Farm Mechanization on an Otherwise 'Featureless' Plain: Tractors on the Northern Great Plains and Immigration Policy of the 1920s

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Abstract

Immediately following World War I, Canadian Prairie farmers adopted tractors more rapidly than did farmers on the U.S. Northern Great Plains. However, Canadian adoption rates lagged in the late 1920s. This change can be linked to a significant divergence in immigration policy; the US introduced restrictions while Canada returned to its prewar openness. The essentially homogeneous nature of this Plain on either side of the border sets up a natural experiment of the impact of immigration restrictions. We test the hypothesis using counties in the U.S. and Canada contiguous with the international boundary.

1 Introduction

It is well known that agriculture was rapidly transformed in the second half of the twentieth century, changes that raised substantially the capital-labor ratio in agricultural production. Emblematic of this capital-labor substitution was the introduction of the tractor as the principal source of motive power. The tractor enabled farmers to increase their productivity because it allowed them to farm more land. As a result, average farm sizes in North America increased from about 140 acres in 1910 to over 400 acres today.

The resulting increase in agricultural labor productivity is readily apparent. The number of farmers in the U.S. peaked in 1910, then accounting for one-third of the workforce. In Canada, even as late as 1941, one-third of the male workforce was engaged directly in agriculture. Today, less than 3% of the labor force of Canada and the US is employed in agriculture and that small labor force farms a land area only modestly smaller than it was at its peak. That so few can farm so vast a landscape resulted, in part, from the substantial scale effects from tractor usage.

The adoption of new technology may be affected both by market forces influencing commodity and factor prices, and institutional and political forces shaping the environment in which factor and commodity prices are determined. The adoption rate of the tractor in its initial phase responded surprisingly elastically to changes in factor markets resulting from legislation affecting institutions. Specifically, the influence of immigration policy had an observable impact on the diffusion of the tractor on the Northern Great Plains. The tractor is a labor-saving technology and as such, the value of the labor saved by its adoption depended on the expected supply of labor to agriculture. This labor supply was influenced by changes in immigration policy adopted during this period of the initial wave of tractor adoption.

Tractors were adopted initially in much greater numbers by farmers of the Northern Great Plains. But even among this geographically homogeneous group, adoption rates differed systematically across the region. Canadian Prairie farmers were particu-

larly eager to adopt tractors initially. From World War I until the mid-1920s, Canadian Prairie farmers adopted tractors more rapidly than U.S. farmers on the Northern Great Plains.

In the second half of the 1920s, however, the geographical pattern of adoption rates was reversed and tractors were adopted more rapidly on the U.S. Northern Great Plains. What makes this oddity particularly interesting is that this change in adoption rates on either side of the border is coincident with changes to immigration policy in both Canada and the U.S.—changes that served to tighten labor supply in the U.S. but loosen it in Canada. This suggests that in responding to this policy change, the diffusion of this new technology was quite sensitive to labor market conditions.

The influence of labor market conditions on tractor adoption can be treated as a natural experiment of history. The differential changes to U.S. and Canadian immigration policy in the 1920s and their impact on labor markets can be considered the treatment. This treatment effect can be isolated due to the homogeneous nature of farms on the Northern Great Plains.

We examine the diffusion of tractors on the Northern Great Plains from Kansas through Alberta before and after the changes to immigration policy were implemented. To further control for systematic differences among regions, a very specific subset of counties lying contiguously on both sides of the border is isolated and the diffusion pattern examined. The results suggest that indeed U.S. and Canadian farmers on essentially identical farms were influenced by differing labor supply conditions, and their responses differed in ways consistent with the labor conditions they faced.

2 Tractor Adoption on the Great Plains, on Both Sides of the International Border

The internal combustion engine was introduced into tractors only at the beginning of the twentieth century and initially the tractor was not particularly popular with farmers.[1] The first impetus to their diffusion was the labor shortage due to World War I. From World War I until the Great Depression, farmers in the U.S. and Canada adopted tractors enthusiastically. In 1915 there were 25,000 tractors on farms in the U.S.; by 1920 there were almost 250,000; and approximately 1 million were reported in 1930 (Carter et al., 2006, series Da623). As tractors were initially particularly well-suited for the prairie, farmers on the Great Plains were first to adopt. While only approximately 15% of farms in the U.S. had adopted a tractor by 1930, on the Northern Great Plains the adoption rate was one-third.[2]

The Great Plains were best suited to tractor adoption in this period because farms were much larger on average. As well, because the frontier of new settlement was a grassland, farmers had potentially large farms free of trees from the outset. The use of a tractor increased the area of land a farmer could prepare and harvest within the seasonal constraint.

The use of a tractor sped up operations thereby allowing farmers to do more per season. Farmers could plow more land and plant more seed in the spring; and could then harvest the larger crop in the fall when it ripened. As a consequence of speeding up field operations, farmers using tractors had more time for additional work like raising livestock or providing custom work to other farmers. (Martini and Silberberg, 2006)

As a tractor represented a fixed cost, a sufficiently large scale of operations was re-

[1] They were very heavy, underpowered and had limited use in fieldwork other than plowing. They were used as a source of power for equipment.

[2] These northern Great Plains states considered are Minnesota, North Dakota, South Dakota, Montana, Nebraska and Kansas. Nebraska and Kansas are not strictly similar to the other states as winter wheat is the principal small grain grown; whereas spring wheat is grown from South Dakota north. Nevertheless, techniques did not differ too significantly.

quired to justify the cost of tractor purchase (Sargen, 1979; Clarke, 1994; Ankli, Helsberg, and Thompson, 1980; Lew, 2000). Farms of the Great Plains were large and relatively homogeneous. Average farm size in 1920 was 140 acres for the entire U.S. while for the six Great Plains states average farm size was more than double at 330 acres. Canadian Prairie farms were even modestly larger, averaging 345 acres in 1921.

Farmers on the Canadian Prairies were initially relatively keen to adopt the new technology; and tractor adoption on the Canadian Prairies proceeded more rapidly than on the U.S. Great Plains after World War I. But that pattern persisted only until the mid-1920s. In the second half of the decade, adoption on the U.S. Great Plains accelerated, overtaking Canadian adoption rates.

Tractor adoption is illustrated in Figures 1 and 3 from 1920, when tractor counts were first recorded by state and province, through 1960 when the process of diffusion was complete. Figure 1 illustrates the proportion of farms adopting tractors in the three Canadian Prairie provinces: Manitoba, Saskatchewan and Alberta; and six Great Plains states: Minnesota, North Dakota, South Dakota, Kansas, Nebraska, and Montana. In 1920 there are four states and provinces leading the adopters: North Dakota, South Dakota, Manitoba and Saskatchewan. By 1930, the three Canadian provinces are at the bottom, with two of three Canadian provinces having the fewest farms adopting, and Saskatchewan only slightly ahead of Minnesota, last among states. All adoption rates converge by 1950 as the adoption rates by farmers on the Canadian Prairies catch up in the half-decade from 1945–1950.

[Figure 1 about here.]

Changes in the number of tractors per farm from 1925 to 1930 for a subset of the northern plains are shown in Figure 2. Only the counties in U.S. states and census divisions in Canada that are on the international border or are immediately contiguous with a border county or census division are included. The sample of counties and census divisions runs from Lake of the Woods in the East to the foothills of the Rocky Mountains

in the West. The general shading illustrates the shift in adoption from Canada to the U.S. over the second half of the 1920s.

[Figure 2 about here.]

Figure 3 illustrates the overall average adoption rates for these specific border counties and census divisions. Tractor adoption rates by county are not reported in the 1925 U.S. Census of Agriculture. As an approximation for 1925 only, we report instead the number of tractors adopted rather than number of farms adopting. The number of tractors adopted exceeds the number of farms adopting tractors as some, typically larger, farms report more than one tractor. The actual number of farms adopting tractors in the U.S. counties in 1925 will be fewer than shown in the figure.[3] Even with this boost to the U.S. numbers, the adoption rate for the Canadian census divisions is greater than for U.S. counties in 1925. Canadian Prairie farmers were more likely to adopt tractors by 1925. After 1925, even for census divisions nearest the international boundary, the delayed tractor adoption pattern is apparent. While having been keen early adopters, Canadian Prairie farmers had slowed their adoption of tractors compared to farmers in the U.S. states immediately to their south by 1930.

[Figure 3 about here.]

Tractor adoption rates are shown in more detail for the early period of 1920–1930 in Table 1. In 1920 and 1925, tractor adoption rates were as high or higher on the Canadian Prairies as on the U.S. Great Plains. In 1920, Manitoba had the highest adoption rates—both in tractors per farm and in proportion of farms with tractors—followed by the Dakotas and Saskatchewan. Alberta lagged behind the leaders and fell slightly below average on both measures, but it was the most recently settled region.

[3]The average adoption rate for these three border states in 1925 is 15% while the rate reported in figure 3 is 21%. The equivalent adoption rate for the three Prairie provinces in 1925 is 26%.

There was some shift in adoption rankings in 1925, but farmers in Saskatchewan and Manitoba along with those in North and South Dakota had still adopted most rapidly.[4]

[Table 1 about here.]

The divergence in adoption rates between countries must be due to diverging expectations by Canadian and U.S. farmers of profitability of using tractors. A tractor is a durable good whose profitability for a farmer depends on the purchase price, the interest rate, and expectations of the price of inputs for the tractor and for the competing technology it is replacing, horses, over the expected service life of the asset. The input to tractor usage is gasoline; the input to horses is feed and labor.[5] Feed is a joint product of production; using horses implies a reduction in output yields for the use of crops and land to feed horses. In the short run, for a fixed farm size, the higher the price of output, the greater the opportunity cost of using horses because part of a fixed land endowment is used for feed.[6] Differences in the distribution of farm sizes between regions could also influence tractor adoption. As well, any policy differences between the U.S. and Canada that influenced any subset of these factors could have yielded the divergent pattern in tractor adoption between the two countries.

We hypothesize that the only significant change in policy between the two countries whose timing matches the pattern of tractor adoption is the divergence in immigration policy. Wylie (1989) and Keay (2000) point to the difference in wage rates between Canada and the U.S. in inducing different biases in technological change in Canadian industry during this period, specifically identifying immigration policy divergence between the U.S. and Canada as responsible. Immigration policy influenced wage rates for

[4]Tractor counts are drawn from Census of the Prairie Provinces and the Census of Canada for Canada, and the Census of Agriculture for the U.S. Census dates will be identified as 1920, 1925, ..., 1960 in the text though the Canadian Census dates are actually for 1921, 1926, ..., 1961 and U.S. census dates are 1954 and 1959, not 1955 and 1960.

[5]The actual purchase price of a horse is small relative to their cost of operation (Lew, 2000).

[6]Horses must be fed year round, but when not working horses can be kept on a diet mostly of hay which can be grown on land that is less productive. Working horses need more nutrition, and therefore output must be diverted as an input to the power source.

hired labour and for farmers' opportunity cost of time.

Before addressing the impact of immigration, we will first review the other factors that were important to the decision by a farmer in choosing a tractor over retaining horses. While tractors operate on gasoline, the relative cost of gasoline in the total cost of using tractors is very small. It is the financing of the tractor, or the opportunity cost of the large investment the tractor represented, that is the major burden. The pattern of initial rapid adoption by Canadian farmers in the early 1920s followed by lagging adoption in the later 1920s could be due to changes in the relative purchase price of tractors, productivity of models available in Canada and the U.S., or interest rate changes. We address each of these three possibilities.

One policy difference between Canada and the United States that could have differentially impacted prices of technology was commercial policy. Tariffs in Canada on imported agricultural machinery were high, averaging almost 20% before World War I, and Canada imported much of its agricultural machinery, and all of its tractors in this period. However tractors valued under $1400 were tariff-free beginning in 1918.[7] As well, tariff rates on agricultural equipment were generally declining through this period, with the largest declines in tariff rates in 1924.[8] Because farm equipment in Canada other than tractors was more expensive due to the tariff, Canadian farmers likely substituted labor, land and horses for machinery capital (Norrie, 1974). But while the average price of farm equipment was undoubtedly higher in Canada, the difference was shrinking over the period (Canada, 1969). The decline in average tariffs, particularly the large reductions in 1924, should have induced a more rapid adoption of technology, including tractors, by Canadian farmers if demand for machinery was complementary with demand for tractors. Tariff changes move in the wrong direction so we discount them as the explanation of the pattern of lagging adoption of tractors by Canadian farmers in

[7]The large majority of tractors adopted were in this category.

[8]Rates on harvest equipment fell from 10% to 6%, tillage equipment from 12.5% to 7.5%, and plows from 15% to 10% (Phillips, 1956).

the second half of the 1920s.[9]

Despite changes in tariffs, it is possible that agricultural equipment was more expensive in Canada. Canada was a small market compared to the U.S. and agricultural equipment production and distribution was oligopolistic.[10] However, as reported to the Parliamentary Committee on Farm Implement Prices while there was some premium paid by Canadian farmers for tractors in Canada over the prices in the U.S., it was relatively small (Canada. House of Commons, 1937). The Committee reviewed prices of several popular models of tractors selling in Canada and the U.S., finding that Canadian prices were typically only about 2-3% higher than prices in the U.S. in the late-1920s, and even lower in some years for certain models.[11] The price gap widened in the early 1930s as prices in Canada remained stickier than in the U.S. A price differential of a few percent probably did not make a large difference, but again it is the direction of the change, not the price level itself, that is critical. Prices for tractors in Canada had been falling through the the 1920s. And the Committee's evidence suggests that technological innovations available on U.S. models were also available in Canada. The same tractor models were being sold in both countries.

Borrowing costs may have differed, and higher interest rates in Canada may have slowed Canadian adoption. Canadian farmers certainly complained about the availability of credit and Canadian banks were prohibited by law from accepting real estate as collateral for a loan.[12] However, as early as 1917, the provincial governments of Manitoba and Saskatchewan introduced farm loan programs and offered loans to qualified farmers at rates of approximately 6–6.5% (Bates, 1939; Easterbrook, 1938, p. 102, 108–

[9]Tariffs on all agricultural equipment were eliminated entirely in 1944, so may very well help explain the rapid catchup in the early post-World War II period illustrated in figures 1 and 3.

[10]In the 1930s, both Canada and the U.S. undertook official investigatioU.S. Department of Agriculturens of the trade practices of the agricultural equipment industry. (Canada. House of Commons, 1937; U.S. Federal Trade Commission, 1938)

[11]These are manufacturers suggested retail prices; dealers may have sold for less, or more.

[12]While farm foreclosures became much more frequent on the U.S. Northern Great Plain, they were not nearly as large a problem in Canada during this period. See Lew and McInnis (2007) for a discussion of this difference. For U.S. mortgage foreclosures see Alston (1983) and for farm distress during the 1920s see Johnson (1973/1974).

9). Equipment purchases financed by equipment manufacturers were available at higher rates, approximately 8–9% in the late 1920s, 6–7% during the 1930s (Canada. House of Commons, 1937, p. 464–5). Farm indebtedness is not reported in the census in Canada until 1931.

Because tractor usage required a sufficiently large scale of operation, it is possible that there were a few large farms in Canada, and the early adoption lead in Canada was due to adoption on large farms. Table 2 reports average farm sizes.[13] From 1920 to 1925 average farm size declines slightly in five of the Northern Great Plain States and in Manitoba, while increasing for both Saskatchewan and Alberta. From 1925 to 1930, farm size increases for every state and province. Increases are a bit larger for the Dakotas while in Montana, the large increases reflect increases in pasture land more than cropland. The implications of changes in farm size will be addressed in the formal analysis below.

[Table 2 about here.]

It is more difficult to draw conclusions about the distribution of farms by size since size categories reported in the census differ by year and by country. In 1920, 76% of farms in North Dakota and 71% of farms in Montana were larger than 259 acres, while 65% of farms in Saskatchewan were larger than 299 acres. In 1925, 37% of farms in Montana and 28% of farms in North Dakota were larger than 499 acres will only 19% of farms in Saskatchewan were larger than 480 acres. However, by 1930, while 48% of farms in Montana were larger than 499 acres, in North Dakota 34% were equally large, and in Saskatchewan, 33% were larger than 479 acres. Since the top end of the distribution of farm sizes for both North Dakota and Saskatchewan are very similar by 1930, it does not seem that the differences in tractor adoption depended on a subset of larger farms in the U.S. The shift in distribution of farm sizes was toward larger farms over the decade of the 1920s in Canada.

[13]Source: Census of Canada, 1921, 1925, 1931, 1961; U.S. Census of Agriculture, 1920, 1925, 1930, 1959

During the 1920s, the Canadian and U.S. federal governments responded to post-war wheat price volatility by encouraging cooperative marketing, but these modest policy initiatives were quite similar in both countries and so were unlikely to have caused diverging responses (Alson, Rucker, and Weidenmeir, 2000). There are no other policy differences that alter any of the factors to the farmers choice of adopting tractors. During the Great Depression, farm policy itself took sharply differing paths in the U.S. and Canada. New Deal policies, particularly the Agricultural Adjustment Act, played an important role in increasing tractor adoption in the U.S. through lower interest rates and output price supports (Clarke, 1994; Sorensen, Fishback, and Kantor, 2009). The effects are readily apparent in the continued increasing adoption rates of farmers in U.S. states over the decade 1930–1940. And in comparison to the 1930s, the increase in adoption rates by U.S. farmers in the last half of the 1920s is even greater than in the decade of the New Deal. But during the 1920s, farm policy had yet to evolve into its modern form, despite increasing pressures for such changes.[14] The difference in adoption rates of farmers in the U.S. and Canada in the latter half of the 1920s was not due to farm policy divergence.

We can find reference to no other policies that would otherwise have changed expectations of the prices of tractors, gasoline, or of interest rates. We do have evidence that policies on supplying labor to farmers did differ between Canada and the U.S., and the differences were greatest during the mid- to late-1920s. Changes to immigration policy correlate closely with the change in adoption patterns exhibited above. The U.S. implemented restrictive quotas by 1924 while Canada adopted policies to increase immigration in 1925.

In order to support our hypothesis that diverging immigration policy affected expectations of wages, we now turn to a detailed look at farm labor demand and supply. The important consideration is that investment by farmers in a durable asset implied

[14]See for a discussino of wheat policy in this period for the U.S. and Canada. They conclude it had no affect on prices

an evaluation of future prices, not just current prices. Because tractors are labor-saving, expectations of future wages is critical, so policy affecting labor supply into the future is particularly important. With an immigration policy in place, it is reasonable to conclude that farmers would have had expectations of the impact of that policy on wages into the near future and would have based investment decisions around those expectations.

3 Immigration Policy Divergence and Farm Labor Supply

It was in the 1920s that Canadian and U.S. immigration policy diverged; as the U.S. tightened, while Canada loosened immigration restrictions. The changes in immigration policy impacted farmers' assessment of expected labor supply. Farmers in Canada anticipated continued inflows of labor while farmers in the U.S. realized labor supply would become increasingly inelastic. In other words, the expectation of future labor costs would have diverged, with U.S. farmers expecting wages to rise more rapidly than Canadian farmers.

The shift in immigration policy came in a sequence of changes, and by 1925 the differences were in place. And it is the latter half of the 1920s in which we observe shifts in tractor adoption rates in Canada and the U.S. The U.S. introduced quotas on immigration with the Emergency Quota Act of 1921. Total immigration under the quota was set at 3% of the total number of foreign-born as recorded in the previous Census, which amounted to about 350,000. This was about a third of pre-quota annual immigrant inflows. But this quota was revised downward in the Immigration Act of 1924, reducing the annual flow by half again to about 165,000.[15] In other words, over a period of four years, the immigration rate to the U.S. fell to 15% of its pre-quota rate. The quota was

[15] Under the 1921 law, admission by national origin was based on each country's share in immigration in the Census of 1910. In 1924 the reference year was moved back the 1890 Census giving greater weight to Western Europe while reducing the base. This increased share of the quota for western European countries did not always get filled so the effective reduction of immigration exceeded the nominal reduction implied by the quota.

ultimately lowered further, to 150,000, originally to have gone into effect in 1927 but delayed until 1929.

Canadian immigration policy remained relatively restrictive in the early 1920s, but was liberalized by mid-decade. Superficially, Canadian policy of the 1920s appeared similar to U.S. policy. Canada granted preferred access to Western Europeans while restricting access to Southern and Eastern Europeans.[16] But Canadian policy did differ significantly in that there was no total quota; overall immigration rates were left to the discretion of Cabinet (Green, 1995). And while the new policy explicitly discriminated against those from Southern and Eastern Europe—termed the non-preferred sending countries—there was a significant exception. Immigrants from non-preferred countries destined for agricultural work on the Prairies were admissible (Kelley and Trebilcock, 1998, p. 187-89).[17] In other words, the condition of admission to Canada for an immigrant from a non-preferred country was a requirement they move to the Prairie West as an agricultural laborer.

This exception became the core of a policy introduced in 1925, the Railway Agreement, which was largely responsible for the surge in immigration to Canada in the latter part of the decade. From 1925–30 the Canadian government authorized the two Canadian railway companies to act as its agents in admitting immigrants.[18] The railway companies were given authority to screen and admit immigrants subject to the restrictions in place.[19] Essentially, they were allowed to recruit agricultural labor in Eastern Europe for the Canadian West. The overall effect of this policy was decidedly liberal;

[16]Canadian treatment of Asian immigration matched U.S. policy. It was already highly restrictive and therefore it is only European immigration policy that is relevant.

[17]There is a parallel clause in the U.S. policy in that agricultural workers were to be granted priority within a country's quota.

[18]The railways themselves were large landowners, having been granted large tracts on the Prairies as incentive to 'build ahead of demand' (Lewis and Robinson, 1984). Avery (1995) argues that the railway agreement was introduced at the behest of capital to keep wages low. He is specifically identifying the resource extraction sectors. As well, Green (1996, 1994) suggests that farmers would have benefited through higher land rents and lower wages.

[19]There was public suspicion that the railway companies were not adhering to the requirement that immigrants be admitted only if destined for the Prairies so that in 1927 the terms of the agreement were modified to require that immigrants provide explicit proof of employment in the West prior to admission.

the inflow of immigrants accelerated sharply after 1925 with the adoption of the Railway Agreement. The decade of the 1920s turned out to be the period of the second largest immigrant inflow rate as a share of the resident population.[20]

These policy changes affected the supply and destination choice of immigrants to Canada. Eastern European immigrants were explicitly directed to settle in the Prairie West. During the earlier Wheat Boom era, only a minority of immigrants admitted had intended to settle in the Prairie West (Green and Green, 1993). But during the 1920s immigrant destination choice did shift to the Prairies. Evidence of this shift in destination choice, illustrated in Figure 4, implies an increase in the supply of labor to the Prairies. It is in this context that we argue that farmers had a reasonable expectation of a continued availability of labor and we argue this induced them to delay adopting labor-saving technology as rapidly as farmers just to the south across the international border facing an entirely different expectation about the availability of farm labor into the future. The expectations of labor supply is particularly important for northern agriculture due to the extreme seasonal peaks and troughs in labor demand through the year.

[Figure 4 about here.]

4 Seasonal Labor Demand and Regional Labor Market Integration

There are two features of agriculture on the Northern Great Plains that are relevant to the problem of labor market adjustment to agricultural labor demand: the seasonality of labor demand coupled with harvest volatility, and the remoteness from urban industrial labor markets. Both of these features complicate the labor supply available seasonally to the geographically remote Northern Great Plains. And in addressing this issue of

[20]For Canada, the absorption rate, or ratio of immigrant inflows to resident population, in the 1920s ranks second only to the rate of the Wheat Boom era of 1896-1914.

remoteness, the Canadian government adopted policies that made Prairie farmers dependent on the in-migration of a labour supply.

Agricultural labor demand is highly seasonal, and its seasonality is most volatile on the Northern Great Plain. Farms on the Northern Great Plain were less diversified away from field crop production, and were even undiversified in the grain crops grown.[21] That meant that labor demand peaked twice: once in the spring when the ground was being prepared and seeding was taking place, and again even more strongly in the fall once the crop ripened. Delay at harvest meant increased risk of weather damage to the unharvested crop.[22] But without much livestock, demand for labor during the rest of the year was much lower.

Figure 5 illustrates the spike in labor demand on the Canadian Prairies during the harvest months of August and September.[23] As a benchmark, labor demand is illustrated for the province of Ontario. Farming in Ontario is generally mixed so Ontario farm labor demand is less seasonal.[24] Figure 5 illustrates the fundamental difference in the economics of agriculture on the Prairies. The spike in demand for additional labor at harvest is clearly visible.[25] In contrast, there was only a very modest seasonality to the demand for labor in Ontario, the increase was not even a doubling, and the demand was spread over the full growing season.

The seasonality of labor, along with the undiversified nature of the rural economy of the Northern Great Plains, precluded the availability of a local labor supply suffi-

[21]Generally the farther north and west the less diversified was farm output.

[22]Small grains could not remain in the field once ripened as they were subject to damage from weather. This further exacerbates the peak labor demand problem. In contrast, corn can be harvested more gradually as it is not as sensitive to damage in the field.

[23]Data are from the Labour Gazette, reported monthly (Canada. Department of Labour, 1923/1932). These are job listings with the Employment Service of Canada, part of the Department of Labour, for employers needing labor. Data were only reported monthly by province beginning in October 1922.

[24]Ontario had approximately 80% the number of farms as the Prairies, but farms were smaller, with only about 30% of the improved acreage of the average Prairie farm.

[25]There was demand for jobs categorized either as "personal service" or "household service" that had virtually no seasonal component and accounted for virtually all the demand for labor listed over the winter. The increase in labor demand at spring is also evident and was very modest relative to the harvest demand spike.

ciently large to accommodate the spike in demand at harvest. Temporary labor was essential, particularly at harvest when waiting meant an increased risk of crop damage. Because crop size varied with weather, long-range forecasting of labor demand was not possible. And harvest labor demand was rapidly increasing during the 1920s in Montana, Saskatchewan, and Alberta due to increased settlement and increased wheat output.

[Figure 5 about here.]

There was no formal system adopted to coordinate the geographic redeployment of labor to the harvest in the U.S. According to the traditional story, labor migrated north from Texas, following the progression of the harvest season up the latitudes. This supposedly provided sufficient employment to labor while meeting the labor demand spikes. While there was a small group of professional harvesters who made their living this way, the majority of workers were in fact from the industrial centers who took temporary employment as harvesters during the harvest season (Lescohier, 1922). As well, the seasonal migratory movement of labor itself was predominantly along east-west axes—from urban centers west into the wheat belt of similar latitude—not from south to north as the traditional story would have it (Lescohier, 1924, p. 19-21).[26]

Labor market clearing worked to the extent that the supply of labor in the midwestern industrial centers was integrated with and matched the harvest demand on the farm. The labor supply choice of midwestern industrial workers was influenced primarily by factors more specific to their own industry and local to their region while labor demand was highly volatile due to weather, and could differ dramatically within regions. (Lescohier, 1922, 1924)

In Canada, formal coordination of the movement of labor to the harvest on the Prairies was implemented in the 1890s with the introduction of the harvest excursion

[26]This south-to-north pattern of migration became more apparent when the harvest was further mechanized with the introduction of the self-propelled combined harvester-thresher, or combine. During the 1940s, teams of combine operators migrated from Texas north following the grain harvest (Isern, 1981).

trains as an explicit response to the lack of surplus harvest labor on the Prairies (Thompson, 1978; Haythorne, 1933). Compared to the U.S., there was no easily accessible pool of urban industrial labor geographically near to the Canadian Prairies. Because of the recency of its settlement, the Canadian Prairies lacked large urban centers. Whereas both Minneapolis and Chicago are relatively near the Northern Great Plain states, there were no cities equivalent to Minneapolis or Chicago near the Canadian Prairie provinces. Winnipeg is the closest proxy for the Canadian Prairies, but with a population of only 220,000 in 1931 it was hardly the same urban labor pool as even Minneapolis/St. Paul with 750,000, let alone Chicago with over 4 million.

The difference in labor supply and its effects on tractor adoption is premised on the Canadian Prairies not being linked to U.S. midwestern labor markets. Had the border not mattered, labor should have been able to diffuse from midwestern urban centers throughout the Northern Great Plains.[27] Yet there is no evidence that labor demand on the Canadian Prairie was met by supply from the U.S. There is no mention by either Haythorne (1933) or Lescohier (1924) of cross-border labor flows. Farmers migrated in large numbers from the U.S. to Canada prior to World War I, but as homesteaders, not as laborers.

There is some direct evidence of the lack of cross-border harvest labor flows. In the early 1920s, the Canadian Department of Immigration reported specifically on the movement of harvest labor into Canada from the U.S. (Canada. Department of Immigration and Colonization, 1920–1925, 1924/25–1930/31) The reports mention admission into Canada of approximately three- to four-thousand laborers from the U.S. in 1921 and 1922.[28] But the numbers decline to 655 harvest laborers reported entering from the U.S. in 1924; and there are no reported cross-border flows of harvest labor into Canada after

[27] And immigrants to Canada should have been able to cross into the U.S. To avoid this problem, the Immigration Act of 1924 explicitly left open U.S. borders only to those having lived at least five years in their country of origin in the Western Hemisphere.

[28] In 1923 the domestic harvest labor supply was supplemented with almost twenty-two thousand harvesters from the U.K. and the U.S. without a specific breakdown by country of origin.

1924, just when the demand for harvest labor was increasing due to the increased size of the wheat harvests.[29] Had cross-border labor flows increased in the latter half of the 1920s, it would seem reasonable to assume the Department of Immigration would have reported them given that they are reported earlier in the decade.[30]

The linking of western and eastern labor markets in Canada created additional problems.[31] Effectively, demand for labor by Prairie farmers was competing with harvest labor demand throughout Canada, which because of geography tended to occur essentially simultaneously across the country (Haythorne, 1933). This ultimately constrained the domestic capacity for Canada to expand Prairie settlement and drove the demand for immigrant labor. In the U.S., by contrast, the supply of agricultural labor from city to farm was largely an intraregional movement (Lescohier, 1924). Harvest labor demand was therefore met from industrial labor supplied within the general region.

In effect, the incentive for farmers of the Canadian Prairie to mechanize and save on scarce labor were greater than for similar farmers of the U.S. Northern Great Plains. Farmers on the Canadian Prairies lacked a local source of surplus harvest labor and had to compete for labor inter-regionally. And in response, Canadian Prairie farmers had indeed been more aggressively adopting tractors into the early 1920s. With demand for harvest labor increasing during the 1920s, even with the formal mechanisms for coordinating inter-regional movement of labor in place, supply of surplus seasonal labor sourced domestically could not keep pace. The Canadian response was to source immigrant labor—a reasonable solution in light of the large pool of available labor in Eastern Europe now excluded from the U.S. Further, immigrants were admitted only if destined for the Prairie West. The adoption of an open immigration policy induced Canadian

[29]Evidence cited by Isern (1981) indicates that very few combine teams moving up the latitudes in the 1940s continued across the border; further evidence that the border did act to substantially reduce the diffusion of labor flows.

[30]A lightly-guarded border would not have posed a problem to some flows of labor, but a lack of reporting at the border suggests that the flow was likely modest in relation to labor demand.

[31]Coe and Emery (2004) provide evidence that Canadian labor markets were highly integrated during this period.

Prairie farmers to continue to rely on a inter-regional flow of harvest labor and thereby, relative to farmers in the U.S., delay further farm mechanization despite the otherwise greater incentive for them to mechanize.

5 Testing the 'Featureless' Plain Hypothesis

5.1 Immigration and Wages on the Prairies

The empirical strategy is first to establish that immigration had an impact on Prairie wages. Goldin (1994) has shown the impact of immigration on wages for the U.S., Greasley, Madsden, and Oxley (2000) have shown the impact of immigration on wages in Canada from 1870–1913, while Green (1994) has shown its impact on Canadian Prairie farm wages from 1900 to 1930. The impact of immigration policy is hypothesized to have delayed adoption of capital-intensive farming methods—the use of tractors—by allowing farmers to substitute labor for capital where labor was available sufficiently reliably and inexpensively. The question to be addressed is whether or not factor prices were indeed affected by policies of immigration and therefore could potentially influence tractor adoption.

5.1.1 Wages and Immigration – National Labour Market

Goldin (1994) has demonstrated that immigration to the U.S. prior to implementation of the quotas in the 1920s did lower wages across most industries, and in some cases fairly significantly. She estimated the relationship as follows:

$$\ln\left(\frac{wage_{j,t}}{wage_{j,t-1}}\right) = \alpha + \beta\left(F_{j,t} - F_{j,t-1}\right) + \varepsilon_j$$

where $F_{j,t}$ is the immigrant proportion of the population at time t in city j, and $wage_{j,t}$ is real wages at time t in city j. She analyzed the responsiveness of real wages to changes in

the proportion of immigrants in various cities and for various industries, and concluded that immigrant inflows did lower wages.

The first piece of evidence to add to Goldin's is to show that immigrant inflows influenced wages in Canada during the period of mass immigration, 1900–1930. Wage data for Canada are much thinner. The Department of Labour published wage rates for various trades for thirteen cities in Canada for the period 1900–1930, but not all the data have proved reliable.[32] To run Goldin's test, we use wages for machinists in the metal trades, a series that has sufficient geographic and temporal coverage. Wage response for a skilled trade to changes in immigration would better reflect the impact immigration would have on the labour market more generally since fewer immigrants would likely be directly substitutable for domestic-born labor in a skilled trade.

We utilize data at four points in time: 1901, 1911, 1921 and 1931. To convert nominal wages to real, we use Emery and Levitt's intercity intertemporal price index, covering thirteen cities across Canada (Emery and Levitt, 2002).[33] The data yield a panel of three decadal time-period comparisons for thirteen cities.

We estimate the regression above under two assumptions: pooled and fixed effects by city, and the results are virtually identical in either specification. The coefficient on β, the elasticity of the wage response to changes in immigrant proportion of the population, is approximately -1.0 and is statistically significant at the 1% level. A 1% increase in the immigrant proportion of the population results in a decline in wages of approximately 1%, a result well within the range of responses found by Goldin (1994) for the U.S. prior to the 1920s.

[32]MacKinnon (1996) argues that the reported wages for laborers are too high, and were likely based on fair wage contracts for unionized labor but considers reported wages for skilled labor accurate (Canada. Department of Labour, 1920/1931).

[33]The thirteen cities are: Halifax, Saint John, Quebec, Montreal, Ottawa, Toronto, Hamilton, Winnipeg, Regina, Calgary, Edmonton, Vancouver and Victoria. Population and Immigrant numbers for the thirteen cities are taken from the published Censuses of 1911, 1921 and 1931. Immigrant numbers by city are not reported in the 1901 Census, so the public use census sample is used (Canadian Families Project, 2002).

5.1.2 Agricultural Wages and an Interregional Price index

Given these results, it seems reasonable to assume that immigration policy could have affected expectations for wages, and therefore could have influenced investment decisions in labor-saving durable assets. Focusing directly on agricultural labor, Green (1994) shows that immigration did impact Canadian Prairie farm wages for the period 1900–1930. A cursory look at wages on the three Prairie provinces and the six states of the northern Great Plains, Figure 6, does not reveal much difference between countries.[34] If anything, wages on the Canadian Prairies appear to be relatively high during the 1920s and early 1930s.

[Figure 6 about here.]

That Canadian wages should be as high or higher than wages in the U.S. is not consistent with the general view that protection and a small market in Canada with larger relative inflows of labor due to a more liberal immigration policy served to lower wages (Dales, 1966; Easton, Gibson, and Reed, 1988). Studies like Engel and Rogers (1996) highlight the impact of the border by showing that prices in Canada tended to be much higher than in U.S. locations separated even by modest distance, and Dales (1966) shows that Canadian nominal wages were high because goods prices were inflated by the tariff. Therefore we need an interregional price index to make meaningful comparisons of real wages across regions, including regions separated by the international boundary. Emery and Levitt (2002)'s index would be useful but it is an urban index. And it is for Canadian cities only. To our knowledge, there are none available for an international comparison of Canada and the U.S., particularly for rural regions.

There is one source of data that is available by state and province and reflects rural costs. Farm wages are reported with and without board. Room and board is often necessary to attract workers to a rural location where alternative living facilities may

[34] Wages in Canada converted to $U.S.

be difficult to find, and likely some distance from the farm, particularly important as a workday could be long when the weather is favorable. By assuming that the difference between wages with and without board reflects the cost of board, we can derive a rough cost-of-living index. Because wages with and without board are reported for all Canadian provinces from 1914 and for all U.S. states from 1910, this index has the necessary geographical and temporal scope.

Assuming that board represents a fixed consumption bundle common across all states and provinces, then differences in the value of board represent differences in the cost of living in different regions. The largest component of room and board was meals (Folsom, 1931). It is reasonable to assume that the caloric content would have been relatively constant across regions and over time. And given the focus only on the Great Plains and Canadian Prairies, it is more likely that the uniformity of food produced or available on farms within this region would have been greater than for a comparison across all regions of the U.S. and Canada.

Of the other main components, undoubtedly there was variation in the quality of the room and shelter components. Farm workers typically had access to the farm house. Some had rooms in the house while others may have stayed in a bunkhouse. It is likely that there was variation in quality of shelter within each state and province. The degree of variation across states and provinces is unknown, but the focus only on the Northern Great Plains and Canadian Prairies may reduce that variation. But even with differences in average quality of shelter by region, as long as those quality differences did not vary systematically over time, then a cost of living index will reflect changes in prices over time despite differences in the price levels.[35]

[35]It is possible that in the newly-settled regions, particularly northwestern Saskatchewan and much of Alberta, as well as Montana, housing quality was changing as new farmers added building improvements more rapidly than settled farmers. Census data evidence on the changes in value of farm buildings per farm, deflated by a cpi, may be illustrative even though building values would capture the expansion of the stock of all farm buildings and not just reflect the quality of the farm house. As well, the census timing makes a comparison a little misleading because 1920 and 1921, and 1930 and 1931 were years with large differences in inflation rates. Nevertheless, these data show that the value of buildings per farm for the two most recently settled Canadian prairie provinces increased from 1911–1921 while they decreased

Real wages calculated as the nominal farm wage, monthly without board, deflated by an index of the cost of board, are illustrated in Figure 7. They show a pattern of wages that are consistent with both the immigration patterns and the evidence of tractor adoption. Real farm wages in Canada are lower prior to WWI. During the War and the high wartime inflation, Canadian wages rise into the range of wages for some states, particularly North Dakota and Montana. By 1922, Canadian farm wages have fallen well below U.S. farm wages, and remain well below until 1939 with Canada's entry into World War II. After the war, Canadian farm wages remain lower than U.S. farm wages, but by the mid-1950s, while still lower than average, they are well within the range of U.S. farm wages.

[Figure 7 about here.]

As a check on the plausibility of these estimates, we recalculate real farm wages for Canada using the Emery-Levitt interurban index rather than the Board cost index. The deflator constructed using the Board costs show a higher cost of living than does the Emery-Levitt index as illustrated in Figure 8. And the largest gap is in the 1920s. To illustrate further the impact, farm wages in Canada deflated using the Emery-Levitt index are shown with farm wages in the U.S. deflated using the index of farm board costs in Figure 9. Using the Emery-Levitt index reduces, but does not eliminate the difference in real wages between Canadian provinces and U.S. states. Wages in Manitoba in the 1920s and 1930s remain much lower, while wages in Saskatchewan are also lower than U.S. farm wages, but by less of a difference. Real wages in Alberta are relatively high

for Manitoba and for four of the six U.S. Great Plains states for the period 1910–1920. That pattern is consistent with the expansion of building stock on farms on the newly-settled Canadian Prairie provinces. For the next five year period, building values per farm rose a little over 4% per annum for Alberta and Saskatchewan, and about 3% per annum for Kansas, Minnesota, Nebraska and North Dakota. From 1926–1931 building values per farm did not change in Canada while from 1925–1930 in the U.S., building values per farm continued to increase at about the same rate as in the previous five years. The evidence suggests that if there was any building quality or quantity increase over the 1920s, the effect was larger for the U.S. Great Plains states. Therefore, any bias from assuming no change in housing quality would work to reduce the cost of housing in Canada relative to the U.S. The deflator constructed from the value of room and board in fact moves in the opposite direction, with the cost of living in the Canadian provinces rising faster through the 1920s than for the U.S. Great Plains states.

because the Emery-Levitt index has the cost of living in Edmonton and Calgary much lower than in the cities of Saskatchewan and Manitoba. The change in wages in 1944–1947 suggest that the Emery-Levitt index may not be perfect for this comparison. It has Canadian cost of living falling below the cost of living in the U.S. such that real farm wages in Canada rise above real farm wages in the U.S.

[Figure 8 about here.]

[Figure 9 about here.]

If the consumption basket underlying the provision of room and board is indeed constant across regions and over time, then the board index should be best. However, we cannot know for sure that it is a constant consumption basket; such information is unavailable in the detail needed. While we believe that the cost of living reflecting differences in cost of board is best, we will use both sets of deflators in the analysis that follows. Using the Emery-Levitt interurban index for deflating Canadian farm wages biases the test against supporting our hypothesis.

5.1.3 Wages and Immigration – Prairie Labour Market

Evidence suggests that immigration differences can explain the evolution of farm wages over this period. Green (1994) looked at Prairie farm wages as a function of the terms of trade and the immigration rate (immigration inflow per year divided by resident population over that period) and found that immigration did lower Prairie farm wages in Canada. His test is repeated here at the state and province level for the three Prairie provinces: Manitoba, Saskatchewan and Alberta; as well as the six wheat-growing states of the northern Great Plains: Minnesota, North Dakota, Montana, South Dakota, Nebraska and Kansas. In the test, we use the price of wheat, the principal crop influencing the value of the marginal product of labor, and we include a remoteness index to capture relative distance of a state or province from labor markets.[36] For wages, we use both our

[36]See data appendix for discussion of construction of remoteness measure.

real wage series, the first deflated by the room and board index and the other deflated using the Emery-Levitt index for Canada and the room and board index for the U.S.

$$\ln wage_{i,t} = \alpha \ \ln wage_{i,t-1} + \sum_{j=0}^{1} \beta_j \, imshare_{i,t-i} + \gamma \ln wheatprice_{i,t} + \kappa \ln remote_{i,t} + c_i + u_t + \varepsilon_{i,t} \tag{1}$$

The years covered are 1908–1930.[37]

Regression results are reported in table 3. Results confirm expectations. Wages respond to the price of wheat. The higher the price of wheat, the higher are wages, confirming the large role that wheat production plays in Prairie labor markets. Wages and the immigration inflow rate are negatively correlated. The current immigration share is not statistically significant, but the coefficient on the one-year lag of immigration is negative and highly significant.

There is evidence that the wage series and the immigration series are *I(1)*, and the evidence for cointegration is weak. Therefore, the estimates of the impact of immigration on wages are repeated using the first differences of all variables to demonstrate that the results in table 3 are not spurious. Again, we use both measures of real wages. The results are reported in table 4. Results in table 4 using differenced data point to the same conclusions. Lagged immigration lowers current wages, regardless of which price deflator used. Having provided evidence that differences in farm wages between Canada and the U.S. can be the result of differences in immigration policies, we now turn to examine the impact the differences in wages had on farmers' decisions to adopt tractors.

[Table 3 about here.]

[37]Immigration rates by state of intended destination are from U.S. Bureau of Immigration (1910/1930) and Canada. Department of Immigration and Colonization (1920–1925). Prairie destination of immigrants to Canada for the period 1925–1930 are adjusted, discussed in data appendix.

[Table 4 about here.]

5.2 Explaining Adoption of Tractors

Our thesis is that differences in the diffusion pattern of tractors between the U.S. Northern Great Plains and the Canadian Prairies were influenced by differences in immigration. We have established in the previous section that immigration did have an impact on wages, both at the national level, and on farm wages by state and province of the Northern Great Plains. We now turn to testing whether wages influenced tractor adoption. If we find that tractor adoption was sensitive to wages, then given that wages were influenced by immigration, we can conclude that immigration policy through its effect on labor markets did influence diffusion of tractor technology.

We run two tests of the effects of wages on tractor adoption. We first look at a long-run time series of tractor sales as a test of the sensitivity of tractor adoption to wages, and therefore to labor market conditions. The second test is the test of our hypothesis, looking at tractor adoption by U.S. county and Canadian census division along the international border. We run this test over the two periods identified in figures 1 and 3 when tractor adoption first diverged (1925–1930) and then converged (1945–1955).[38]

5.2.1 Long-run Patterns of Tractor Adoption on the Canadian Prairies

We first estimate the elasticity of the response of tractor adoption to wages. An annual time series of tractor sales by prairie province is available for the period 1919–1954. These data are available for Canadian provinces only; we are unaware of comparable data available at the state level. Data are for tractor sales annually by province, but there are no data on number of farms purchasing tractors. Therefore, to test the long-run

[38] We cannot extend our test for the first period back before 1925 as county-level data on tractors were not reported.

response of tractor adoption to factor prices, we estimate a stock adjustment model. The basic model is

$$\frac{S_t}{S_{t-1}} = \left(\frac{S_t{}^*}{S_{t-1}}\right)^{\gamma}$$

where $S_t{}^*$ is the desired stock at time t and is determined by tractor prices, input prices and farm size. The actual stock adjusts by a factor γ . The equation to be estimated is

$$\ln S_{i,t} = \gamma \ln S_{i,t}{}^* + (1-\gamma) \ln S_{i,t-1} + \varepsilon_{i,t} \tag{2}$$

where

$$\begin{aligned} \ln S_{i,t}{}^* &= \alpha_0 + \alpha_1 \ \ln pTrac_{i,t} + \alpha_2 \ \ln int_{i,t} + \alpha_3 \ \ln pGas_{i,t-1} \\ &+ \alpha_4 \ \ln wage_{i,t-1} + \alpha_4 \ \ln cropland_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3}$$

The annual sales data are converted to a stock measure by the perpetual inventory method using depreciation rates from Olmstead and Rhode (2001). Equation (2) is estimated with province dummy variables and an adjustment for first-order autocorrelation. We also estimate it using a fixed effects panel model. Coeffecient estimates are presented in table 5. The coefficients on the input prices reported in the first two columns of table 5 are the products of each α and γ so the α parameters, the elasticities of stock adjustment to input prices, are shown separately in the last two columns of table 5.

[Table 5 about here.]

The elasticity of tractor stock adjustment to wages is positive and statistically significant, and the elasticities with respect to gasoline prices and interest rates are negative and statistically significant. The own price elasticity for tractor stock adjustment is positive, though very small (inelastic) and statistically insignificant. The poor estimate of own price elasticity is probably due to mis-specification because unlike the other inputs, the demand for and supply of tractors are undoubtedly endogenously determined. Tractor manufacturers, a relatively small number of firms, likely adjusted output and prices

to demand for tractors.[39] An estimate of a tractor supply function is necessary to sort this out, but the data for such a specification are not readily available. Endogeneity is not likely a factor for the price setting of the other inputs as tractor demand would be a very small proportion of the market for the other inputs.

Tractor demand by Canadian Prairie farmers responded to changes in input prices, increasing with rising wages, and responding inversely to changes in interest rates and gasoline prices. In particular, the response to wages supports our hypothesis that labor markets were an important determinant of tractor adoption. If labor markets influenced adoption, then changes to labor market policy through diverging immigration policies could be responsible for the pattern of lagging Canadian tractor adoption in the early period of their diffusion.

Armed with the long-run evidence, we now proceed to examine a specification comparing tractor adoption in Canada and the U.S. to highlight the differences in labour market effects on farmers' decisions to adopt a tractor within narrower time frames. We will examine the critical periods: from 1925–1930 when the gap between adoption in the U.S. Northern Great Plains and the Canadian Prairie opened up, and the period from 1945–1955 when that gap was effectively closed.

5.2.2 Controlling for Heterogeneity Using County-level Data

To control for geographic heterogeneity, data are analyzed for a small subset of this region: U.S. counties and Canadian census divisions bordering the forty-ninth parallel.[40] As the forth-ninth parallel arbitrarily separates Canada from the U.S. without consideration for topography or geographic features, it will artificially divide regions that are geographically, climatically and agriculturally homogeneous. Therefore, differing outcomes for contiguous divisions on either side of the border will highlight the treatment

[39] At least that is the main premise and conclusion drawn from several government commissions: the 1937 Special Committee on Farm Implement Prices, the 1939 Saskatchewan Provincial Royal Commission on Farm Equipment and the 1971 Canadian Federal Royal Commission on Farm Machinery.

[40] The Canadian prairie provinces are subdivided into census divisions.

effect of policy differences between the two countries.

Adoption is estimated for two periods, the period when adoption rates diverged, 1925–1930; and the period when adoption rates converged, 1945–1955. Adoption rates are ideally measured as the odds ratios, the ratio of the proportion of adopters to non-adopters. However, the U.S. Census does not report number of adopters in 1925, only number of tractors adopted. The measure of number of tractors per farm is used instead.

As an additional test, we replace the missing number of adopters in U.S. counties in 1925 with the number of tractors adopted. Because the number of tractors adopted is always greater than the number of adopters when both are measured, the use of number of tractors for tractor adopters will increase the calculated odds ratio for U.S. counties in 1925. The implication for our test is that this edited measure of adopters will understate the increase in the number of adopters from 1925 to 1930 in the U.S., which will bias our estimates against finding increasing divergence between the two countries between 1925 and 1930.

We estimate the following equation using two dependent variables, ln tractors per farm and the ln odds of tractor adoption:

$$\begin{aligned} \ln trac_{i,t} = \alpha + \gamma_1 \ln cropPFarm_{i,t} + \gamma_2 \ln cattlePFarm_{i,t} + \beta_1 \ln pTracServ_{j,t} \\ + \beta_2 \ln pGas_{j,t} + \beta_3 \ln wage_{j,t} + \sum_{s=1}^{4} \delta_s \, soilType_i + \sum_{r=1}^{10} \delta_r \, region_i + \varepsilon_{i,t} \end{aligned} \tag{4}$$

where

trac	alternatively number of tractors per farm or the odds ratio of tractor adoption
cropPFarm	acres of cropland per farm
cattlePFarm	number of cattle per farm
pTracServ	tractor service price, calculated as tractor price $\times$ (interest rate + inflation expectation + depreciation rate)
pGas	gasoline price
wage	monthly farm labour for summer months without board
soilType	categorical variable denoting different soil types
region	categorical variable denoting geographically-distinct regions
i	county or census division
j	state or province.

All prices are deflated using the cost of board index derived above. Prices are specific to a state or province, not to a county or census division as no price data are available at that level of detail. The soil regions are defined by the predominant type of soil—black, dark brown, brown and gray—for each county or census division. These are general categories reflecting the quantities of moisture and organic matter in the soil, with black corresponding to higher yielding soils. We also define ten regions of contiguous counties and census divisions to control for variation in weather and landscape along a northwest–southeast gradient. All variables except the categorical variables are ln transformed. Data sources are described in the data appendix.

Two sets of estimates are presented for each period: 1925–1930 and 1945–1955, and are pooled for each period. Time period indicators are included in each regression. Results are in table 6.

[Table 6 about here.]

Farm size is important as the coefficients on acreage in crops per farm were positive and statistically significant in all periods for both specifications. Farm size is even

more important in the later period, when tractor technology had been much improved, and tractor capacity was greatly enhanced. In the earlier period, number of cattle correlated with fewer tractors. Farms with more cattle tended to be smaller, so tractors were not as critical given the implied smaller scale to cropping. After the War, farms size had increased, so size of cattle operations seems to no longer have had an effect on likelihood of tractor adoption.[41]

The coefficients on factor prices are of particular interest. The coefficients on tractor service costs are negative in three of four models, but never statistically significant. This is clearly a measure with a lot of noise. The other two factor prices, gasoline and labor, have coefficients as expected. The coefficient on the price of gasoline is negative, and statistically significant in three of four estimates.

The coefficient on wages are positive in all specifications, though only statistically significant for the 1925–30 period. By 1945, farm size had increased, but more importantly wages had risen and technology had changed sufficiently making tractor adoption appropriate for virtually all commercial farming operations of the period. The reason tractors were adopted so rapidly after 1945 was catch up for the loss of a decade and a half due to depression and war. That this catch-up adoption is not correlated with wages is because there are simply no observations in the data where we observe delayed adoption due to cheap labour. Wages were high for all regions, so any differences in tractor adoption by region that remained were not due to a farmer's assessment of labor markets. Other considerations would have played a role, like access to capital, proximity of equipment dealers, etc.

The consideration of location is reflected in the impact of a location's remoteness. In the regressions for 1925–1930, a county or census division's remoteness increases the likelihood of tractor adoption. For the later period, 1945–1955, the likelihood of tractor

[41] We tested this explicitly by running our regressions for the 1925–30 period with cropland per farm interacted with cattle per farm. The sign on the interaction term was positive indicating that greater cropland coupled with more cattle would lead to increased tractor adoption.

adoption decreases with remoteness. This switch is consistent with our hypothesis. In the prewar period, the more remote a location from labor markets, the more pressing is the need for farmers to substitute capital for labor. By the postwar period, labor is relatively costly regardless of location. The effect of distance on acquiring technology comes to dominate. The more remote a rural location, the farther it is from equipment dealers and from access to supplies and repairs, and therefore the less likely the farmer to adopt a tractor.

We did try additional tests. In particular, we ran all regressions with an indicator variable for whether a location was in Canada or the U.S. The coefficient on the indicator was not significant. We also interacted the Canada dummy indicator with the time period, so we included in the 1925–1930 regressions an indicator for Canada in 1930. The hypothesis being tested by its inclusion is that, all else being equal, Canadian farmers adopted fewer tractors than U.S. farmers. Again, the interaction dummy variable was not statistically significant either when included alone, or included along with the Canada dummy indicator. So for the 1925–1930 period, factor prices do determine the pace of tractor adoption.

The conclusion is that once factor market differences are included, Canadian adopters did not differ from U.S. adopters. Both responded to market signals as rational optimizers. Canadian farmers simply observed different factor prices because labor markets differed between the two countries. Canada had a relatively open immigration policy which meant lower wages and greater availability of labor. The U.S. had tightened its immigration implying higher wages and less availability of surplus labor at harvest and spring seeding.

6 Conclusion

As farming technique on the Great Plain states and provinces evolved under conditions of a flexible supply of labor available at demand peaks, changes in labor supply must have had a strong influence on the outlook of farmers. In particular, it must have influenced the pace of adoption of a new labor-saving technology in the form of a durable asset, the tractor.

In the 1920s with the introduction of immigration restrictions, U.S. farmers were forced to change their expectations and substitute capital for labor. The dramatic increase in research and writing about the farmer's choice of tractor adoption during this period as Olmstead and Rhode (1994) review is certainly consistent with this changed outlook facing farmers in the U.S. By the mid-1920s, farmers in Canada felt less compelled to change their technologies as they realized they could rely on a flexible labor supply into the future due to the re-adoption of an open immigration policy by the Canadian government.

The result of the U.S. policy response can be judged against its counterfactual of restricted immigration. That counterfactual does not need to be theorized; it was adopted north of the forty-ninth parallel. After the U.S. imposed highly-restrictive immigration quotas, tractor adoption rates accelerated in the U.S., surpassing adoption rates of Canadian farmers who had been the more enthusiastic and rapid adopters of this new technology in the early 1920s.

As there is otherwise no apparent difference in conditions facing farmers of the Northern Great Plains, and particularly for those farmers on either side of the international boundary, the timing of this accelerated adoption seems to be simply too coincident with changes in rules affecting the market for a principal input to farming in this region. The change to immigration policy in the 1920s was a dramatic shift in policy, and was implemented in such a way as to signal strongly that it was a permanent change. Farmers were able to adjust to the changes by accelerating their adoption of labor-saving

technology.

The diffusion of this new labor-saving technology did respond to policy affecting labor markets. We hypothesize that agricultural technique today may well be quite sensitive to labor markets conditions and changes in immigration policy and enforcement will likely result in changes in the capital-labor ratio in agriculture. The debate over immigration policy is particularly relevant to agriculture given agriculture's extensive reliance on unskilled, seasonal labor, most of which is supplied by migrants. It turns out that we have been down this path before. Prior to the diffusion of the combine and the virtually complete mechanization of harvesting, farmers were dependent on temporary labor for the harvest. Yet despite this reliance, the U.S. restricted immigration.

Data Appendix

Farm Wages

Farm wages are the average annual monthly wages without board from U.S. Department of Agriculture, *Farm Wage Rates by States, Revised, 1910-1948* and *Farm Labor*; and from Canada. Dominion Bureau of Statistics, *Monthly Bulletin of Agricultural Statistics*. Both sources report wages with and without board. The cost of board is calculated as the difference between wages with and without board.

Price Deflators

All prices are expressed in real 1913 $U.S. U.S. prices deflated using the BLS CPI Index, series Cc1-2 in Carter *et al.*, *Historical Statistics of the United States*; Canadian prices deflated using Department of Labour Cost of Living index for 1913 on from series J139 *Historical Statistics of Canada*, and the Bertram-Percy index (Bertram and Percy, 1979) with missing years linearly interpolated using the Department of Labour's wholesale price index for years prior to 1913 from series J34, in *Historical Statistics of Canada*. Base year is 1913. Canada–U.S. dollar exchange rate is from

series H625 of *Historical Statistics of Canada*.

Immigration

Immigration rates by state or province of intended destination are from U.S. Bureau of Immigration, *Annual Report of the Commissioner-General of Immigration* and Canada, Department of Immigration and Colonization, *Annual Report*. Destination of immigrants to the Canadian Prairies in the period 1925–1930 is clearly distorted as reported in the Immigration Department reports, with a disproportionate number indicating Manitoba as destination. As immigrants from the non-preferred countries were admitted only for agricultural employment most of those indicating Manitoba were in fact using Winnipeg as a point to coordinate their employment elsewhere on the Prairies. Immigrant destination for these years in Canada are calculated as the total number of immigrants to all three Prairie provinces allocated according to the distribution of immigrant arrivals for this period as reported in Canada. Dominion Bureau of Statistics, *Census of Canada, 1931*.

Tractor Counts

Number of tractors per farm and number of farms adopting tractors are taken from the agricultural censuses. For the U.S., the number of farms adopting tractors is not available until the 1930 Census. The U.S. agricultural censuses used are 1925, 1930, 1940, 1945, 1950, 1955, 1959. The Canadian agricultural censuses used are quinquennial from 1926–1961.

Annual time series of tractor counts from Saskatchewan, Royal Commission on Agriculture and Rural Life, *Mechanization and Farm Costs*; Alberta, Department of Agriculture, *Historical Series of Agricultural Statistics for Alberta*; and Manitoba Department of Agriculture, *Ministry of Agriculture in Manitoba, 1870-1970*.

Interest Rates

Canada: Canadian Farm Loan Board, *Annual Report*, Bates, *Financial History of*

Canadian Governments, and Easterbrook, *Farm Credit in Canada*. U.S.: Horton et al., *Farm-Mortgage Credit Facilities in the United States* and U.S. Department of Agriculture, *Yearbook of Agriculture* and *Agricultural Statistics*. The latter two report only regional rates.

Tractor Prices

For the U.S., Olmstead and Rhode, "Reshaping the Landscape," and U.S. Department of Agriculture, *Agricultural Prices*. For Canada, 1926-1935 from Canada. House of Commons, *Minutes of Proceedings and Evidence and Reports of Canada Parliament House of Commons Special Committee on Farm Implement Prices*, p. 124, 141; for 1936 on, Canada, Dominion Bureau of Statistics, *Farm Implement and Equipment Sales in Canada*. For each country, tractor price is for the smallest farm tractor reported. For Canada, tractor prices from 1936 are reported as a prairie price only. To generate provincial prices, we adjust the quoted prairie tractor price for a transport cost component. Transport costs for tractors by destination city are reported in Board of Transport Commissioners For Canada, *Waybill Analysis*. Data are available from 1949 on. We interpolated transport costs for 1937–1948 by linking the series starting in 1949 with data on tractor prices by prairie destination from *House of Commons Special Committee Report*, p. 193 for 1920–1936.

Tractor service rates are derived as tractor prices $\times$ (interest rate + inflation expectation + depreciation rate). Inflation expectations are derived using a centered three-year moving average of the CPI for each country. Depreciation rates are from Olmstead and Rhode, "Reshaping the Landscape."

Gasoline Prices

U.S. gasoline prices provided by Paul Rhode from Olmstead and Rhode, "Reshaping the Landscape." For Canada, gasoline prices are from Canada. Dominion Bureau of Statistics, *Prices and Price Indexes*.

Wheat Prices

Prices received by farmers, Canada by province from *Handbook of Agricultural Statistics* (Canada. Dominion Bureau of Statistics, 1964); U.S. by state from USDA *Yearbook of Agriculture* and *Agricultural Statistics*.

Cropland

Data for state and province comparison is from the Census of Agriculture, cropland harvested. Annual series for Canadian provinces from Cansim table 001-0001, sum of seeded acreage for all field crops.

Farm Counts, Farm Sizes, Cattle, Population (State/Province)

Censuses of Agriculture.

Soils

Canada: Fuller, *Chernozemic Soils of the Prairie Region of Western Canada*, p. 40. For the U.S., Patterson, "Soil Survey Report," and U.S. Department of Agriculture, *Soil Survey Manual*.

Regional Fixed Effects

Region	Province	Census Division	State	County
1	Manitoba	1, 5	Minnesota	Roseau
2	Manitoba	2, 6	Minnesota North Dakota	Kittson, Marshall Pembina, Walsh
3	Manitoba	3, 7	North Dakota	Benson, Cavalier, Ramsey, Towner
4	Manitoba	4, 8	North Dakota	Bottineau, McHenry, Pierce, Rolette
5	Saskatchewan	1, 5	North Dakota	Burke Mountrail, Renville, Ward
6	Saskatchewan	2, 6	North Dakota Montana	Divide, Williams Sheridan
7	Saskatchewan	3, 7	Montana	Daniels, Roosevelt, Valley
8	Saskatchewan	4, 8	Montana	Blaine, Phillips
9	Alberta	1, 3	Montana	Hill, Liberty, Toole
10	Alberta	2, 4	Montana	Glacier

Remoteness

A common definition of remoteness of location i from all other locations is

$$r_i = \frac{\sum_{j \neq i} dist_{i,j} \times Pop_j}{\sum_j Pop_j}$$

the population-weighted distance of location i. Distance is measured from the Prairie state/province to sources of labor, all urban centers in the country. An urban center is defined as an urban area of 50,000 or more people. Data for U.S. urban centers are from the Censuses of 1920 and 1930, averaged over those two Census years. Data for Canada are from the Censuses of 1921 and 1931 and again

averaged over the two Census years. Urban agglomeration is the basic unit used, so in some cases urban centers smaller than 50,000 are included where they are part of a larger urban area. An example is the quad cities of Davenport, Bettendorf, Rock Island and Moline none of which individually would make the 50,000 cutoff. The locations for the five states are taken as the geographic centers of the states ignoring population distribution across the state. The coordinates of the three Canadian provinces are not taken as the geographic centers because the northern half of the provinces include extensive uninhabited forest. Using the geographical center would exaggerate the remoteness of the Canadian Prairies. Instead the provincial coordinates are taken as the mean location between the two largest cities of each province. For Manitoba these are Winnipeg and Brandon; for Saskatchewan: Regina and Saskatoon; and for Alberta: Edmonton and Calgary.

The basic distance concept is the great circle distance between two points. This distance measure is further modified to account for geography and transport routes. In Canada, labor moving from east to west generally traveled through Toronto and on to Winnipeg before being dispersed across the Prairies and beyond to the West Coast. The great circle distance from Montreal to Edmonton would be a route through northern Ontario, appropriate for air travel, but not the rail route. To accommodate the geography of the trip, distances between eastern and western Canada are taken as the sum of the great circle distance from eastern origin to Toronto, the rail line distance from Toronto to Winnipeg (2074 km), and the great circle distance from Winnipeg to the western location. A similar approach is used for calculating distances between East and West for the U.S. where distance is the sum of the great circle distances between eastern origin and Chicago and great circle distance from Chicago to western destination for all origin points east of Chicago. Distances for points west of Chicago for the U.S., or north and west of

Toronto for Canada are taken as the simple great circle distances because of the relatively few urban centers of the West, and the more general uniform geography of the West.

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Table 1: Tractors per Farm and Proportion of Farms Adopting Tractors, 1920, 1925, 1930

	Tractors per Farm			Proportion of Farms with Tractors		
	1920	1925	1930	1920	1925	1930
Alberta	0.11	0.15	0.25	0.10	0.13	0.23
Manitoba	0.19	0.23	0.27	0.17	0.20	0.24
Saskatchewan	0.16	0.23	0.32	0.15	0.20	0.29
Kansas	0.10	0.19	0.40	0.10	0.17	0.36
Minnesota	0.09	0.14	0.26	0.08	0.14	0.25
Montana	0.13	0.14	0.40	0.12	0.12	0.36
Nebraska	0.09	0.15	0.31	0.08	0.14	0.29
North Dakota	0.17	0.23	0.48	0.15	0.21	0.44
South Dakota	0.17	0.22	0.41	0.16	0.21	0.37

Source: See data appendix.

Table 2: Average Farm Size (ac), 1920, 1925, 1930, 1960

	1920	1925	1930	1960
Alberta	353	371	400	645
Manitoba	275	271	279	420
Saskatchewan	369	390	408	686
Kansas	275	264	283	481
Minnesota	169	160	167	211
Montana	608	698	940	2,216
Nebraska	339	329	345	528
North Dakota	466	452	496	755
South Dakota	464	403	439	805

Source: See data appendix.

Table 3: Reduced-form Wage Regressions for Effect of Immigration, 1910–1930

	$\ln$ *wage*			$\ln$ *wage-el*		
$\ln pwheat_t$	0.4383^{***}	0.4599^{***}	0.4713^{***}	0.2719^{**}	0.3005^{***}	0.3116^{***}
	[0.0622]	[0.0596]	[0.0668]	[0.0909]	[0.0833]	[0.0984]
$imShr_t$	-1.3083^{*}		1.1782	-1.8409^{*}		1.1488
	[0.6586]		[1.0233]	[0.8324]		[1.3542]
$imShr_{t-1}$		-2.2910^{***}	-3.0167^{***}		-2.9195^{***}	-3.6270^{***}
		[0.5503]	[0.5761]		[0.8474]	[0.7194]
$\ln remote_t$	-4.6293^{**}	-4.2860^{*}	-4.0821^{*}	-8.4855^{**}	-8.0264^{**}	-7.8276^{**}
	[1.7818]	[1.9034]	[2.0273]	[2.7498]	[2.6071]	[2.7256]
adj. R^2	0.67	0.70	0.70	0.60	0.65	0.65

Standard errors in brackets
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Notes: The dependent variables are ln real wages: the first version all series are deflated by the room and board index and the second version the Canadian series are deflated by the Emery-Levitt index. Standard errors are robust to heteroskedasticity. All regressions have $n = 180$. *pwheat* is price of wheat, *imShr* is immigrant share of state/province population, and *remote* is state/province remoteness. Regressions include year indicator variables, not reported.
Sources: See text.

Table 4: Reduced-form, Differenced, Wage Regressions for Effect of Immigration, 1910–1930

	$\Delta \ln wage$			$\Delta \ln wage\text{-}el$		
$\Delta \ln pwheat_t$	0.3577^{***}	0.3724^{***}	0.3738^{***}	0.2618^{**}	0.2842^{**}	0.2847^{**}
	[0.0831]	[0.0822]	[0.0813]	[0.1099]	[0.1071]	[0.1080]
$\Delta imShr_t$	0.3465		1.3404	-0.9232		0.4933
	[1.2123]		[1.1215]	[1.4784]		[1.5924]
$\Delta imShr_{t-1}$		-1.7525^{**}	-2.0253^{**}		-2.7859^{***}	-2.8863^{***}
		[0.7605]	[0.7041]		[0.7331]	[0.8365]
$\Delta \ln remote_t$	-21.5272^{***}	-24.6989^{***}	-25.5377^{***}	-28.3365^{***}	-33.7433^{***}	-34.0520^{***}
	[5.7492]	[5.0037]	[4.8919]	[5.2889]	[5.5055]	[5.4593]
adj. R^2	0.51	0.52	0.52	0.36	0.40	0.39

Standard errors in brackets
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Notes: Standard errors are robust to heteroskedasticity. All variables in first-differenced form. The dependent variables are ln real wages: the first version all series are deflated by the room and board index and the second version the Canadian series are deflated by the Emery-Levitt index. *pwheat* is price of wheat, *imShr* is immigrant share of state/province population, and *remote* is state/province remoteness. Regressions include year indicator variables, not reported.
Sources: See text.

Table 5: Tractor Stock Demand Regressions–Canadian Prairie Provinces

	stock adjustment equation		elasticity equation	
	pooled	fixed effects	pooled	fixed effects
$\ln pTrac_t$	0.0479	0.0130	0.1453	0.0479
	[0.0516]	[0.0517]	[0.1659]	[0.1930]
$\ln int_t$	-0.2522^{**}	-0.2483^{**}	-0.7653^{**}	-0.9145^{**}
	[0.1096]	[0.1099]	[0.3240]	[0.4113]
$\ln pGas_{t-1}$	-0.3221^{***}	-0.3499^{***}	-0.9770^{***}	-1.2886^{***}
	[0.0730]	[0.0722]	[0.1793]	[0.2617]
$\ln wage_{t-1}$	0.2522^{***}	0.1741^{***}	0.7648^{***}	0.6414^{***}
	[0.0533]	[0.0637]	[0.2005]	[0.2415]
$\ln Stock_{t-1}$	0.6703^{***}	0.7285^{***}		
	[0.0365]	[0.0446]		
$\ln acre/farm_t$	0.2188	0.2072	0.6635^{*}	0.7633^{*}
	[0.1335]	[0.1297]	[0.3689]	[0.4415]
Manitoba	0.0197			
	[0.0434]			
Saskatchewan	0.1271^{**}			
	[0.0543]			
constant	-0.4007	-0.3903^{**}	-1.2155	-1.4377^{*}
	[0.5730]	[0.1865]	[1.7601]	[0.7763]

Standard errors in brackets
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
N=105. AR(1) error structure assumed. See text for discussion of data and method. Entries in columns titled 'stock adjustment' are coefficient estimates. Entries in columns titled 'elasticity' are calculated as $\epsilon = \frac{\text{coefficient}}{\gamma}$ where $1 - \gamma$ is the coefficient on $\ln Stock_{t-1}$.

Table 6: County-Level Border-State/Province Tractor Demand Regressions

	tractors per farm		tractor adopters	
	1925–30	1945–55	1925–30	1945–55
ln *cropPFarm*	0.7990***	0.2746***	0.9658***	0.6793**
	[0.1096]	[0.0791]	[0.1325]	[0.2909]
ln *cattlePFarm*	−0.1888**	0.0468	−0.2988***	−0.0622
	[0.0803]	[0.0548]	[0.1082]	[0.1747]
ln *pTracServ*	−0.3129	0.0252	−0.0969	−0.1379
	[0.4297]	[0.1017]	[0.5770]	[0.3173]
ln *pGas*	−1.1838***	−0.0932	−2.2325***	−0.6936**
	[0.4131]	[0.0899]	[0.5519]	[0.2701]
ln *wage*	2.8129***	0.0139	4.1264***	0.4529
	[0.4922]	[0.1939]	[0.6780]	[0.6242]
ln *density*	0.0389	−0.0117	−0.0122	−0.1121
	[0.0391]	[0.0201]	[0.0557]	[0.0789]
ln *remote*	5.8887***	−1.5400***	7.4348***	−2.4665*
	[1.6331]	[0.3654]	[2.0495]	[1.4288]
soil.DBrown	0.1364	−0.0716**	0.1008	−0.1101
	[0.0937]	[0.0346]	[0.1270]	[0.1114]
soil.Brown	−0.1572	−0.0904	−0.2423	−0.0563
	[0.1440]	[0.0731]	[0.1680]	[0.1889]
soil.Gray	−0.0087	−0.0516	−0.1807	−0.4270
	[0.1290]	[0.0479]	[0.1495]	[0.3582]
year.1930	0.1966	—	0.2639	—
	[0.1277]		[0.1713]	
year.1950	—	0.3796***	—	1.0803***
		[0.0628]		[0.2003]
year.1955	—	0.5079***	—	1.3343***
		[0.0502]		[0.1918]
N	98	149	98	149

Standard errors in brackets.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Standard errors robust to heteroskedasticity. Dependent variables are ln number of tractors per farm, and ln odds of tractor adoption. Regressions are weighted by number of farms. In the regressions for 1925–1930, the omitted year category is 1925; and for 1945–1955, the omitted year category is 1945. Omitted soil type category is Black. Regressions include ten regional indicators, not reported.

Figure 1: Proportion of Farms with Tractors: Great Plains States and Prairie Provinces

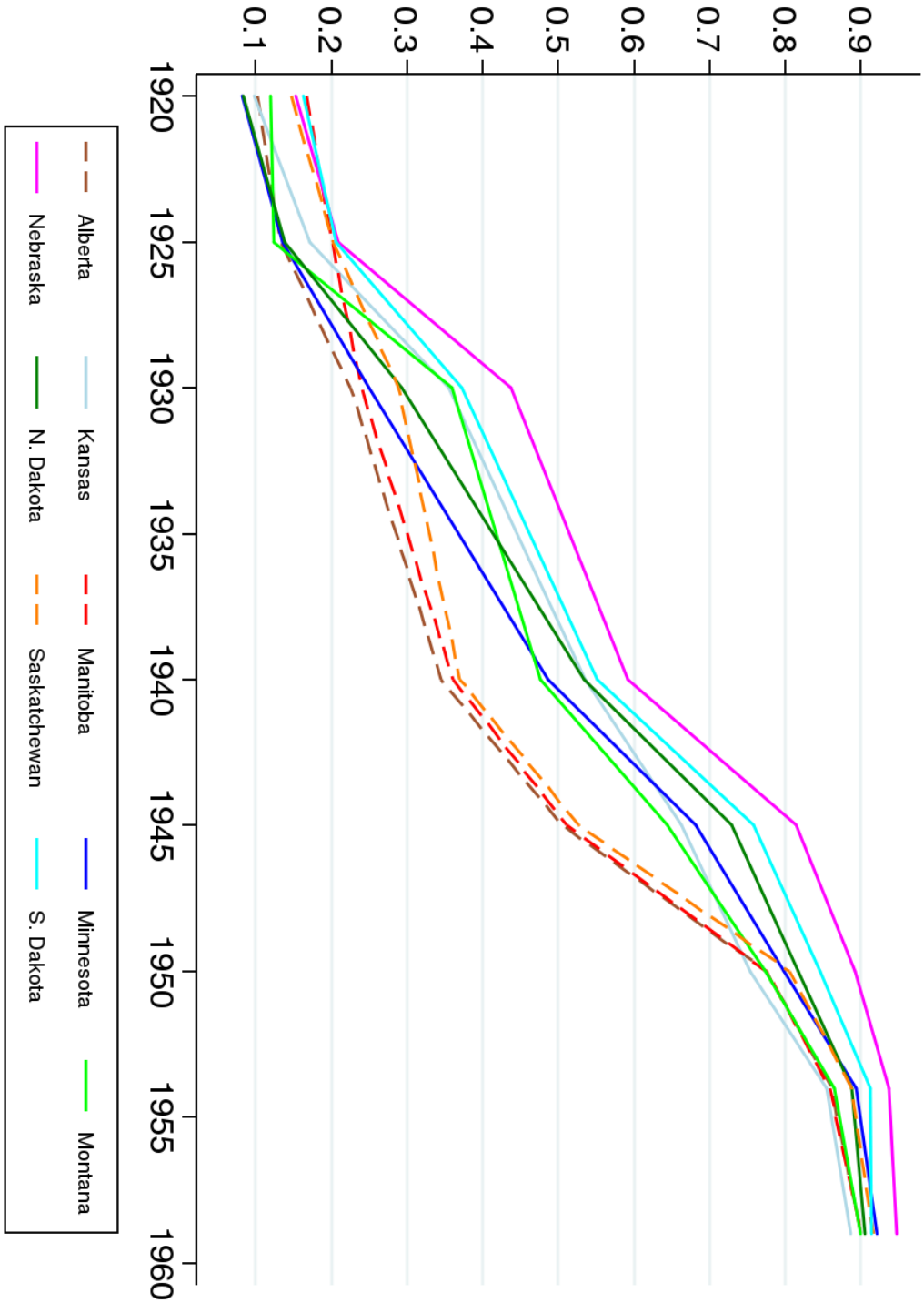


Figure 2: Tractors per Farm: U.S. Counties and Canadian Census Divisions–Along the 49th Parallel

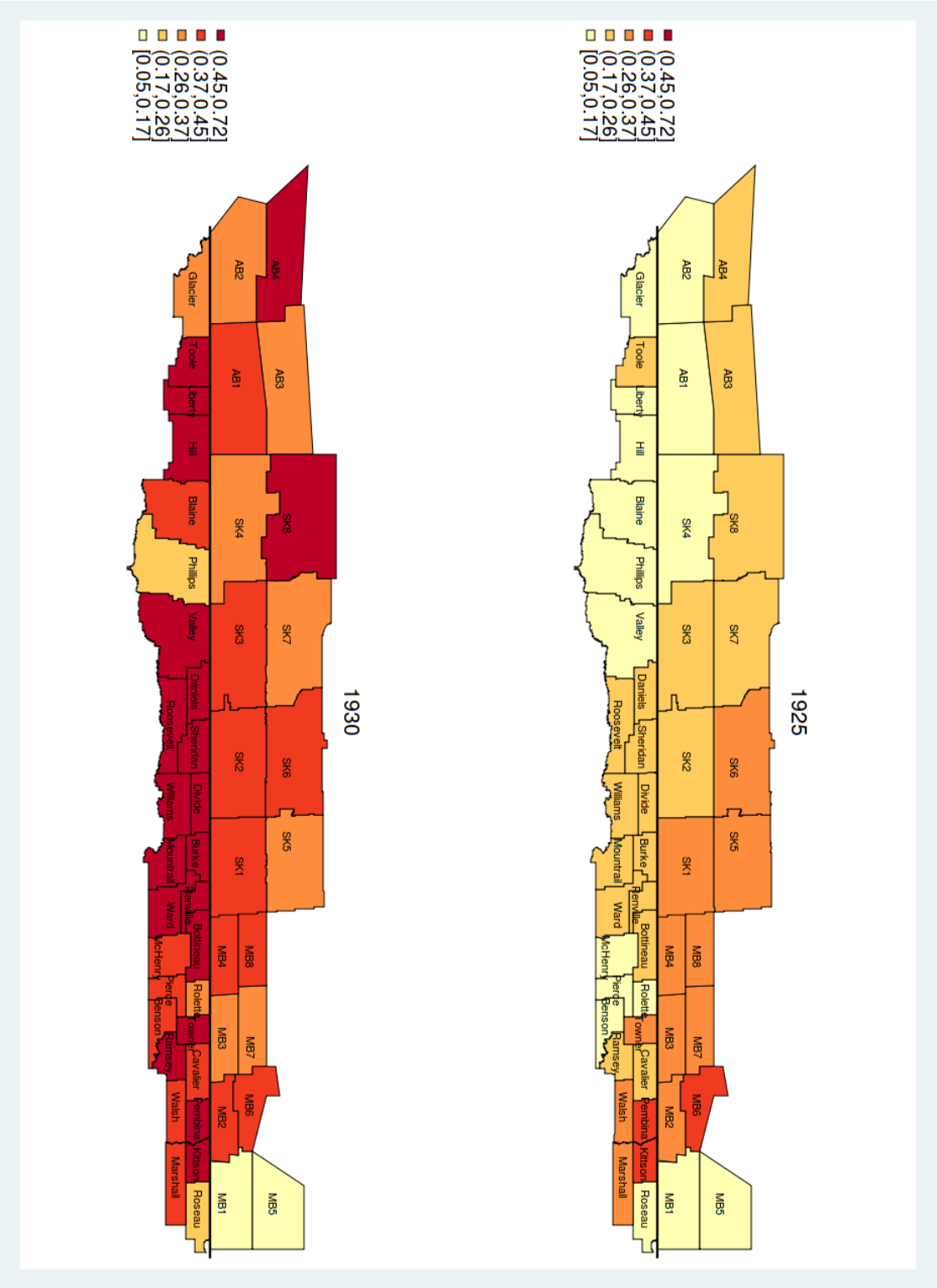
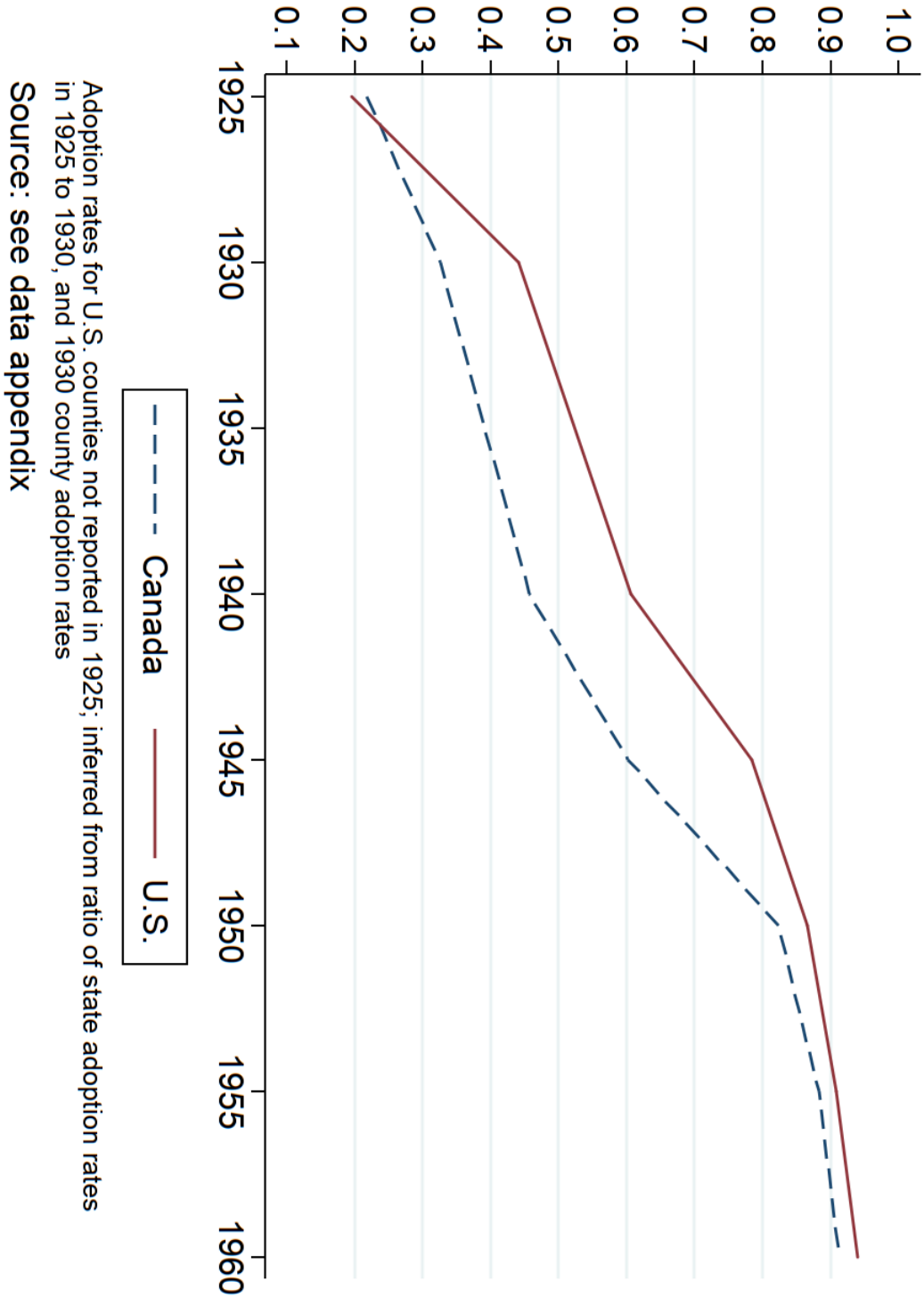


Figure 3: Proportion of Farms With Tractors: Canada–U.S. Border Counties, 1925-1960



Adoption rates for U.S. counties not reported in 1925; inferred from ratio of state adoption rates in 1925 to 1930, and 1930 county adoption rates

Source: see data appendix

Figure 4: Immigration Inflows and Share Destined for Prairie Province, Canada, 1901–1932

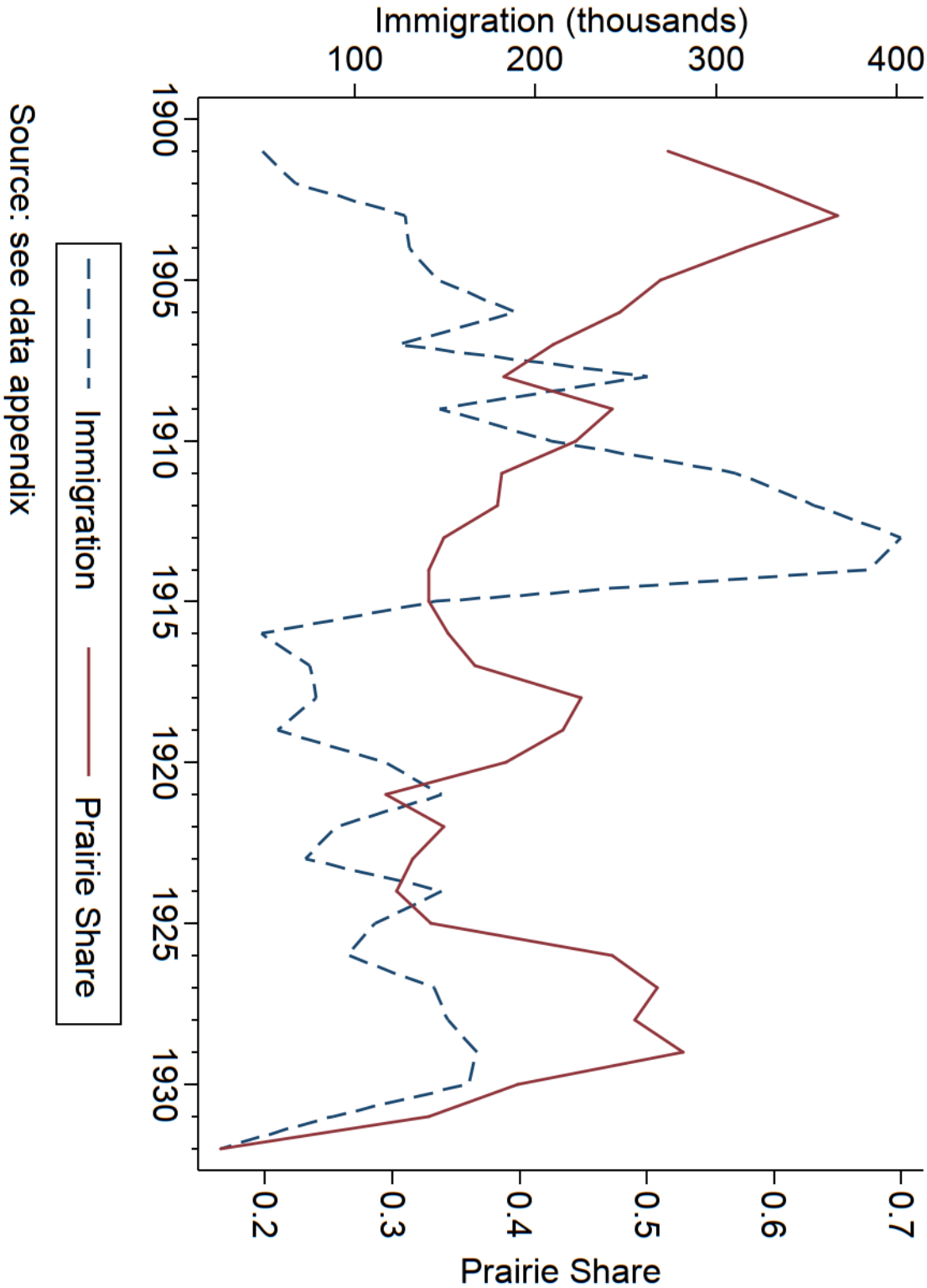


Figure 5: Job Vacancies (Monthly) Listed with Employment Service of Canada, Ontario and Prairie Provinces

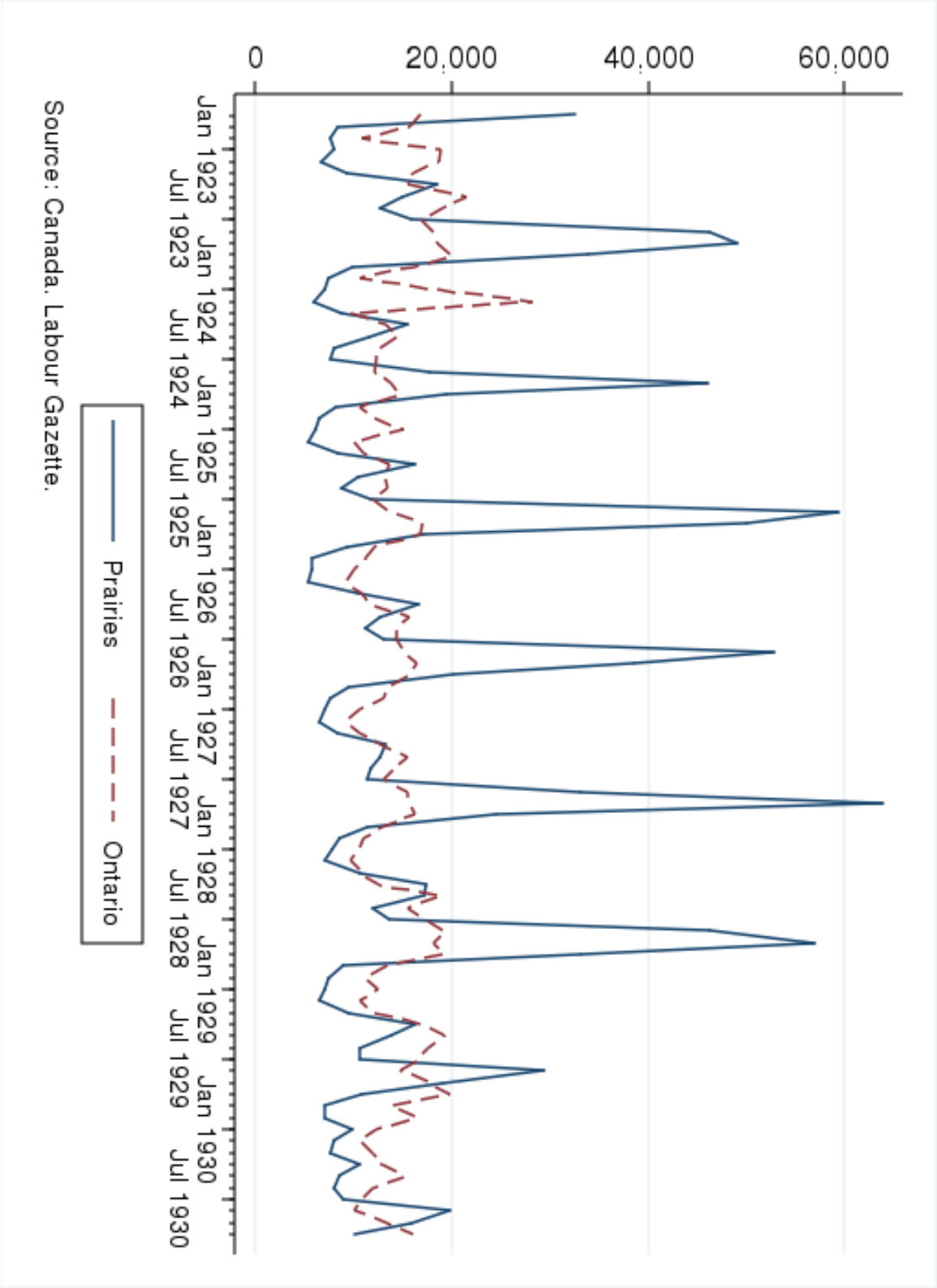


Figure 6: Farm Wages, Great Plains States and Prairie Provinces

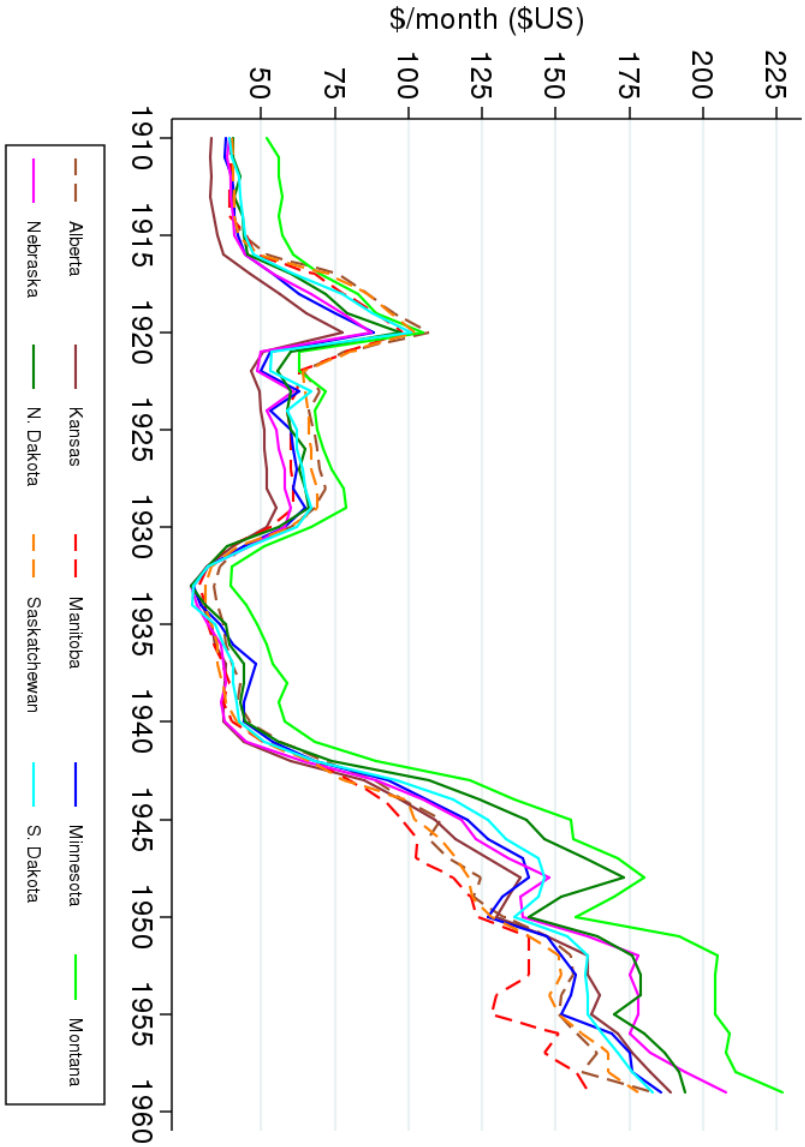


Figure 7: Real Farm Wages, Great Plains States and Prairie Provinces, Using 'Board' Deflator

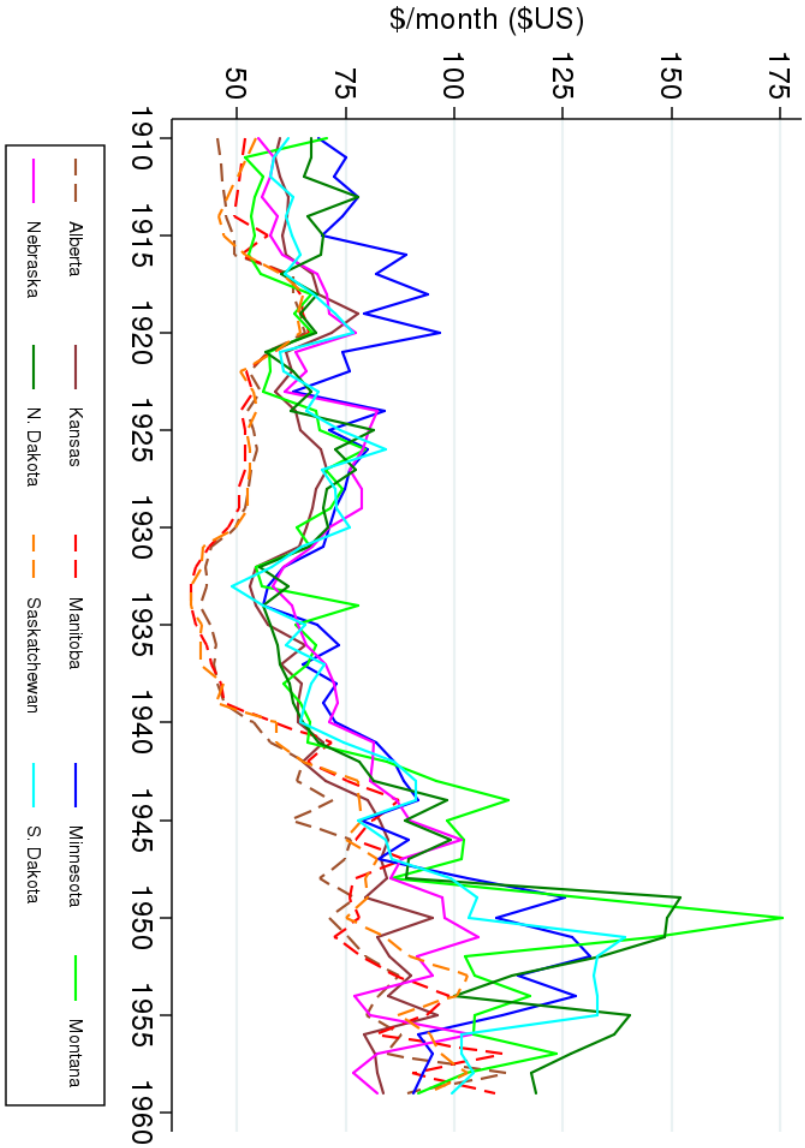


Figure 8: Emery and Levitt Interurban versus 'Board' Cost-of-Living Indices

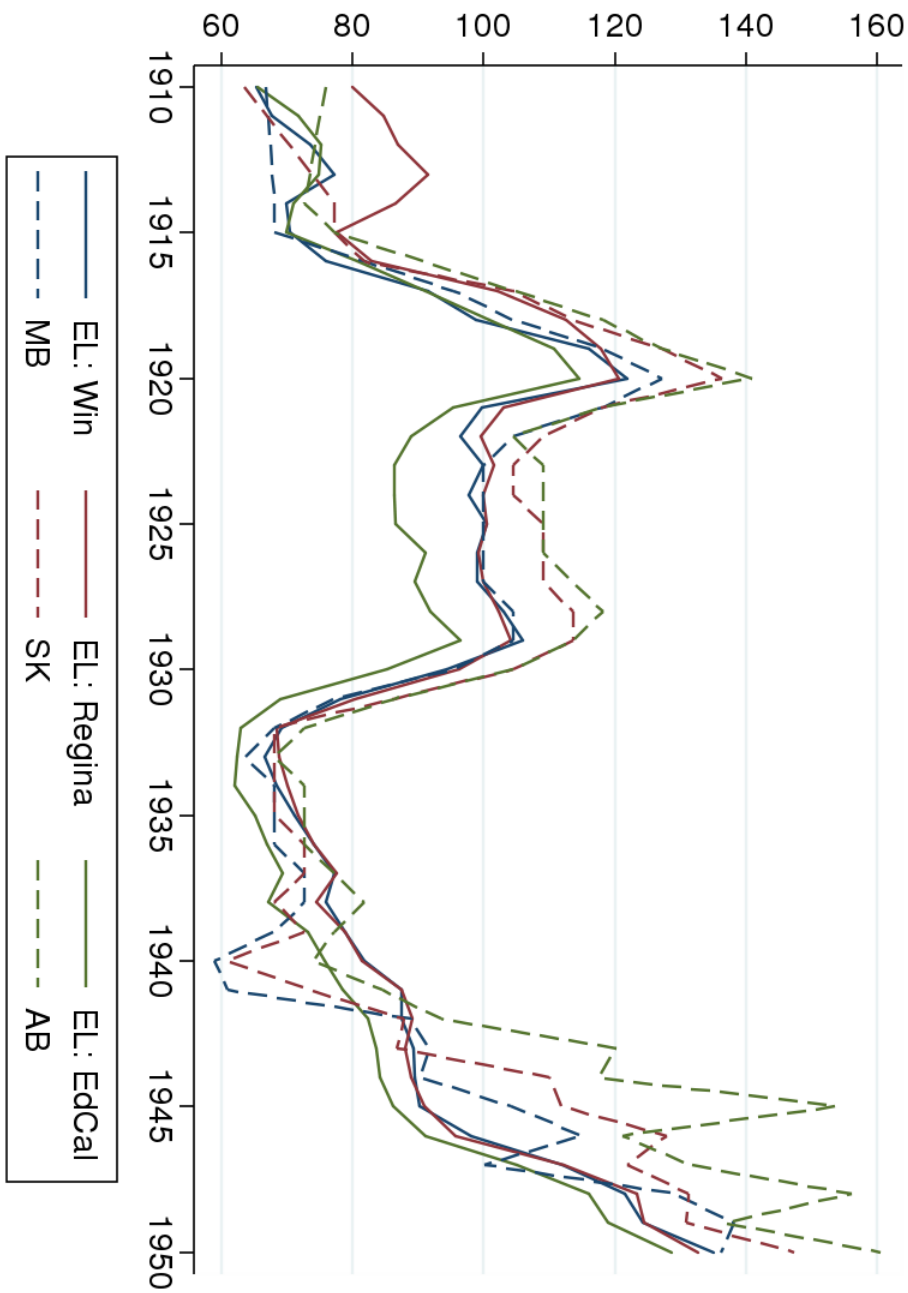


Figure 9: Real Farm Wages, Great Plains States and Prairie Provinces, Using Emery-Levitt Deflator for Canada