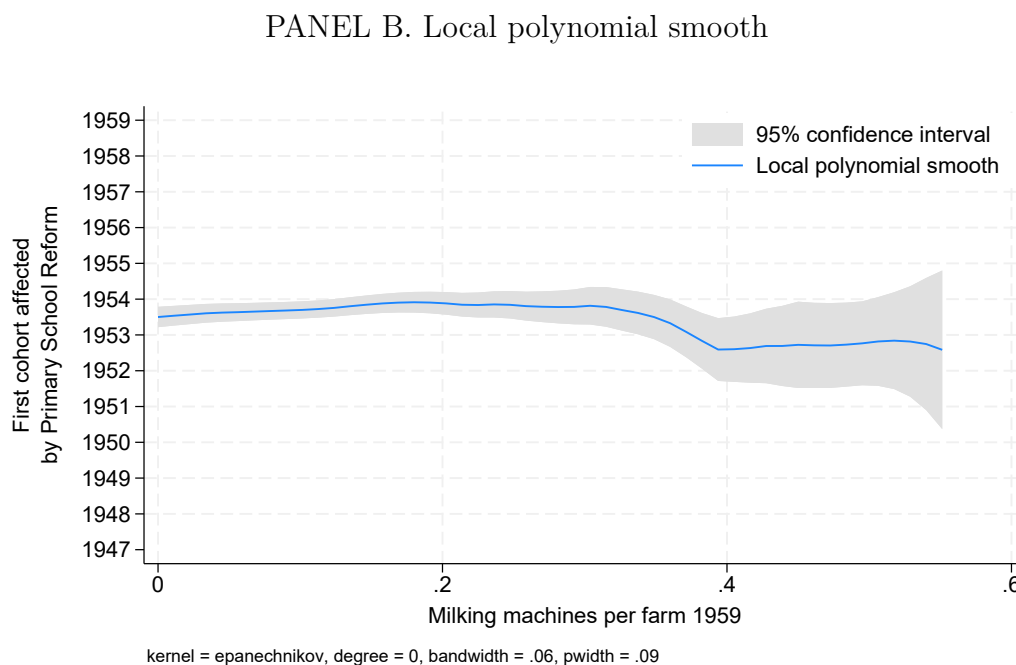
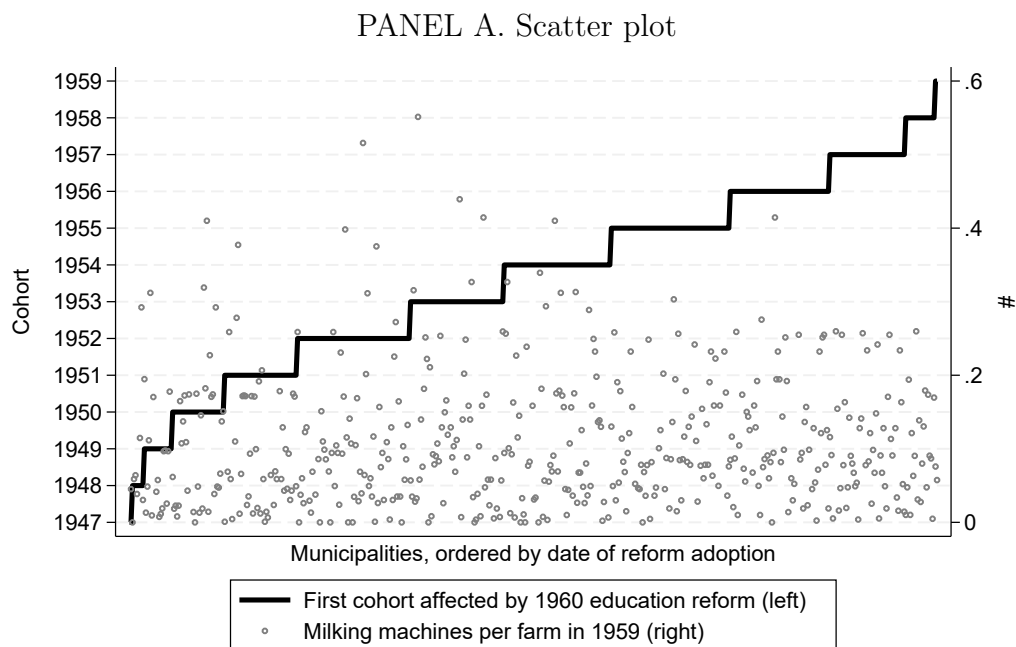
Figure A.10

Milking machines per farm in 1969



NOTE.— This figure shows the distribution of milking machines per farm in 1969 across Norwegian municipalities. A darker color refers to higher values of milking machines per farm. Red polygons denote missing observations. Source: Census of Agriculture (own calculations).

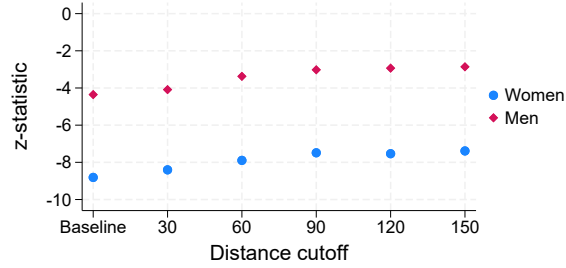
Figure A.11: The roll-out of the Primary School Reform and the diffusion of milking machines across municipalities



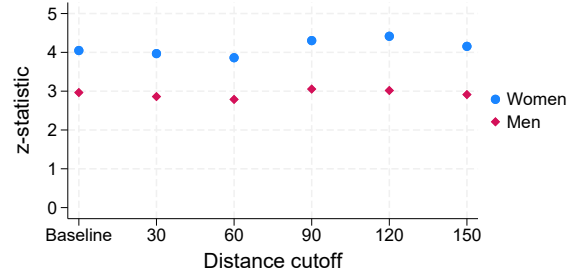
NOTE.— The sample consists of 497 municipalities based on their 1960 borders, with at least one farm in 1929. Data on the first cohort affected by the Primary School Reform in each municipality is from [Black et al. \(2005\)](#).

Figure A.12: Conley Standard Errors with different distance cutoffs

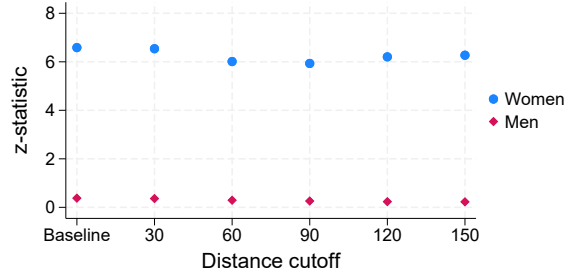
(a) Employment in agriculture (Table 2, col. 2)



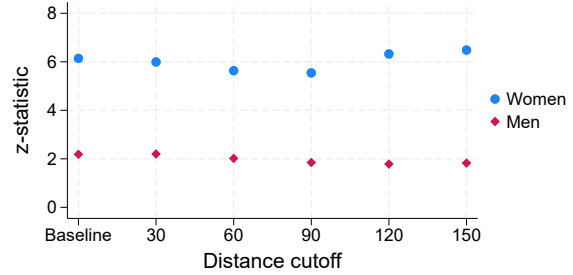
(b) Migration to city (Table 3, col. 1)



(c) Income percentile rank (Table 3, col. 2)

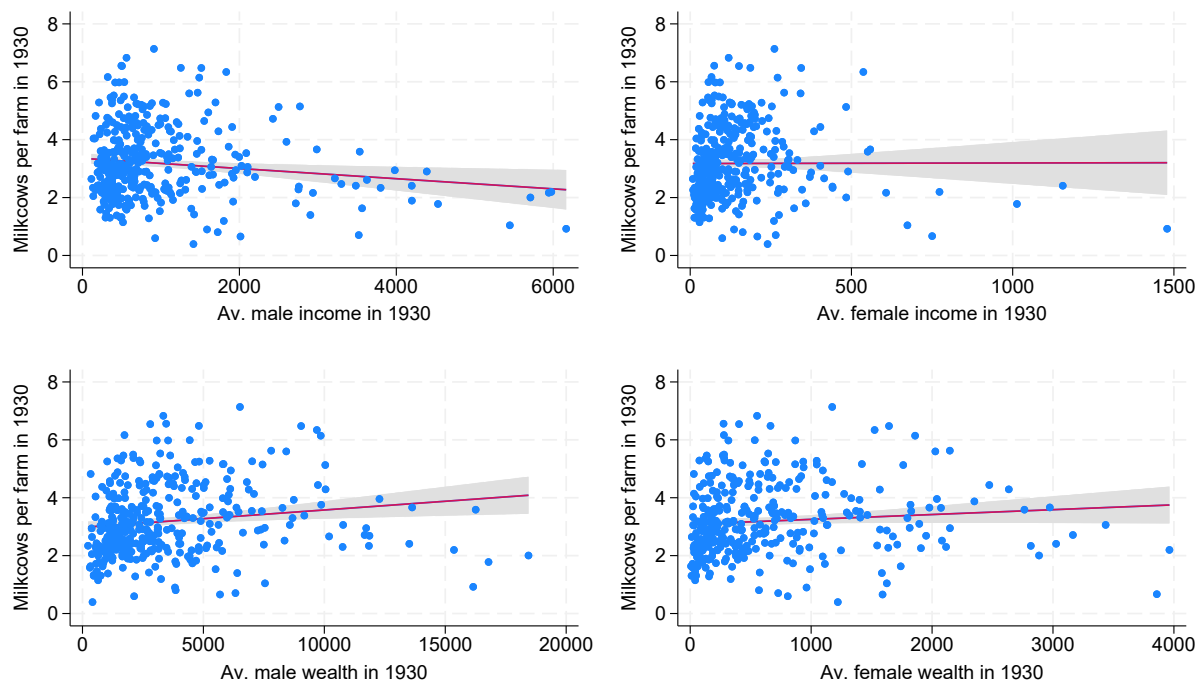


(d) Labor force participation (Table 3, col. 3)



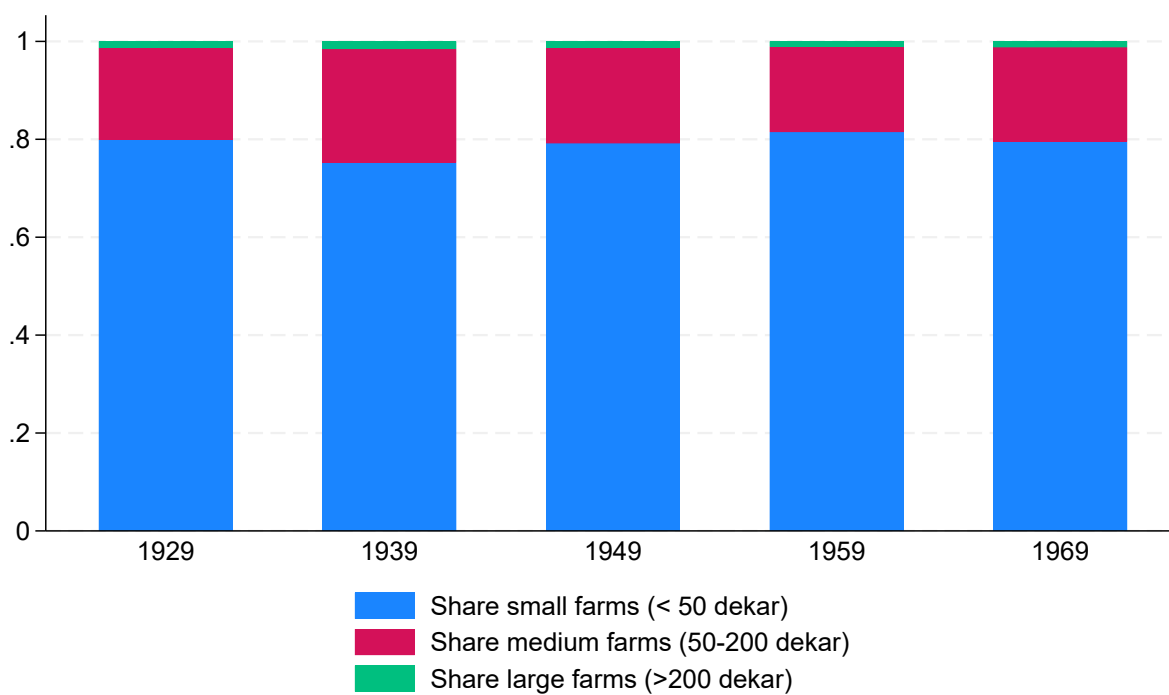
NOTE.— This figure shows spatially-adjusted z-statistics for the effect of milking machines per farm on the main long-term outcomes for women and men. Z-statistics are based on our baseline IV specifications with the full set of FE and controls, using the full sample (see Tables 2 and 3 for further details). The distance cutoff is the point at which the spatial error correlation is assumed to be 0. Spatially-adjusted z-statistics calculated using [acreg Colella et al. \(2019\)](#). Baseline z-statistics allow for spatial correlation within municipalities; i.e., are based on standard errors clustered by municipality.

Figure A.13: Milk cows per farm, income, and wealth by 1930



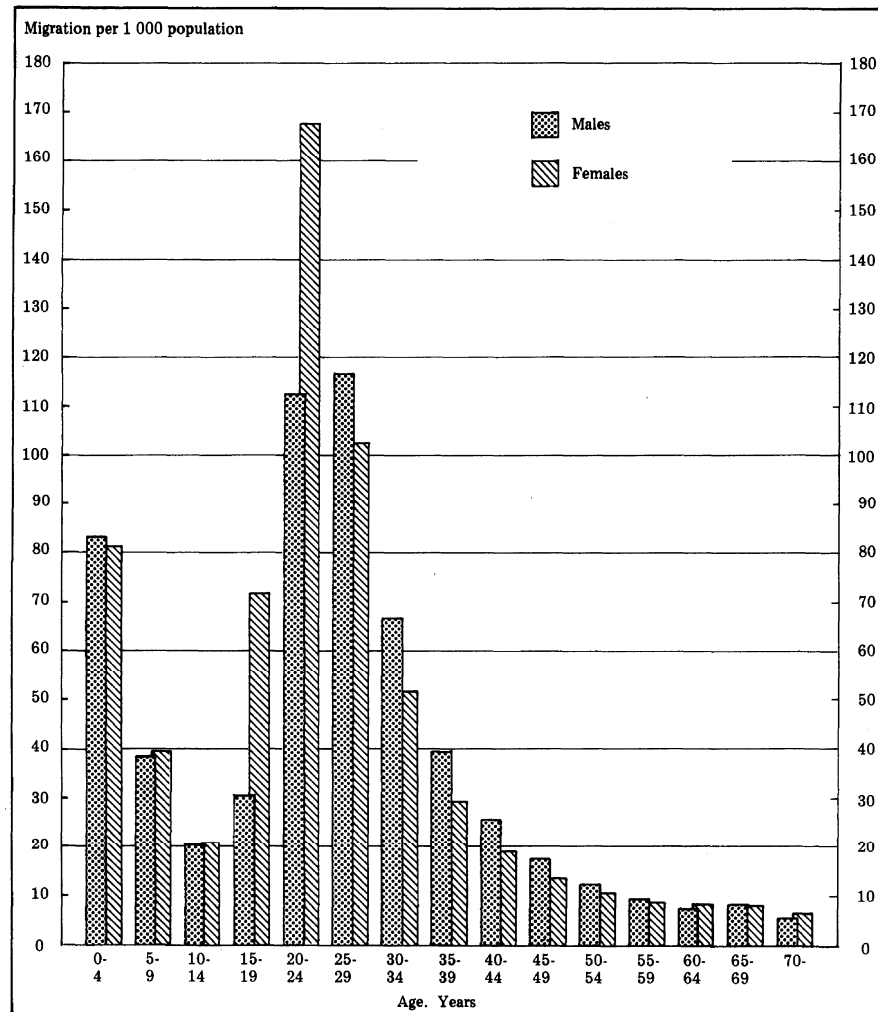
Note: Income and wealth data based on F.O.B. 1930 data digitized from Statistics Norway archives. The figure excludes outlier municipalities with male and female incomes above, respectively, 10,000 and 2,000 NOK, and with male and female wealth above, respectively, 20,000 and 5,000.

Figure A.14: Farm size distribution over time (1929–1969)



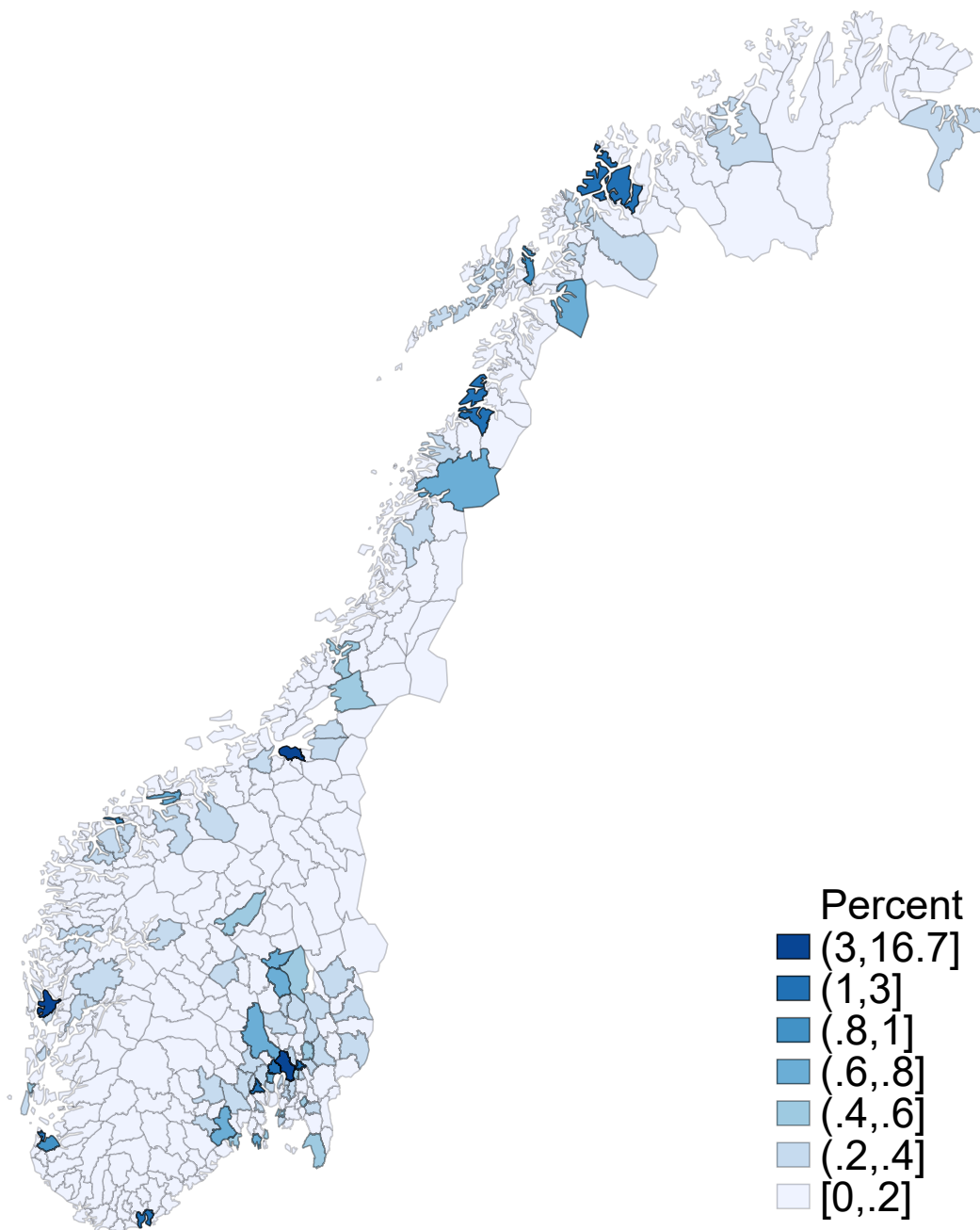
Note: This figure plots the distribution of farms by size (below 50 dekar, 50-200 dekar, and above 200 dekar).
Source: Census of Agriculture (own calculations).

Figure A.15: Mobility for males and females in different groups, per 1,000 (1976–1980)



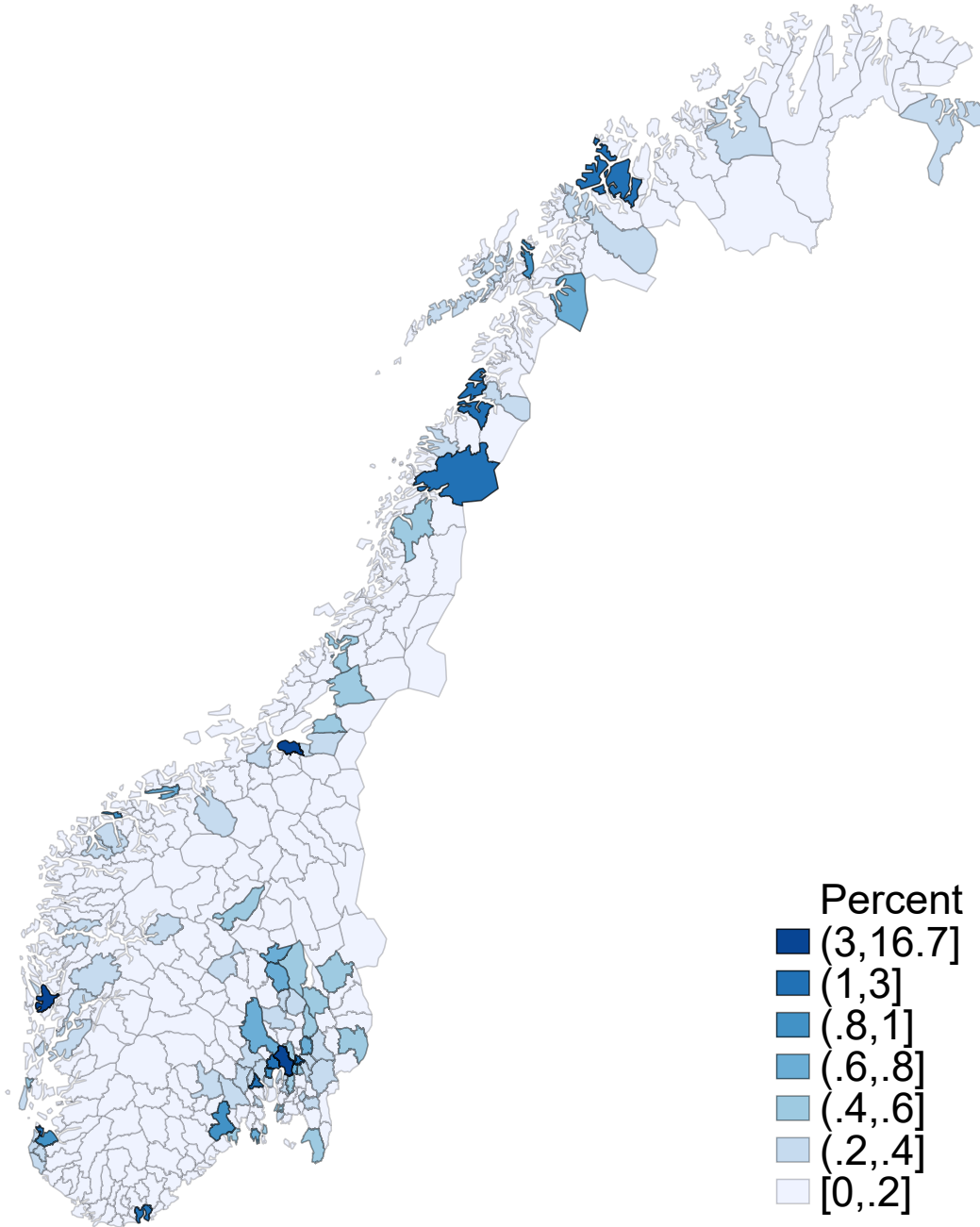
Source: Lian (1981), p. 33. Mobility is the number of internal migrations as per 1 000 of the mean population within each age group.

Figure A.16: Percent of rural female migrants, by destination (1960 census)



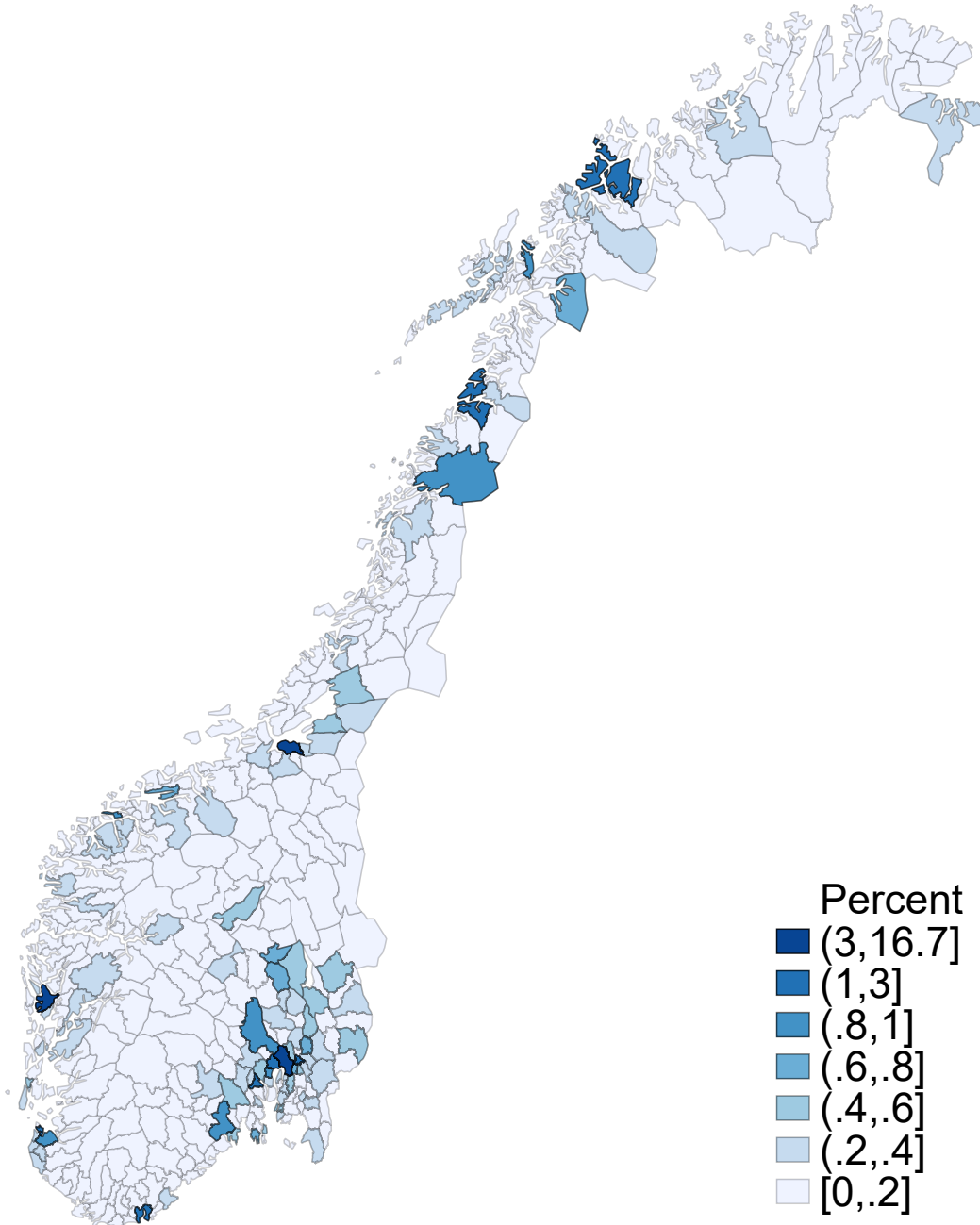
NOTE.— This figure reports the share of female migrants by municipality of destination. The sample comprises women in our baseline sample who migrated out of their (rural) birthplace in 1960. Municipality borders fixed at 1980 borders.

Figure A.17: Percent of rural female migrants, by destination (1970 census)



NOTE.— This figure reports the share of female migrants by municipality of destination. The sample comprises women in our baseline sample who migrated out of their (rural) birthplace in 1970. Municipality borders fixed at 1980 borders.

Figure A.18: Percent of rural female migrants, by destination (1980 census)



NOTE.— This figure reports the share of female migrants by municipality of destination. The sample comprises women in our baseline sample who migrated out of their (rural) birthplace in 1980. Municipality borders fixed at 1980 borders.

Table A.2: Summary statistics for individuals in baseline sample

	Mean	Standard deviation	Observations
Technology diffusion in municipality of birth:			
Milking machines per farm	0.071	0.104	726,537
Milking machines per farm (cohort 16-25 in 1930)	0.000	0.000	72,581
Milking machines per farm (cohort 16-25 in 1940)	0.003	0.008	141,897
Milking machines per farm (cohort 16-25 in 1950)	0.018	0.035	151,571
Milking machines per farm (cohort 16-25 in 1960)	0.110	0.097	161,552
Milking machines per farm (cohort 16-25 in 1970)	0.153	0.125	198,936
Milk cows per farm in 1930	3.089	1.242	726,537
Share women in farming (milkmaids) 1930	0.064	0.036	726,537
Outcomes for women in baseline sample:			
Employment in agriculture (after age 25)	0.091	0.288	379,366
Migration anywhere (ever)	0.689	0.463	379,366
Migration to city (ever)	0.257	0.437	379,366
Migration to town with higher-education institution (ever)	0.327	0.469	359,943
Migration outside county of birth (ever)	0.398	0.490	379,366
Migration inside county of birth (ever)	0.291	0.454	379,366
Distance to migration destination in km migrating (1960)	79.45	202.50	370,126
Distance to migration destination in km migrating (1970)	117.13	248.88	375,843
Distance to migration destination in km migrating (1980)	126.62	259.05	376,984
Income at age 45 [†] in NOK	65,016	82,474	342,792
Labor force participation (age 45)	0.781	0.413	271,450
Undergraduate education or more	0.099	0.298	379,366
Outcomes for men in baseline sample:			
Employment in agriculture (after age 25)	0.176	0.381	347,171
Migration anywhere (ever)	0.580	0.494	347,171
Migration to city (ever)	0.227	0.419	347,171
Migration to town with higher-education institution (ever)	0.281	0.449	333,345
Migration outside county of birth (ever)	0.351	0.477	347,171
Migration inside county of birth (ever)	0.229	0.420	347,171
Distance to migration destination in km migrating (1960)	60.93	179.985	338,703
Distance to migration destination in km migrating (1970)	98.89	235.67	343,600
Distance to migration destination in km migrating (1980)	110.72	249.36	344,571
Income at age 45 [†] in NOK	127,630	129,785	344,829
Labor force participation (age 45)	0.955	0.208	277,608
Undergraduate education or more	0.097	0.296	347,171
Outcomes for women in non-agriculture occupation:			
High-skill occupation	0.125	0.330	344,658
Mid-skill occupation	0.183	0.387	344,658
Low-skill occupation	0.343	0.475	344,658
Outcomes for men in non-agriculture occupation:			
High-skill occupation	0.272	0.445	286,086
Mid-skill occupation	0.562	0.496	286,086
Low-skill occupation	0.078	0.268	286,086
Municipality-level controls:			
Share improved farmland in 1929	0.704	0.241	726,537
Farms p.c. in 1930	0.132	0.037	726,537
Early-tractor adoption by 1930 (0/1)	0.456	0.498	726,537
Ratio large to small farms (in 1929)	0.119	0.239	726,537
Ratio large to small farms (contemporaneous)	0.065	0.253	723,766
Hydropower potential	0.432	0.780	698,324
Hydropower status in 1900-1910	0.071	0.258	701,787

NOTE.— This table shows summary statistics for our baseline sample: women and men born in rural municipalities with at least one farm in 1929, who were aged 16–25 in the census years 1930–70. [†]Income is measured at age 45 for cohorts aged 16–25 in 1950, 1960, and 1970 and at age 52 and 62 for the cohorts aged 16–25 in 1940 and 1930, respectively.

Table A.3: Determinants of milking machine diffusion (1929–69)

	(1)	(2)	(3)	(4)	(5)	(6)
	Dep. Var.: Milking machines per farm					
	OLS		LASSO		OLS	LASSO
Milk cows per farm in 1930	0.031***	(0.003)	X	0.031***	(0.003)	X
Share milkmaids in 1930	-0.346	(0.226)		-0.351	(0.231)	
Share females in agriculture in 1930	-0.015	(0.127)		-0.016	(0.130)	
Female labor force participation in 1930	0.132*	(0.070)		0.134*	(0.071)	
Female net-migration rate in 1930	-0.027	(0.020)		-0.027	(0.020)	
Population density in 1930	0.241***	(0.075)		0.241***	(0.077)	
Farms per capita in 1930	0.399***	(0.073)	X	0.401***	(0.075)	X
Share improved farmland in 1930	0.070***	(0.011)	X	0.070***	(0.012)	X
Tractor dummy in 1930	-0.008	(0.005)		-0.008	(0.006)	
Share females age 15-19 in 1930	-0.415**	(0.206)		-0.392*	(0.211)	
Share females age 20-39 in 1930	-0.177	(0.121)		-0.170	(0.123)	
Share females age 40-59 in 1930	-0.094	(0.131)		-0.092	(0.134)	
Share females 60+ in 1930	-0.158	(0.126)		-0.151	(0.128)	
Share manufacturing workers in 1930	-0.022	(0.019)		-0.022	(0.019)	
Capital-labor ratio in 1930	0.555	(1.060)		0.571	(1.082)	
Land area in 1930	0.000**	(0.000)		0.000*	(0.000)	
Ratio large to small farms in 1930	0.020**	(0.008)	X	0.020**	(0.009)	X
Avg. income males in 1930	-0.000	(0.000)		-0.000	(0.000)	
Avg. income females in 1930	0.000*	(0.000)		0.000*	(0.000)	
Avg. wealth males in 1930	-0.000	(0.000)		-0.000	(0.000)	
Avg. wealth females in 1930	-0.000	(0.000)		-0.000	(0.000)	
Crude birth rate in 1930	0.001	(0.000)		0.001	(0.000)	
Crude death rate in 1930	-0.001	(0.001)		-0.001	(0.001)	
Marriage rate in 1930	0.002**	(0.001)		0.002**	(0.001)	
Observations	1,449			1,449		
R-squared	0.6124			0.707		
County FE	Y			Y		
Cohort FE	Y			Y		
County $\times$ year FE	.			Y		

NOTE.— Column (1) regresses milking machines per farm on municipality characteristics in 1930 and fixed effects for census year and county. Column (2) shows the selected controls by the Lasso procedure. Columns (3) and (4) show the corresponding results including county-by-census year fixed effects. Controls marked by "X" are selected by the Lasso procedure. The share of milkmaids is negatively associated with milking machine diffusion, conditional on the number of milk cows per farm (see Panel C of Table A.8 for the unconditional positive association between share milkmaids and milking machines). Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.4: Main results conditional on reporting an occupation

	(1) Employed agriculture	(2) Migration	(3) Income pctile rank	(4) Labor force participation
Panel A. IV				
Milking machines per farm (women)	-0.053*** (0.007)	0.048*** (0.009)	2.338*** (0.342)	0.046*** (0.007)
Milking machines per farm (men)	-0.028*** (0.008)	0.029*** (0.009)	-0.132 (0.360)	0.004* (0.002)
p-value (women = men)	0.000	0.003	0.000	0.000
Panel B. Reduced form				
Cows per farm 1930 $\times$ National rollout (wom)	-0.048*** (0.005)	0.043*** (0.008)	2.124*** (0.302)	0.039*** (0.006)
Cows per farm 1930 $\times$ National rollout (men)	-0.025*** (0.007)	0.026*** (0.008)	-0.118 (0.326)	0.003** (0.001)
p-value (women = men)	0.000	0.002	0.000	0.000
Panel C. OLS				
Milking machines per farm (women)	-0.017*** (0.003)	0.013*** (0.004)	0.838*** (0.153)	0.015*** (0.003)
Milking machines per farm (men)	-0.010** (0.004)	0.007* (0.004)	-0.220 (0.150)	0.000 (0.001)
p-value (women = men)	0.068	0.077	0.000	0.000
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-year FE	Y	Y	Y	Y
Mean dep. variable	0.16	0.38	54.10	0.91
F-stat first stage (women)	105.4	105.4	104.6	85.8
F-stat first stage (men)	100.1	100.1	100.0	80.4
Observations	603,816	603,816	594,999	476,047

NOTE.— This table shows IV, reduced-form, and OLS estimates for the long-term effect of milking machines based on equations (3) and (3), conditional on a sample of women and men reporting an occupation. The sample includes all women and men who report an occupation in the censuses after age 25, who were born in rural municipalities with at least one farm in 1930, and who were aged 16–25 in the census years 1930–1970. Dependent variable and flexible trends are defined as in Table 2 and 3. Independent variables are normalized to have a mean of zero and an SD of one. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.5: Alternative definitions of labor force participation (LFP)

	Dep. Var.: = 1 if > income in tax registry		Dep. Var.: = 1 if occupation in Census (after age 25) and > income in tax registry	
	at age 45 (baseline) (1)	at age 45, 52, 62 (2)	at age 45 (3)	at age 45, 52, 62 (4)
Panel A. IV				
Milking machines per farm (women)	0.038*** (0.007)	0.029*** (0.005)	0.043*** (0.007)	0.032*** (0.006)
Milking machines per farm (men)	0.006** (0.002)	0.007*** (0.002)	0.006** (0.002)	0.006*** (0.002)
p-value (women = men)	0.000	0.000	0.000	0.000
Panel B. Reduced form				
Cows per farm 1930 × National rollout (wom)	0.032*** (0.005)	0.026*** (0.004)	0.036*** (0.006)	0.028*** (0.005)
Cows per farm 1930 × National rollout (men)	0.005*** (0.002)	0.006*** (0.001)	0.005** (0.002)	0.006*** (0.002)
p-value (women = men)	0.000	0.000	0.000	0.000
Panel C. OLS				
Milking machines per farm (women)	0.011*** (0.003)	0.010*** (0.002)	0.013*** (0.003)	0.011*** (0.003)
Milking machines per farm (men)	0.001 (0.001)	0.002** (0.001)	0.002* (0.001)	0.003** (0.001)
p-value (women = men)	0.000	0.000	0.001	0.003
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-byear FE	Y	Y	Y	Y
Mean dep. variable	0.87	0.89	0.79	0.81
F-stat first stage (women)	81.8	95.8	81.8	95.8
F-stat first stage (men)	79.8	98.5	79.8	98.5
Observations	549,058	651,670	549,058	651,670

NOTE.— This table shows IV, reduced-form, and OLS estimates based on Equation (4) for alternative definitions of labor force participation. Our baseline measure (col. 1) is an indicator variable equal to one if an individual reported a positive income at age 45. Because the income registry only starts in 1967, this measure excludes the cohorts aged 16–25 in 1940 and 1930. In col. 2 we consider an indicator variable equal to one if an individual reported a positive income at age 45 (for cohorts aged 16–25 in 1950 to 1970), at age 52 (for cohorts aged 16–25 in 1940), and at age 62 (for cohorts aged 16–25 in 1930). In col. 3, we consider an indicator variable equal to one if an individual reports a non-missing occupation in the Census conducted after age 25 and a positive income in the tax registry at age 45. In col. 4, we consider an indicator variable equal to one if an individual reports a non-missing occupation in the Census conducted after age 25 and a positive income in the tax registry at age 45 (for cohorts aged 16–25 in 1950 to 1970), at age 52 (for cohorts aged 16–25 in 1940), and at age 62 (for cohorts aged 16–25 in 1930). Independent variables and flexible trends are defined as in Table 3. The sample includes women and men born in rural municipalities with at least one farm in 1930, who were aged 16–25 in the census years 1930–70, and with no missing information on income at the relevant age. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.6: The diffusion of milking machines and income at ages 40–45

	(1)		(2)		(3)		(4)		(5)		(6)	
	Income at age 40		Income at age 45		log (income + 1)		Percentile rank		1 (income > 0)		log (income + 1)	
	Percentile rank	1 (income > 0)	Percentile rank	1 (income > 0)	log (income + 1)	Percentile rank	1 (income > 0)	log (income + 1)	Percentile rank	1 (income > 0)	log (income + 1)	Percentile rank
Panel A. IV												
Milking machines per farm (women)	1.200*** (0.392)	0.031*** (0.008)	0.322*** (0.078)	1.495*** (0.347)	0.030*** (0.006)	0.347*** (0.067)						
Milking machines per farm (men)	0.261 (0.380)	0.001 (0.002)	0.032 (0.026)	0.253 (0.423)	0.007*** (0.002)	0.081** (0.034)						
p-value (women = men)	0.063	0.001	0.000	0.013	0.000	0.000						
Panel B. Reduced form												
Cows per farm 1930 × National rollout (wom)	0.967*** (0.321)	0.025*** (0.007)	0.259*** (0.063)	1.204*** (0.277)	0.025*** (0.005)	0.280*** (0.053)						
Cows per farm 1930 × National rollout (men)	0.211 (0.302)	0.001 (0.002)	0.026 (0.021)	0.205 (0.333)	0.005*** (0.002)	0.066*** (0.024)						
p-value (women = men)	0.078	0.001	0.000	0.022	0.000	0.000						
Panel C. OLS												
Milking machines per farm (women)	0.426*** (0.155)	0.014*** (0.003)	0.140*** (0.029)	0.428*** (0.148)	0.010*** (0.003)	0.107*** (0.027)						
Milking machines per farm (men)	0.250 (0.164)	0.001 (0.001)	0.028** (0.014)	0.152 (0.172)	0.001 (0.001)	0.020 (0.014)						
p-value (women = men)	0.379	0.000	0.000	0.178	0.002	0.002						
Municipality and birth year FE	Y	Y	Y	Y	Y	Y			Y	Y	Y	
Flexible trends (Lasso)	Y	Y	Y	Y	Y	Y			Y	Y	Y	
County-by-year FE	Y	Y	Y	Y	Y	Y			Y	Y	Y	
Mean dep. variable	50.59	0.85	9.43	51.51	0.89	10.08			0.89	68.8	67.1	
F-stat first stage (women)	68.8	68.8	68.8	68.8	68.8	68.8			68.8	68.8	67.1	
F-stat first stage (men)	67.1	67.1	67.1	67.1	67.1	67.1			67.1	67.1	67.1	
Observations	504,373	504,373	504,373	504,373	504,373	504,373			504,373	504,373	504,373	

NOTE.— This table shows IV, reduced-form, and OLS estimates for the effect of the diffusion of milking machines on women's income at the age of 40 and 45, based on equations (3) and (3). The sample includes women and men born in rural municipalities with at least one farm in 1929, who were aged 16–25 in the census years 1950–1970, and whose income at age 45 is listed in the tax registry (1967–2010). The dependent variable is the income percentile rank at age 40 (Column 1) or 45 (Column 4), a dummy variable equal to 1 if a woman reported any income at age 40 (Column 2) or 45 (Column 5), and log (income + 1) at age 40 (Column 3) and at age 45 (Column 6). In cols. 1–3, we assign income 45 values to two cohorts (born 1925 and 1926) who were older than 40 when income registry started in 1967. Independent variables are normalized to have a mean of zero and an SD of one. Flexible trends are defined as in Table 2. Standard errors (in parentheses) clustered at the municipality level; *p < .05; **p < .01; ***p < .001.

Table A.7: Decomposition of the income effect by mover status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Income at age 40		Income at age 45				
	Percentile rank	1($y > 0$)	$\log(y+1)$	Percentile rank	1($y > 0$)	$\log(y+1)$	High-skill occupation
Panel A. Women							
Stayers (omitted)	-	-	-	-	-	-	-
Migrates to rural	2.178*** (0.245)	0.022*** (0.004)	0.266*** (0.039)	2.606*** (0.235)	0.018*** (0.003)	0.270*** (0.033)	0.039*** (0.002)
Migrates to urban	7.705*** (0.293)	0.073*** (0.004)	0.907*** (0.047)	7.814*** (0.282)	0.051*** (0.003)	0.749*** (0.039)	0.089*** (0.002)
p-value (to rural = to urban)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mean dep. variable	33.09	0.74	7.88	36.72	0.82	9.00	0.12
Observations	248,859	248,859	248,859	248,859	248,859	248,859	344,658
Panel B. Men							
Stayers (omitted)	-	-	-	-	-	-	-
Migrates to rural	6.632*** (0.320)	0.002 (0.001)	0.181*** (0.016)	6.908*** (0.327)	0.004*** (0.001)	0.210*** (0.018)	0.129*** (0.005)
Migrates to urban	10.622*** (0.411)	-0.000 (0.001)	0.259*** (0.021)	10.918*** (0.405)	-0.000 (0.001)	0.267*** (0.022)	0.195*** (0.005)
p-value (to rural = to urban)	0.000	0.049	0.000	0.000	0.000	0.000	0.000
Mean dep. variable	67.64	0.96	10.94	65.91	0.95	11.13	0.27
Observations	255,514	255,514	255,514	255,514	255,514	255,514	286,086
Municipality FE	Y	Y	Y	Y	Y	Y	Y
Birth cohort year FE	Y	Y	Y	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y	Y	Y	Y
County-by-year FE	Y	Y	Y	Y	Y	Y	Y

NOTE.— This table decomposes the income effect by mover status. The variable "Stayers" is the omitted category, "Migrate to rural" is a dummy variable equal to one if the woman moved from her birthplace to another rural municipality, and "Migrate to urban" is a dummy variable equal to one if the woman moved from her birthplace to an urban town. Sample and dependent variables defined as in Appendix Table A.6 (columns 1-6) and as in Table 4 (column 7); Flexible trends defined as in Table 2. Standard errors (in parentheses) clustered at the municipality level; * $p < .05$; ** $p < .01$; *** $p < .001$.

Table A.8: Results using milkmaid employment shares as treatment-exposure measure

	(1) Employed agriculture	(2) Migration	(3) Income pctile rank	(4) Labor force participation
Panel A. Reduced form				
Share milkmaids 1930 $\times$ National rollout (wom)	-0.030*** (0.003)	0.018*** (0.005)	1.078*** (0.202)	0.022*** (0.005)
Share milkmaids 1930 $\times$ National rollout (men)	-0.014** (0.006)	0.004 (0.006)	0.025 (0.240)	0.004*** (0.001)
p-value (women = men)	0.002	0.001	0.000	0.000
Panel B. IV second stage				
Milking machines per farm (women)	-0.083*** (0.018)	0.050*** (0.016)	2.969*** (0.811)	0.061*** (0.020)
Milking machines per farm (men)	-0.039** (0.019)	0.010 (0.016)	0.068 (0.658)	0.010** (0.004)
p-value (women = men)	0.002	0.002	0.000	0.005
Panel C. IV first stage				
	Dep. Var.: Milking machines per farm			
Share milkmaids 1930 $\times$ National rollout (wom)	0.358*** (0.073)	0.358*** (0.073)	0.363*** (0.074)	0.362*** (0.076)
Share milkmaids 1930 $\times$ National rollout (men)	0.368*** (0.074)	0.368*** (0.074)	0.366*** (0.074)	0.372*** (0.076)
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-year FE	Y	Y	Y	Y
F-stat first stage (women)	24.1	24.1	24.3	23.0
F-stat first stage (men)	24.8	24.8	24.8	23.9
Observations	726,537	726,537	687,621	549,058

NOTE.— This table shows IV and reduced-form estimates using the share of women employed as milkmaids in 1930 instead of the number of cows per farm in 1930 in the instrument. Specifically, the instrument is $\frac{\bar{M}_{d(b)}}{\bar{F}_{d(b)}} \times \frac{L_{j,1930}}{P_{j,1930}}$. As before, the first component is the national “shift” in the adoption of milking machines, i.e., the total number of milking machines in Norway, $\bar{M}_{d(b)}$, normalized by the total number of farms in Norway, $\bar{F}_{d(b)}$, at the census year $d(b)$ when birth cohort b was aged 16-25. The second component is the treatment intensity at the municipality level, here the share of women employed as milkmaids: $L_{j,1930}$ denotes the number of young women employed in farming in municipality j in 1930 and $P_{j,1930}$ the total female population in municipality j in 1930. Dependent variables, flexible trends, and samples are defined as in Table 2 (col. 2) and Table 3. Independent variables are normalized to have a mean of zero and an SD of one. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.9: Comparing stratified samples

	(1) Employed agriculture	(2) Migration	(3) Income pctile rank	(4) Labor force participation
<i>Panel A. Municipalities with >0 milking machines in 1950</i>				
Cows per farm 1930 $\times$ National rollout (wom)	-0.037*** (0.005)	0.037*** (0.009)	1.702*** (0.325)	0.031*** (0.007)
Cows per farm 1930 $\times$ National rollout (men)	-0.026*** (0.008)	0.028*** (0.009)	0.151 (0.405)	0.005*** (0.002)
p-value (women = men)	0.125	0.096	0.002	0.000
Observations	522,549	522,549	494,548	392,861
Mean dep. variable	0.13	0.37	50.41	0.87
<i>Panel B. Municipalities with no milking machines in 1950</i>				
Cows per farm 1930 $\times$ National rollout (wom)	-0.055*** (0.008)	0.029** (0.013)	1.387*** (0.490)	0.035*** (0.009)
Cows per farm 1930 $\times$ National rollout (men)	-0.024* (0.014)	0.015 (0.012)	-0.280 (0.469)	-0.000 (0.004)
p-value (women = men)	0.004	0.203	0.002	0.000
Observations	203,986	203,986	193,070	156,197
Mean dep. variable	0.14	0.38	48.47	0.86
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-by-year FE	Y	Y	Y	Y

NOTE.— This table replicates reduced-form estimates on stratified samples. All samples include women and men born in rural municipalities with at least one farm in 1929, who were aged 16–25 in the census years 1930–1970. Panel A considers women and men in municipalities which had adopted milking machines in 1950 (switchers by 1950); Panel B considers women and men in municipalities which had not adopted milking machines in 1950 (non-switchers by 1950). Dependent variables and flexible trends are defined as in Tables 2 and 3. Independent variables are normalized to have a mean of zero and an SD of one. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.10: Robustness to excluding migrants to Oslo

	(1) Employed agriculture	(2) Migration	(3) Income ptile rank	(4) Labor force participation
Panel A. IV				
Milking machines per farm (women)	-0.045*** (0.006)	0.027*** (0.007)	1.505*** (0.306)	0.035*** (0.007)
Milking machines per farm (men)	-0.025*** (0.009)	0.017** (0.007)	-0.309 (0.371)	0.006** (0.002)
p-value (women = men)	0.003	0.093	0.000	0.000
Panel B. Reduced form				
Cows per farm 1930 $\times$ National rollout (wom)	-0.040*** (0.004)	0.024*** (0.006)	1.333*** (0.268)	0.029*** (0.006)
Cows per farm 1930 $\times$ National rollout (men)	-0.022*** (0.007)	0.016** (0.006)	-0.273 (0.334)	0.005*** (0.002)
p-value (women = men)	0.005	0.098	0.000	0.000
Panel C. OLS				
Milking machines per farm (women)	-0.017*** (0.003)	0.008** (0.004)	0.475*** (0.130)	0.011*** (0.003)
Milking machines per farm (men)	-0.010** (0.004)	0.004 (0.003)	-0.138 (0.158)	0.002 (0.001)
p-value (women = men)	0.078	0.208	0.001	0.001
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-by-year FE	Y	Y	Y	Y
Mean dep. variable	0.15	0.30	48.89	0.86
F-stat first stage (women)	103.7	103.7	99.5	80.3
F-stat first stage (men)	97.9	97.9	97.8	78.2
Observations	644,447	644,447	608,398	485,642

NOTE.— This table shows IV, reduced-form, and OLS estimates for the long-term effect of milking machines based on equations (3) and (3), using a sample that excludes women and men who migrated to Oslo. Specifically, the sample includes all women and men who were born in rural municipalities with at least one farm in 1930, who were aged 16–25 in the census years 1930–1970, and who did not migrate to Oslo. Dependent variables and flexible trends are defined as in Table 2 (cols. 2, 4, and 5) and Table 3. Independent variables are normalized to have a mean of zero and an SD of one. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.11: Robustness controlling for access to hydroelectric power plants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Employment in agriculture		Migration		Income pctile rank		FLFP	
Panel A. IV								
Milking machines per farm (women)	-0.045*** (0.006)	-0.045*** (0.006)	0.041*** (0.009)	0.041*** (0.009)	1.906*** (0.318)	1.884*** (0.320)	0.041*** (0.007)	0.040*** (0.007)
Milking machines per farm (men)	-0.032*** (0.009)	-0.030*** (0.009)	0.030*** (0.009)	0.029*** (0.009)	-0.014 (0.39)	-0.046 (0.395)	0.005** (0.002)	0.005** (0.002)
p-value (women = men)	0.06	0.02	0.04	0.04	0.00	0.00	0.00	0.00
Panel B. Reduced form								
Cows per farm 1930 × National rollout (women)	-0.040*** (0.004)	-0.040*** (0.004)	0.036*** (0.007)	0.036*** (0.008)	1.70*** (0.259)	1.673*** (0.270)	0.034*** (0.005)	0.033*** (0.005)
Cows per farm 1930 × National rollout (men)	-0.029*** (0.007)	-0.027*** (0.007)	0.027*** (0.008)	0.026*** (0.008)	-0.013 (0.348)	-0.041 (0.351)	0.004** (0.002)	0.004** (0.002)
p-value (women = men)	0.07	0.02	0.04	0.04	0.00	0.00	0.00	0.00
Panel C. OLS								
Milking machines per farm (women)	-0.017*** (0.002)	-0.017*** (0.002)	0.010** (0.004)	0.010** (0.004)	0.609*** (0.144)	0.615*** (0.145)	0.012*** (0.003)	0.012*** (0.003)
Milking machines per farm (men)	-0.011*** (0.004)	-0.011*** (0.004)	0.007* (0.004)	0.007* (0.004)	-0.173 (0.156)	-0.177 (0.156)	0.001 (0.001)	0.001 (0.001)
p-value (women = men)	0.14	0.12	0.28	0.26	0.00	0.00	0.00	0.00
Municipality and birth year FE	Y	Y	Y	Y	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y	Y	Y	Y	Y
County-by-byear FE	Y	Y	Y	Y	Y	Y	Y	Y
Hydropower instrument × byear FE	Y	.	Y	.	Y	.	Y	.
Hydropower 1900-10 status	.	Y	.	Y	.	Y	.	Y
Mean dep. variable	0.13	0.13	0.38	0.38	49.90	49.91	0.87	0.87
F-stat first stage (women)	99	94	99	94	95	89.5	76	71
F-stat first stage (men)	92	87	92	87	92	87	73	69
Observations	698,324	701,787	698,324	701,787	661,141	664,319	527,750	530,127

NOTE.— This table shows IV estimates in extended specifications of equations (2) and (3) controlling for different measures of access to hydroelectric power plants. Odd columns control for the hydropower potential × birth year FE; Even columns control for the hydropower status between 1900 and 1910 (early adopters). Dependent and independent variables, flexible trends, and the baseline sample are defined as in Table 2 (cols. 2, 4, and 5) and Table 3. Samples are smaller than in Tables 2 and 3 because of missing hydropower data for some municipalities. Standard errors (in parentheses) clustered at the municipality level; *p < .05; **p < .01; ***p < .001.

Table A.12: Robustness to the roll-out of the Primary School Reform (1960-72)

	(1) Employed agriculture	(2) Migration	(3) Income pctile rank	(4) Labor force participation	(5) Education ≥ undergrad
Panel A. IV					
Reform: not treated	ref.	ref.	ref.	ref.	ref.
treated	0.000 (0.004)	0.010 (0.008)	-0.146 (0.253)	0.002 (0.003)	0.005 (0.004)
missing data	0.034 (0.039)	-0.008 (0.011)	-0.688 (0.956)	-0.007 (0.009)	-0.016 (0.012)
Milking machines (women)	-0.044*** (0.005)	0.041*** (0.008)	1.893*** (0.305)	0.038*** (0.007)	0.014*** (0.004)
Milking machines (men)	-0.029*** (0.008)	0.029*** (0.009)	0.031 (0.371)	0.006** (0.002)	0.006** (0.003)
p-value (women = men)	0.015	0.03	0.000	0.000	0.035
Panel B. Reduced form					
Reform: not treated	ref.	ref.	ref.	ref.	ref.
treated	0.002 (0.004)	0.009 (0.008)	-0.196 (0.250)	0.000 (0.003)	0.005 (0.004)
missing data	0.034 (0.040)	-0.008 (0.011)	-0.682 (0.960)	-0.007 (0.009)	-0.016 (0.012)
Cows per farm 1930 × National rollout (women)	-0.040*** (0.004)	0.037*** (0.007)	1.693*** (0.263)	0.032*** (0.005)	0.012*** (0.003)
Cows per farm 1930 × National rollout (men)	-0.026*** (0.007)	0.026*** (0.007)	0.028 (0.331)	0.005*** (0.002)	0.005** (0.003)
p-value (women = men)	0.022	0.035	0.000	0.000	0.044
Panel C. OLS					
Reform: not treated	ref.	ref.	ref.	ref.	ref.
treated	0.001 (0.004)	0.009 (0.008)	-0.180 (0.250)	0.001 (0.003)	0.005 (0.004)
missing data	0.034 (0.040)	-0.008 (0.011)	-0.676 (0.967)	-0.007 (0.009)	-0.016 (0.012)
Milking machines (women)	-0.017*** (0.002)	0.011*** (0.004)	0.637*** (0.137)	0.011*** (0.003)	0.005*** (0.002)
Milking machines (men)	-0.011*** (0.004)	0.007* (0.004)	-0.115 (0.154)	0.001 (0.001)	0.001 (0.002)
p-value (women = men)	0.103	0.177	0.000	0.000	0.061
Municipality and birth year FE	Y	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y	Y
County-by-byear FE	Y	Y	Y	Y	Y
F-stat first stage (women)	105.1	105.1	101.0	81.6	105.1
F-stat first stage (men)	99.1	99.1	99.0	79.6	99.1
Observations	726,537	726,537	687,621	549,058	726,537

NOTE.— This table replicates our estimates of Equation (4) controlling for the Primary School Reform roll-out between 1960 and 1972. The variable Reform is an indicator equal to one if an individual born in cohort c studied after their municipality of birth j fully implemented the Primary School Reform, and equal to zero if they studied under the pre-reform system. We also report effects for municipalities with missing data on the reform. Dependent and independent variables, flexible trends, and samples are defined as in Table 2 (cols. 2, 4, and 5) and Table 3. Standard errors (in parentheses) clustered at the municipality level; * $p < .05$; ** $p < .01$; *** $p < .001$.

Table A.13: Robustness to controlling for the intensity of WW2

	(1) Employed agriculture	(2) Migration	(3) Income ptile rank	(4) Labor force participation
Panel A. IV				
Milking machines per farm (women)	-0.044*** (0.005)	0.041*** (0.008)	1.890*** (0.305)	0.038*** (0.007)
Milking machines per farm (men)	-0.029*** (0.008)	0.029*** (0.009)	0.034 (0.372)	0.006** (0.002)
p-value (women = men)	0.016	0.029	0.000	0.000
Panel B. Reduced form				
Cows per farm 1930 $\times$ National rollout (wom)	-0.236*** (0.024)	0.220*** (0.043)	10.017*** (1.558)	0.193*** (0.033)
Cows per farm 1930 $\times$ National rollout (men)	-0.157*** (0.040)	0.156*** (0.044)	0.179 (1.965)	0.029*** (0.010)
p-value (women = men)	0.023	0.033	0.000	0.000
Panel C. OLS				
Milking machines per farm (women)	-0.017*** (0.002)	0.011*** (0.004)	0.647*** (0.137)	0.012*** (0.003)
Milking machines per farm (men)	-0.010*** (0.004)	0.006* (0.004)	-0.122 (0.156)	0.001 (0.001)
p-value (women = men)	0.095	0.153	0.000	0.000
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-year FE	Y	Y	Y	Y
WW2 investment (0/1) $\times$ birth year	Y	Y	Y	Y
Mean dep. variable	0.13	0.38	49.87	0.87
F-stat first stage (women)	105.65	105.65	101.57	82.47
F-stat first stage (men)	99.74	99.74	99.57	80.46
Observations	726,537	726,537	687,621	549,058

NOTE.— This table shows IV, reduced-form, and OLS estimates for the long-term effect of milking machines based on equations (3) and (3), controlling for flexible trends by the intensity of WW2, captured by german investments in industry, airports, and coastal infrastructure. Specifically, we use data from [Abramitzky et al. \(2024\)](#) and include the interaction of birth year FE with a dummy variable equal to one if the municipality received German investments in these areas during WW2, and zero otherwise. The sample and flexible trends are defined as in Table 2 and 3. Independent variables are normalized to have a mean of zero and an SD of one. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.14: The diffusion of milking machines on younger versus older women, Reduced-form and OLS estimates

	(1) Employed agriculture	(2) Migration	(3) Income pctile rank	(4) Labor force participation
Panel A. Reduced form				
Cows per farm 1930 $\times$ National rollout (younger)	-0.058*** (0.007)	0.027*** (0.008)	1.402*** (0.353)	0.029*** (0.008)
Cows per farm 1930 $\times$ National rollout (older)	0.052*** (0.006)	-0.003 (0.003)	0.508 (0.433)	-0.000 (0.009)
p-value (younger = older)	0.000	0.000	0.156	0.041
Panel B. OLS				
Milking machines per farm (younger)	-0.028*** (0.004)	0.017*** (0.004)	0.577*** (0.191)	0.015*** (0.004)
Milking machines per farm (older)	0.006* (0.003)	0.000 (0.002)	0.441** (0.220)	0.004 (0.005)
p-value (younger = older)	0.000	0.000	0.681	0.112
Municipality and birth year FE	Y	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y	Y
County-by-byear FE	Y	Y	Y	Y
Mean dep. variable	0.09	0.20	31.05	0.71
Observations	319,092	319,092	289,187	289,187

NOTE.— This table shows reduced-form and OLS estimates based on equations (3) and (3), where instead of comparing women versus men we compare “younger” versus “older” women. The sample includes women aged 16–25 (younger) and 36–45 (older) living in a rural municipalities in 1950, 1960, and 1970. The number of milking machines per farm is measured at their municipality of residence, based on the 1960 and 1970 census. For younger cohorts, all dependent variables are defined as in Tables 2 and 3. For older cohorts, employment in agriculture and migration are based on the occupation and residency reported in the following census (i.e., for women aged 36–45 in 1950, 1960, and 1970, we look, respectively, into the 1960, 1970, and 1980 census); income rank is defined as before; and FLFP is equal to one if the older cohort in 1950, 1960, and 1970 reported a positive income at, respectively, age 45, 52, and 62. We use different ages because the income registry only starts in 1967 so we do not observe income at age 45 for all the “older cohorts.” Similarly, because we do not observe women aged 36–45 before 1950 (e.g., born before 1905) in the registry data, the sample is restricted by construction to young and old cohorts in 1950, 1960, and 1970. Independent variables are normalized to have a mean of zero and an SD of one. Standard errors (in parentheses) clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.15: Migration decisions and schooling structure, IV estimates

	(1)	(2)	(3)
	Migrates to town with higher-edu.	Long-dist. rural-urban migration	Short-dist. rural-rural migration
Milking machines (women)	0.391***	0.346***	-0.043
× municipality high school in 1963 = NO	(0.081)	(0.072)	(0.038)
Milking machines (men)	0.283***	0.251***	-0.021
× municipality high school in 1963 = NO	(0.071)	(0.074)	(0.038)
p-value (women = men)	0.053	0.081	0.532
Milking machines (women)	0.180**	0.182**	0.110***
× municipality high school in 1963 = YES	(0.089)	(0.083)	(0.041)
Milking machines (men)	0.120	0.089	0.115**
× municipality high school in 1963 = YES	(0.080)	(0.080)	(0.045)
p-value (women = men)	0.324	0.117	0.898
Municipality FE	Y	Y	Y
Birth year FE	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y
County-by-byear FE	Y	Y	Y
Observations	677,235	703,918	703,918
F-stat women, high schol NO	88.88	90.23	90.23
F-stat women, high schol YES	10.51	11.06	11.06
F-stat men, high schol NO	84.71	85.93	85.93
F-stat men, high schol YES	10.32	10.81	10.81
Mean dep. variable	0.31	0.30	0.11

NOTE.— This table shows IV estimates based on equations (2) and (4). Interactions capture the differential effect of the diffusion of milking machines in municipalities with at least one high-school (gymnasium) in 1963, and are instrumented with our exposure measure (Equation (1)) × a dummy for municipalities with at least one high-school in 1963. The sample includes women and men born in rural municipalities with at least one farm in 1930, who were aged 16–25 in the census years 1930–1970. In col. 1 the dependent variable is equal to 1 if an individual migrated to one of the 28 towns with a higher-education institution where academic (university) or vocational programmes (høyskole) were offered in 1963. In cols- 2-3, urban (rural) areas are towns with a population above (below) 10,000 in 1929. Independent variables are normalized to have a mean of zero and an SD of one. All specifications are fully-interacted models, where gender dummies are interacted with fixed effects for municipality and birth cohort; flexible trends selected with a LASSO procedure (see Appendix Table A.3) and defined as in Table 2; and county-by-birth cohort fixed effects. Standard errors in parentheses clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.16: Migration decisions and schooling structure, reduced-form estimates

	(1)	(2)	(3)
	Migrates to town with higher-edu.	Long-dist. rural-urban migration	Short-dist. rural-rural migration
Milkcows $\times$ National rollout (women)	0.037***	0.032***	-0.004
$\times$ municipality high school in 1963 = NO	(0.007)	(0.006)	(0.004)
Milkcows $\times$ National rollout (men)	0.027***	0.024***	-0.002
$\times$ municipality high school in 1963 = NO	(0.006)	(0.006)	(0.004)
p-value (women = men)	0.060	0.099	0.540
Milkcows $\times$ National rollout (women)	0.022***	0.021***	0.008*
$\times$ municipality high school in 1963 = YES	(0.008)	(0.007)	(0.004)
Milkcows $\times$ National rollout (men)	0.015**	0.012*	0.008*
$\times$ municipality high school in 1963 = YES	(0.007)	(0.007)	(0.005)
p-value (women = men)	0.231	0.108	0.816
Municipality FE	Y	Y	Y
Birth year FE	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y
County-by-byear FE	Y	Y	Y
Observations	677,235	703,918	703,918
Mean dep. variable	0.31	0.30	0.11

NOTE.— This table shows RF estimates based on equation (4). Interactions capture the differential effect of the diffusion of milking machines in municipalities with at least one high-school (gymnasium) in 1963. The sample includes women and men born in rural municipalities with at least one farm in 1930, who were aged 16–25 in the census years 1930–1970. In col. 1 the dependent variable is equal to 1 if an individual migrated to one of the 28 towns with a higher-education institution where academic (university) or vocational programmes (høyskole) were offered in 1963. In cols- 2-3, urban (rural) areas are towns with a population above (below) 10,000 in 1929. Independent variables are normalized to have a mean of zero and an SD of one. All specifications are fully-interacted models, where gender dummies are interacted with fixed effects for municipality and birth cohort; flexible trends selected with a LASSO procedure (see Appendix Table A.3) and defined as in Table 2; and county-by-birth cohort fixed effects. Standard errors in parentheses clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.17: Migration decisions and schooling structure, OLS estimates

	(1)	(2)	(3)
	Migrates to town with higher-edu.	Long-dist. rural-urban migration	Short-dist. rural-rural migration
Milking machines (women)	0.090**	0.108***	0.000
× municipality high school in 1963 = NO	(0.036)	(0.036)	(0.018)
Milking machines (men)	0.062**	0.072**	-0.006
× municipality high school in 1963 = NO	(0.029)	(0.032)	(0.020)
p-value (women = men)	0.328	0.232	0.730
Milking machines (women)	-0.037	0.028	0.110***
× municipality high school in 1963 = YES	(0.043)	(0.042)	(0.025)
Milking machines (men)	-0.040	-0.015	0.109***
× municipality high school in 1963 = YES	(0.035)	(0.034)	(0.024)
p-value (women = men)	0.909	0.164	0.978
Municipality FE	Y	Y	Y
Birth year FE	Y	Y	Y
Flexible trends (Lasso)	Y	Y	Y
County-by-byear FE	Y	Y	Y
Observations	677,235	703,918	703,918
Mean dep. variable	0.31	0.30	0.11

NOTE.— This table shows OLS estimates based on equation (4). Interactions capture the differential effect of the diffusion of milking machines in municipalities with at least one high-school (gymnasium) in 1963. The sample includes women and men born in rural municipalities with at least one farm in 1930, who were aged 16–25 in the census years 1930–1970. In col. 1 the dependent variable is equal to 1 if an individual migrated to one of the 28 towns with a higher-education institution where academic (university) or vocational programs (høyskole) were offered in 1963. In cols- 2-3, urban (rural) areas are towns with a population above (below) 10,000 in 1929. Independent variables are normalized to have a mean of zero and an SD of one. All specifications are fully-interacted models, where gender dummies are interacted with fixed effects for municipality and birth cohort; flexible trends selected with a LASSO procedure (see Appendix Table A.3) and defined as in Table 2; and county-by-birth cohort fixed effects. Standard errors in parentheses clustered at the municipality level; *p<.05; **p<.01; ***p<.001.

Table A.18: Percent of rural female migrants to 10 largest towns

	(1)	(2)	(3)
	1960 census	1970 census	1980 census
Oslo	16.67	14.86	12.96
Bergen	5.39	5.26	4.73
Trondheim	3.48	3.87	3.87
Stavanger	1.67	1.63	1.64
Bærum (Greater Oslo)	1.88	2.00	1.81
Kristiansand	1.21	1.30	1.20
Drammen	1.19	1.20	1.13
Tromsø	1.13	1.36	1.58
Bodø	1.12	1.30	1.33
Other (urban municipalities)	30.43	32.28	32.61
Other (rural municipalities)	35.85	34.94	37.14

NOTE.— This table shows the distribution of female rural migrants across the 10 largest cities in Norway. Other urban (rural) municipalities are those with a population above (below) 10,000 in 1969. The sample comprises women in our baseline sample who migrated out of their (rural) birthplace in the census year 1960 (column 1), 1970 (column 2), and 1980 (column 3).

Table A.19: Public-sector occupations, as defined by the *Standard for yrkesklassifisering*

Digit	Description
11	Legislators and senior officials in public administration and interest organisations
1227	Production and operations department managers in public administration
1228	Production and operations department managers in education, health and social security
222	Health professionals
223	Nursing and midwifery professionals
23	Teaching professionals
24	Public service administrative professionals
323	Nursery and Registered Nurses for the Mentally Subnormal (RNMS)
33	Teaching associate professionals
344	Public service administrative associate professionals
345	Police officers
346	Social workers (college-trained), child care officers, etc.
5161	Fire-fighters
5162	Prison guards

NOTE.— This table lists the four-digit occupations included in our variable “Public sector occupation” (Table 4, column 4). Definitions based on the *Standard for yrkesklassifisering* for occupations in the full count Censuses of 1960, 1970, and 1980.

A.3 Model

In this appendix, we develop a simple conceptual framework that links the adoption of milking machines to the displacement of female labor, its reallocation from dairying into the urban sector jobs (e.g., public sector), and the eventual long-term income gains for women. To do so, we combine a task-based production function, which accounts for the gender division of labor in traditional agriculture and for the automation of hand milking (Zeira, 1998; Autor et al., 2003; Acemoglu and Autor, 2011), with the key ideas of comparative advantage, which explain labor reallocation across sectors (Roy, 1951).

A.3.1 Set up

Consider an economy with a large number of municipalities specialized in two sectors: a rural sector (R) and urban sector (U). The rural sector consists of primary industries such as agriculture, dairying, or fisheries, as well as construction and timber industries located in rural municipalities. The urban sector comprises manufacturing, services and, especially, the growing public sector jobs which abounded in urban areas.

Men and women inelastically supply one unit of labor. Each individual i is endowed with two skills, $\alpha_R(i)$ and $\alpha_U(i)$. These skills represent efficiency units for labor in the rural and urban sector, respectively. In our setting, $\alpha_U(i)$ represents skills demanding more general human capital for white-collar occupations, e.g., skills required in public sector jobs. The skill pair $(\alpha_R(i), \alpha_U(i))$ is equally distributed by gender. We define an individual i 's comparative advantage in the urban sector as $\alpha_U(i)/\alpha_R(i)$.

Individuals maximize their consumption. To do so, they face the choice of supplying their labor to either the urban or rural sector. To gain insights for our empirical analysis, we focus on the decisions of individuals starting off in the rural sector, for whom supplying labor to the urban sector requires reallocating across occupations and, in most cases, migrating out of rural municipalities. This entails a cost c , which we assume to be a fraction of their earnings (Nakamura et al., 2021). This cost can be thought of as sectoral reallocation costs—e.g., the educational investments necessary to secure employment in the growing public sector—and/or as migration costs²—e.g., the economic cost of moving to a new locality and the foregone social ties and rural insurance networks (Munshi and Rosenzweig, 2016). Additionally, for female labor, this cost incorporates barriers to moving across sectors due

²Although we do not directly observe moving costs, our empirical analysis provides important insights on it. First, we show that migration patterns did not differ across more and less dairy-intensive municipalities in the pre-milking machine era. Second, by using fixed effects for municipalities and county-by-birth cohorts, we account for time-invariant *municipality-specific* and for time-varying *county-specific* moving costs that may have affected women's decisions to migrate and their long-run income gains.

to traditional norms on the gender division of labor, family ties, larger opportunity costs of having children and, more generally, social norms about the role of women in the labor market.

The rural sector produces one final good Y_R by combining two tasks, y_1 and y_2 . For simplicity, we assume a constant returns to scale Cobb-Douglas technology:

$$Y_R = y_1^{1-\beta} y_2^\beta . \quad (\text{A.4})$$

Two factors of production are used in the rural sector: labor L_R and capital M . To capture the gender division of labor in traditional agriculture, we assume that task y_1 uses female labor, and task y_2 uses male labor. In our setting, task y_1 can be interpreted as milking cows, and task y_2 as work traditionally done by men, e.g., cultivating fields, seasonal work in construction or in fisheries. To capture the displacement effects of milking machines, assume that capital (milking machines) M and female labor are perfect substitutes. Formally, the production function of each task is:

$$y_1 = A_R L_R^f + M \quad \text{and} \quad y_2 = A_R L_R^m , \quad (\text{A.5})$$

where $L_R^f = \int_{i \in \mathcal{F}_R} \alpha_R(i) di$ and $L_R^m = \int_{i \in \mathcal{M}_R} \alpha_R(i) di$ are female and male labor in the rural sector, and $\mathcal{F}_R$ and $\mathcal{M}_R$ denote the set of female and male rural workers.

This task-based production function encompasses the canonical labor-augmenting technological change (A_R) and labor-saving technological change. Specifically, the machines used in the first task, M , are supplied perfectly elastically at market price $\mu > 1$, which falls exogenously due to technological advances. Hence, the declining price of the machines is the labor-saving technological change in our model.

The urban sector produces one final good Y_U using labor L_U as the only factor of production, irrespective of gender. Formally, the production function is:

$$Y_U = A_U L_U , \quad \text{where} \quad L_U = \int_{i \in \mathcal{S}_U} \alpha_U(i) di \quad (\text{A.6})$$

and $\mathcal{S}_U$ denotes the set of female and male workers employed in the urban sector.

A.3.2 Equilibrium

Three main conditions govern the remainder of the equilibrium. The first is that labor markets are perfectly competitive and the economy is small. Therefore, the prices of the rural (P_R) and urban (P_U) goods are taken as given. This implies that the wage per efficiency

unit of labor in the urban sector is $W_U = A_U P_U$.

The second condition is the perfect substitutability of female labor and machines in the rural sector. This implies that the wage per efficiency unit of female labor in the rural sector is pinned down by the labor-augmenting technological change, A_R , and by the labor-saving technological change, captured by the price of machines μ :

$$W_R^f = A_R \mu . \quad (\text{A.7})$$

The third condition is worker self-selection among the rural and urban sectors. The labor earnings for worker i are $W_R^f \cdot \alpha_R(i)$ for women in the rural sector, $W_R^m \cdot \alpha_R(i)$ for men in the rural sector, and $W_U \cdot \alpha_U(i)$ for women and men in the urban sector. Taking into account the cost c of reallocating across sectors, this implies that the marginal female worker, i^* , is indifferent between remaining in the rural sector and reallocating to the urban sector if $W_R^f \cdot \alpha_R(i^*) = (1 - c) \cdot W_U \cdot \alpha_U(i^*)$ and the marginal male worker j^* is indifferent if $W_R^m \cdot \alpha_R(j^*) = (1 - c) \cdot W_U \cdot \alpha_U(j^*)$. It is useful to re-define these indifference conditions as a function of the relative earnings in the urban vs. rural sector of female, η_i^f , and of male, η_i^m , workers:

$$\eta_i^f := \frac{W_U}{W_R^f} \cdot \frac{\alpha_U(i)}{\alpha_R(i)} \quad \text{and} \quad \eta_i^m := \frac{W_U}{W_R^m} \cdot \frac{\alpha_U(i)}{\alpha_R(i)} .$$

The indifference condition is then:

$$\eta_{i^*}^f = \eta_{j^*}^m = \frac{1}{1 - c} . \quad (\text{A.8})$$

Note that this indifference condition differs from the optimal allocation of workers, which is achieved when the marginal female worker is $\tilde{i}$ and the marginal male worker is $\tilde{j}$ with $\eta_{\tilde{i}}^f = \eta_{\tilde{j}}^m = 1$.

The model's equilibrium is illustrated in Panel (a) of Figure A.19. Female workers with a higher comparative advantage in the urban sector have higher relative earnings in that sector.³ All women with a comparative advantage above $\tilde{i}$ would earn a higher salary in the urban sector. However, the cost of reallocating across sectors implies that all women with a comparative advantage below i^* will remain employed in the rural sector, and that only women with a comparative advantage above i^* will relocate to the urban sector. Hence, all women between $\tilde{i}$ and i^* will be “misallocated” and their earnings would increase if they moved to the urban sector. As we will discuss in the next sub-section, a large technology

³For simplicity, the figure η_i^f takes a linear form by assuming that $\alpha_U(i)$ and $\alpha_R(i)$ are uniformly distributed, but that different skill distributions can lead to different shapes. The only necessary assumption is that η_i^f is upward-sloping, i.e., that $\frac{\alpha_U(i)}{\alpha_R(i)}$ reflects a comparative advantage in the urban sector.

shock like milking machines can break this allocative inefficiency and generate long-term income gains for these “misallocated” workers.

A.3.3 Comparative statics

Here we consider the situation at the time of the mechanization of agriculture and derive comparative statics. This exercise helps us a) to identify the compliers of our quasi-experiment; b) to motivate our empirical strategy based on using differences in dairy-farming intensity in the pre-milking machines era; c) to rationalize our main results for the effects of milking machines on displacement from agriculture; and d) to illustrate the mechanisms through which automation can result in long-term income gains.

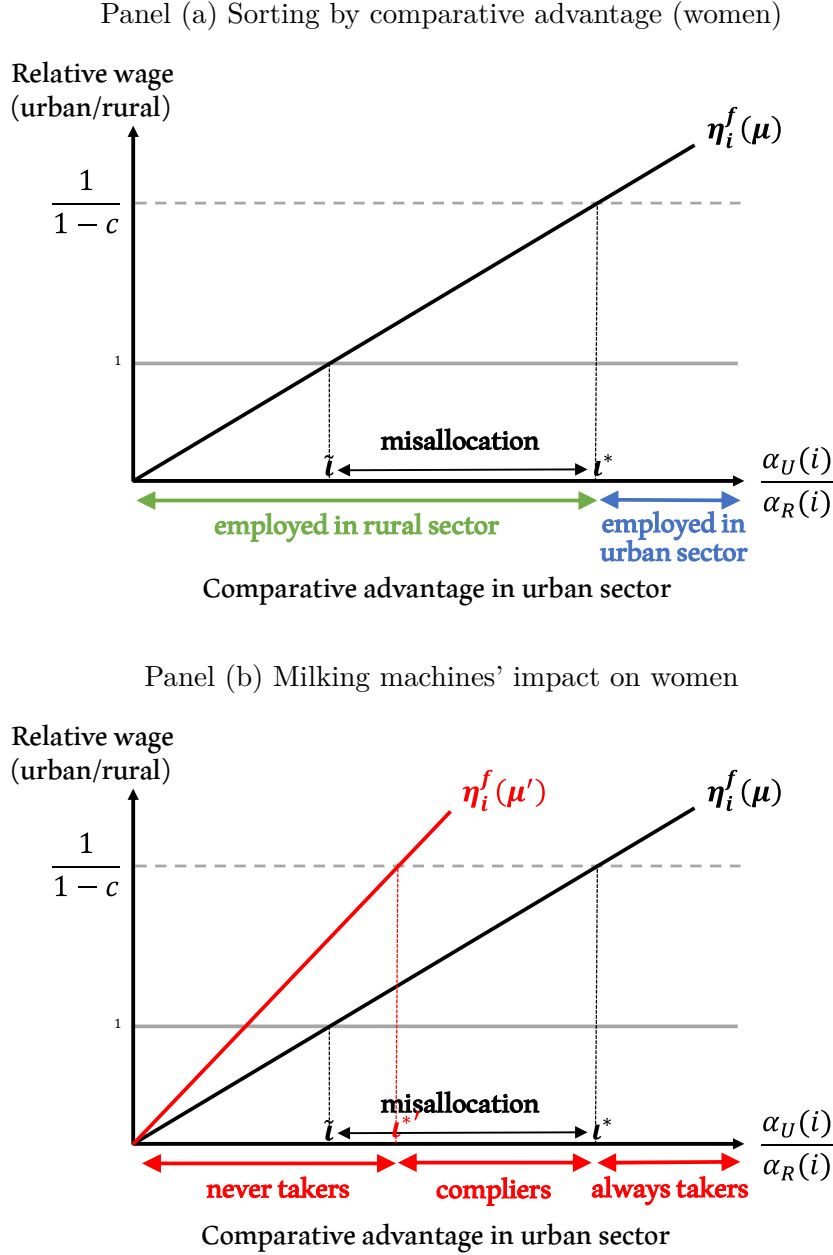
As explained in the main text, the adoption of milking machines automated tasks typically performed by women in rural areas. In our model, this labor-saving technological change is captured by a decline in the price of the machines, M , from μ to μ' . This quasi-experiment is illustrated in Panel (b) of Figure A.19.

The *first comparative-static result* is that the adoption of milking machines will displace women from agricultural jobs in the rural sector and push them out of the countryside to find employment in the urban sector. It is immediately clear from equation (A.7) that a decline in the price of machines reduces the female wage in the rural sector. That is, $\partial W_R^f / \partial \mu = A_R > 0$, and hence, $\partial \eta^f / \partial \mu = -(A_U P_U / A_R \mu^2) \cdot (\alpha_U(i) / \alpha_R(i)) < 0$. This is illustrated by the relative earnings curve shifting up (red line) in Panel (b) of Figure A.19. Since female and male workers are bound to a task in the rural sector, this does not generate any re-sorting of female workers across tasks in the rural sector. Instead, the Roy framework that we adopted implies that female workers’ decisions to reallocate to the urban sector will respond elastically to relative wage levels in the rural and urban sectors. Specifically, all women with a comparative advantage between $\iota^{*'} and ι^* will be displaced by milking machines from agricultural jobs in the rural sector, migrate out of rural areas, and reallocate to the urban sector. This rationalizes our main empirical results on employment in agriculture and migration for women exposed to the adoption of milking machines.$

This comparative static result also allows us to identify the compliers of our quasi-experiment. Based on the terminology of Angrist (2004), female workers to the left of ι^{*} in Panel (b) of Figure A.19 are “never-takers.” They have such a strong comparative advantage in the rural sector that they will not reallocate to the urban sector, even after the adoption of milking machines. Female workers between ι^{*} and $\iota^{*'}$ are “compliers.” They will reallocate to the urban sector if and only if their municipality adopts milking machines. Finally, female workers to the right of $\iota^{*'}$ are “always-takers”. They have such a strong com-

parative advantage in the urban sector that they will reallocate, even if their municipality does not adopt milking machines.

Figure A.19



NOTE.— For illustrative purposes, we assume that $\alpha_U(i)$ and $\alpha_R(i)$ are uniformly distributed.

The *second comparative-static result* is that, on average, displaced women will experience long-run income gains. This prediction emanates from the fact that the first women displaced by milking machines are those with the highest comparative advantage in the urban sector.

These women are misallocated workers, in the sense that their earnings would be higher in the urban sector to begin with, but they remain in the rural sector only due to the reallocation cost—which we defined above as the costs to upskill, economic costs of moving, family ties, or barriers to the reallocation of labor across sectors due to gender norms. In Figure A.19, this is illustrated by the fact that the displaced women (between v^{*f} and v^*) are in the region of misallocated workers (between $\tilde{v}$ and v^*). A substantial depression in female rural wages, such as the one induced by the automation of milking tasks, can break up this allocative inefficiency and induce long-run income gains to the displaced female workers who relocate to the urban sector. This result hinges on the assumption that the reallocation cost c is large enough such that a substantial share of the compliers are misallocated in rural areas prior to the technology shock.

Recent evidence supports the assumption that the reallocation cost c is large. In detail, barriers to migration and moving costs have been shown to be substantial in rural settings similar to our case study (see e.g., Nakamura et al. (2021) and Munshi and Rosenzweig (2016)). In addition, for female labor, barriers to moving across sectors and out of rural areas were even larger due to traditional norms on the gender division of labor and from family ties in rural areas. This is illustrated by the fact that the automation of hand milking also triggered changes in fertility (see Table 5), which were knitted with and necessary to facilitate women’s reallocation from the rural to the urban sector.

More generally, the comparative-static result on women’s long-term income gains is in line with the prediction of Acemoglu and Restrepo (2019) that automation can benefit displaced workers if employment opportunities in new occupations emerge and labor is reinstated. This process typically requires investments in education and upskilling—which in our simple framework would further suggest a non-negligible reallocation cost c .

The *third comparative-static result* is that rural municipalities with farming conditions better suited for dairy production will adopt milking machines to a greater extent, and hence, will experience more drastic displacement effects. To see this, we need to extend the model. Let this economy be a collection of rural municipalities $j \in J$. Each municipality operates with the production functions in equations (A.4) and (A.5), but municipalities are heterogeneous with respect to $\beta(j)$, the factor share of different farming tasks. A small $\beta(j)$ represents a task- y_1 -intensive municipality—in our setting, municipalities better suited for dairy production. Although all municipalities face the same price of milking machines, μ , the degree to which municipalities adopt this technology depends on $\beta(j)$. To see this, it is useful to define the input demand in rural municipalities as $\theta(j) = (A_R L_R^f(j) + M(j)) / (A_R L_R^m(j))$. In other words, $\theta(j)$ captures how much a rural municipality j demands milking machines and/or female labor (i.e., task- y_1 input) relative to male labor (i.e., task- y_2 input). Assuming

that each municipality satisfies productive efficiency,

$$\partial Y_R(j)/\partial L_R^f(j) = W_R^f(j), \partial Y_R(j)/\partial M(j) = \mu, \text{ and } \partial Y_R(j)/\partial L_R^m(j) = W_R^m(j),$$

implies that the the input demand in rural municipalities is $\theta(j) = [P_R(1 - \beta(j))/\mu]^{\frac{1}{\beta(j)}}$. The partial derivative of $\ln\theta(j)$ with respect to μ and $\beta(j)$ is:

$$\frac{\partial \ln\theta(j)}{\partial \mu} = \frac{-1}{\mu\beta(j)} < 0 \quad \text{and} \quad \frac{\partial^2 \ln \theta(j)}{\partial \mu \partial \beta(j)} = \frac{1}{\mu\beta(j)^2} > 0. \quad (\text{A.9})$$

Equation (A.9) shows that as the price of milking machines declines, the demand for milking machines and/or female labor (i.e., for task- y_1 input) increases. As shown above, this increased input demand will be met entirely by an influx of milking machines, as female wages in the rural sector will fall and marginal female workers will reallocate their labor input to the urban sector. In addition, the cross-partial derivative shows that the aforementioned influx of milking machines, and hence, the first-order displacement effect of milking machines on female labor, will be relatively larger in municipalities with a large $1 - \beta(j)$.

Importantly, we adopt this theoretical insight in our estimation strategy. We capture municipality-level heterogeneity in dairy production prior to the diffusion of milking machines by using the number of milk cows per farm in 1930 (see Section III). As explained in the main text, this captures both formal and informal employment in the dairy sector, and hence, it is a good proxy for $1 - \beta(j)$ in the model. In detail, in our model the factor shares for female labor, milking machines, and male labor in the rural sector are, respectively, $(1 - \beta)\frac{A_R L^f}{A_R L^f + M}$, $(1 - \beta)\frac{M}{A_R L^f + M}$, and β . In the pre-milking machines era, i.e., with $M = 0$, the factor share for female labor in rural municipalities is equal to $1 - \beta$. In other words, there is a one-to-one correspondence between our model's $1 - \beta$ and the pre-milking machine formal and informal employment of women as milkmaids, which we proxy in our empirical analysis with our cross-sectional measure of exposure to milking machines.

The *fourth comparative-static result* is that the adoption of milking machines will affect women relatively more than men in the long term. In short, this is because milking machines will not only displace women from the rural sector, but will also increase their comparative advantage in the urban sector *relatively more* than men's. As a result, women will reallocate to the urban sector at larger rates than men which, as discussed above, will break allocative inefficiencies and raise long-term incomes for women but not for men.

Formally, let $\frac{\eta_i^f}{\eta_i^m}$ be a woman's comparative advantage in the urban sector relative to the comparative advantage of a man endowed with the same skill pair $\alpha_R(i)$ and $\alpha_U(i)$. In

equilibrium,

$$\frac{\eta_i^f}{\eta_i^m} = P_R \beta \left(\frac{(1 - \beta)^{1-\beta}}{\mu} \right)^{\frac{1}{\beta}}, \quad (\text{A.10})$$

which implies that

$$\frac{\partial(\eta_i^f/\eta_i^m)}{\partial\mu} = -P_r(1 - \beta)^{\frac{1-\beta}{\beta}} \left(\frac{1}{\mu} \right)^{\frac{1+\beta}{\beta}} \leq 0. \quad (\text{A.11})$$

The partial derivative in Equation A.11 shows that the adoption of milking machines (i.e., a fall in their price from μ to μ') will increase a woman's comparative advantage in the urban sector relatively to that of a man of similar skill. Hence, this labor-saving technological change will trigger a larger displacement effect and migration out of rural areas for women than for men. This is consistent with the evidence in Section I that the rapid mechanization of farming led to the masculinization of agriculture in Norway, as well as with our empirical results that women's employment in agriculture and migration were relatively more affected by the adoption of milking machines than men's.

Note that, under a Cobb-Douglas production technology, machines used in task y_1 and male labor used in task y_2 are q-complements. By construction, this implies that the wage per efficiency unit of male labor in the rural sector will increase with a fall in the price of milking machines. That said, this positive effect for men is smaller than the wage gains for women who reallocate to the urban sector because $\partial W_R^f/\partial\mu$ is larger in magnitude (i.e., in absolute value) than $\partial W_R^m/\partial\mu$, as long as $\mu > P_R(1 - \beta)$. This condition is satisfied when milking machines are first introduced, as the pre-adoption price of new technologies, here μ_0 , tends to infinity. Importantly, under a more general CES production function that relaxes the q-complementarity between milking machines and male labor, the model can also generate a decline in male wages in the rural sector after the adoption of milking machines, triggering some male migration and reallocation to the urban sector—albeit at a smaller rate than women, as we observe in our empirical results.

Overall, this simple conceptual framework can rationalize our main results that milking machines displaced women from agriculture, pushed them to migrate out of rural areas, and that the effects were stronger than for men, contributing to reduce gender gaps. The model also justifies our exposure design based on using pre-milking machine dairy intensity. Finally, it formalizes the mechanisms described in Section IV.B on how automation can break-up allocative inefficiencies, reinstate labor into jobs requiring higher skills in the urban sector, and generate long-term income gains.

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