

THE U.S. WESTWARD EXPANSION

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ABSTRACT

The U.S. economic development in the nineteenth century is characterized by the westward movement of population and the accumulation of productive land in the West. What are the quantitatively important forces driving this phenomena? This paper presents a model of migration and land improvement, to address this question. Counterfactual experiments reveals that two forces are key in accounting for the Westward Expansion: the decrease in transportation costs and population growth.

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1 INTRODUCTION

The United States of 1900 differed dramatically from the country created after the Revolutionary War. The first prominent difference was the size. From less than one million square miles in 1800, the nation encompassed about three million in 1900. A consequence of this territorial expansion was that the stock of productive land was multiplied by 14 between 1800 and 1900 – that is an annual growth rate of 2.7%. Second was the geographic distribution of population. Less than seven percent of it lived in the West in 1800. By 1900 this number was about 60% – see Figure 1. The combination of these two facts constituted what has been called the Westward Expansion. The magnitude of the expansion is also captured by the geographical shift of economic activity. In 1840, the West accounted for less than 30% of total personal income. This share rose to 54% in 1900 and remained stable at about 60% ever since.

One can view the Westward Expansion as a part of the growth experience of the United States. From this perspective, the present paper contributes to the literature addressing phenomena such as the demographic transition and the structural transformation.¹ It is also interesting to note that the Westward Expansion did not affect only the United States. During the nineteenth century, 60 million European migrated to the new world. Most were attracted by the economic opportunities they expected to find there and, in particular, the possibilities to acquire land in the western part of the United States. In fact, the Westward Expansion is a phenomenon similar to the international immigration to the United States as a whole.

This paper proposes an investigation of the quantitatively important forces driving the Westward Expansion. The focus is on the time path of the geographic distribution of population and the accumulation of productive land. More precisely, the question is: What forces can account for the magnitude and pace of the westward movement of population and accumulation of land, during the nineteenth century? The strategy adopted to address this question is the following.

First, the facts about population movement and productive land are detailed and potential driving forces are discussed in Section 2. Additional facts regarding these forces are also presented. In Section 3, a model incorporating these forces is presented. The model is first developed and analyzed in a static setting, for simplicity. The question at hand, however, requires a dynamic model in order to compute the transition, i.e., the pace of the Westward Expansion. Thus, a dynamic version of the model is also presented. The dynamic model differs from the static model in terms of the demography and the introduction of investment decisions. It incorporates all the mechanisms at work in the static version, though. Section 4 presents the computational experiment. First, the model is calibrated to fit the main facts characterizing the Westward Expansion. Then, through a set of counterfactual exercises, the relative contributions of the forces driving the results are analyzed. The central message of the paper is that two forces are key in accounting for the Westward Expansion: the decrease in transportation costs and population growth. More precisely, the decrease in transportation costs induced the westward migration, while population growth is mostly responsible for the investment in productive land. Section 5 concludes.

2 FACTS AND HYPOTHESIS

2.1 Population

In 1803, at the time when president Thomas Jefferson purchased the Louisiana territory, a small U.S. army unit, lead by Meriwether Lewis and William Clark, headed west across the continent. The goal of the expedition was to find a route to the Pacific ocean using the Missouri and Columbia river systems. Lewis and Clark returned more than 2 years later. Their findings concerning the land, its natural resources, and its native inhabitants became most valuable for migrants that,

¹Contributors to this literature are, for instance, Greenwood and Seshadri (2002) and Caselli and Coleman (2001).

throughout the rest of the century, settled the continent.

The demographic aspect of the Westward Expansion is represented by the increasing share of western population, displayed in Figure 1. It is important to keep in mind that there are two causes leading to an increase in this share: migration and, potentially, an excess rate of natural increase of the western population over the eastern population.

The Census does not report population by state of birth and state of residence before 1850. Hence, it is difficult to build a consistent measure of migration for the entire nineteenth century. There is little debate, however, about the existence of such migration. Gallaway and Vedder (1975), for instance, estimate the components of population growth for the “Old Northwest,” for the period 1800-1860.² They show that between 1800 and 1810, 80% of population growth in this region was accounted for by net migration. This percentage was 77 in the 1810s and 50 in the 1820s. Along the same line, Oberly (1986) reports that a third of the veterans of the war of 1812 lived as old men in a more western state as the one where they volunteered to serve.

There was a fertility differential, in favor of western regions, during the nineteenth century – see Yasuba (1962). It is not easy to conclude, from this evidence, that the rate of natural increase was higher in the West than in the East, though. There are two reasons for that. First, one needs to compare mortality rates. Unfortunately, region-specific mortality rates going back to 1800 are not available. Second, the rate of natural increase also depends on the male/female ratio, which was higher in the West. This could offset the effect of higher fertility. Imagine a fertility rate of 1 kid per woman in the East and 2 in the West. Suppose now that there is 1 man per woman in the East and 3 in the West. Then, everything else equal, the rate of natural increase is the same in both locations.

A few additional points are as follows. First, Steckel (1983) show evidence that settlers moved along lines of latitudes, that is, the movement was really westward. Second, Yasuba (1962, Table V-17) shows that the proportion of foreign born increases, between 1820 and 1860, in the West as in the East. In other words, it is hard to discern a preferred pattern of settlement of foreign born households. Third, O’Rourke and Williamson (1999) note that immigrants to the new world during the nineteenth century were mostly young males. Assuming this must have been the case for migration within the United States, one is led to think that migrants did not face tight borrowing constraints. As a matter of fact, Atack, Bateman, and Parker (2000, Table 7.1) describe the federal land policy during the nineteenth century and show that, until 1820, the federal government offered a credit to would-be-settlers. This credit was then abolished, but the price of public land was greatly reduced too. In 1862, the Homestead Act stipulated that five years residence on the land was enough to be the legal owner. Finally, the westward movement, represented in Figure 1, appears to have ended by the eve of the twentieth century. As a matter of fact, the “Frontier,” defined in the Census reports as areas with 2 to 6 people per square mile was officially “closed” after a bulletin by the Superintendent of the Census of 1890 claimed³:

Up to and including 1880 the country had a frontier of settlement, but at present the unsettled area has been so broken into by isolated bodies of settlement that there can hardly be said to be a frontier line.

2.2 Land

The territorial expansion of the United States during the nineteenth century was mostly a political and military process. The Louisiana purchase, for instance, was a spectacular acquisition that doubled the size of the country. From the perspective of economic analysis, though, only productive land matters and the process of its acquisition is an investment. At the eve of the nineteenth century, the vast majority of western land had never been used for productive purposes. Settlers moving

²The Old Northwest corresponds to today’s East North Central states: Ohio, Indiana, Illinois, Michigan and Wisconsin.

³Quoted from Turner (1894).

to the West had to clear, break, drain, irrigate and sometime fence the land before it could be used to produce goods. In doing so they built an important part of the country’s capital stock. Gallman (2000, Table 1.12) computed that, in the 1830s, 40% of gross investment was accounted for by land improvement – that is clearing, breaking, irrigating, draining and fencing new areas of land to make them productive. Figure 2 displays the stock of improved land. Note how the bulk of improved-land accumulation took place in the West. Note also the magnitude of the increase: one cannot view land as a fixed factor during the nineteenth century in the United States.

Interestingly, the technology for improving raw land got better during the century. In other words, a settler in 1900 would improve more acres of land in one day of work than in 1800. Thus, the cost of settling down into the West decreased partly because of technological progress in land-improvement techniques. Primack (1962a,b, 1965, 1969) measured the gain in labor productivity in the various activities contributing to land improvement.

2.2.1 Clearing

Consider first the clearing and first-breaking of land per se. What would technological progress, and therefore productivity growth, be like in this activity? First, it depends on the nature of the soil: clearing an acre of forest or an acre of grassland are two different tasks.

Two methods were common to clear forested areas: the “Swedish” or “Yankee” method and the “Indian” or “Southern” method. The Swedish method consisted mainly in cutting down trees, and then piling and burning the wood. Part of the trees, along a fence line, were cut down but reserved for fencing. Two firings were often needed so that the entire process could take several months. The Indian method consisted in girdling the trees by stripping the bark from a section around it. If done during the winter, the tree would die and start losing its limbs by the next spring. Eventually, the whole tree would fall. Both methods left the ground studded with stumps. Early frontiersmen would leave the stumps to rot for a few years and then remove them with the aid of basic tools: ax, lever and a yoke of oxen if they had one. Later, mechanical stump-pullers and blasting powder would help them to finish up the land-clearing more quickly. Productivity gain could also have come from specialization. As Primack (1962a) explains, clearing the land usually required much more manpower than individual settlers had available. Groups of settlers would then gather and help each other so that the newcomer did not have to learn and do everything by himself.

Grassland clearing was easier. Yet, the prairie soil required a special kind of plow and a team of four to eight oxen to be first broken. Many settlers did not have the necessary knowledge or material. Hence professionals were commonly hired to break virgin land. According to Primack (1962a), the introduction of an improved breaking plow and its acceptance by farmers, mainly after the civil war, was the main source of productivity increase in grassland clearing.

Table 1 reports data on land-clearing productivity. It took about 32 man-days to clear an acre of forest in 1860 and 1.5 man-days for an acre of grassland. By 1900 these numbers dropped to 26 and 0.5 respectively. One is naturally led to ask what was the proportion of land that was cleared each period from different types of coverage. In 1860, 66% of the acres cleared were initially under forest cover and 34% under grass cover. These numbers evolved as more western territories got settled. In 1900, just 36% of the land cleared was initially under forest cover, the rest was grassland.

Settlers could choose the type of land they cleared. Hence, the change in labor needed to clear an “average acre” not only captures technological progress, but also the substitution from forest toward prairie. A Tornqvist index is used to correct for this effect.⁴ The annual growth rate of productivity in land-clearing, for the period 1860-1900, is found to be about 0.6%. This figure compares, for instance, with the 0.7% annual rate of total factor productivity growth during the

⁴Let f_0 represents the share of forest in a representative acre at date 0. Let h_0^f be the labor requirement to clear an acre of forest at 0 and h_0^p be the labor requirement to clear an acre of prairie. The share of forest-clearing in the total cost of clearing is

$$\omega_0 = \frac{f_0 h_0^f}{f_0 h_0^f + (1 - f_0) h_0^p}.$$

same period – see Gallman (2000).

2.2.2 Fencing

A second component of farm improvement is the construction of fences. Primack (1969) shows that the cost and time required for fencing a farm was far from negligible, and a subject of continuous discontent for farmers. Initially, fences were made out of natural materials adjacent to the site: wood, stones or brushwood. This material was not always abundant depending on the region. Or, it was simply not convenient at all. For instance, stone fences were cheap but difficult to build, and even more difficult to move if the enclosed area had to be extended. Hence, throughout most of the nineteenth century, farmers have been seeking for better fencing devices. The major cause of productivity increase in fence building was the shift from wood to wire fences. A well known example of a technological innovation can be found here: barbed wire, invented and patented by Joseph F. Glidden in 1874. The effects of such an innovation are quite obvious: Barbed wire is light, easier and faster to set up than wood fencing, and withstand fires, floods and high winds. Primack (1969) reports that the fraction of time a farmer devoted to maintaining and repairing fences dropped from 4% in 1850 to 1.3% in 1900. Although, strictly speaking, this is not fence-building, it still conveys the idea that fences became easier to handle and a lighter burden on the farmer.

Table 2 reports data on fencing productivity. It took about 0.31 man-days to build a rod of wooden fence in 1850. This number remained unchanged until 1900. Stone fences required 2 man-days per rod and, here again, this number remained constant until 1900. In 1860, wire fences were made out of straight wire, which required about 0.09 man-days per rod. This requirement dropped to 0.06 man-days in 1900, thanks to the use of barbed wire.⁵ The shares of wood, stone and wire fences in total fencing are also reported in the table. A calculation similar to the one carried out in the case of land-clearing reveals that the growth rate of productivity in fencing was 0.5%.

2.2.3 Draining and Irrigating

The last two activities, drainage and irrigation, did not undergo any productivity gains during the second half of the century. Primack (1962a) argues that, in both cases, the labor requirements for laying one rod of drain or irrigating an acre of land remained constant from 1850 to 1900.

2.3 Hypothesis

What are the mechanism at work behind the Westward Expansion? It is probably fair to say that there exists a standard view on this matter which goes as follows: the abundance of western land, and thus its low price attracted settlers. This is not fully satisfactory for three reasons. First, and to the best of my knowledge, there are no quantitative assessment of the importance of this channel. Second if raw land was indeed cheap, the cost of transforming it into improved land had to be paid anyways. Finally, and as explained before, western improved land was not in fixed quantity but rather the result of investment decisions. Viewing productive land as an endogenous variable means that its abundance cannot be what explains the Westward Expansion. It is, on the contrary, one of the facts to be explained.

A second view consists in emphasizing population growth. Observe, Figure 2 and the fact that

The Tornqvist index, for the change in the labor requirement between date 0 and 1, is defined as

$$\ln T = \frac{\omega_0 + \omega_1}{2} \ln \left(\frac{h_0^f}{h_1^f} \right) + \left(1 - \frac{\omega_0 + \omega_1}{2} \right) \ln \left(\frac{h_0^p}{h_1^p} \right).$$

The growth rate of productivity between date 0 and 1 is then $T - 1$.

⁵Source: Primack (1962a, Table 25, p. 82). The figure for the productivity in wooden fences building is the average of the labor requirement for three types of fences: The “Virginia Rail:” 0.4 man-days, the “Post and Rail:” 0.34 and the “Board:” 0.20. A rod is a measure of length: 16.5 feet. The posts supporting a fence are usually one rod apart.

Eastern land was essentially a fixed factor as of 1800. As population grew, because of natural increase and immigration, eastern wage growth was slowed down because of the decreasing returns implied by the fixed stock of land. The existence of the West offered the possibility of increasing the total stock of land, and therefore permitted wage growth to be faster. This view is akin to the “safety valve” hypothesis of Turner (1894).

A third approach consists in emphasizing the transportation revolution which took place during the nineteenth century. O’Rourke and Williamson (1999) and Fishlow (1965, 2000) describe the improvements in technologies and transportation infrastructures. There are two potential effects of the transportation revolution on the Westward Expansion. First, the moving cost for settlers went down. Second, the cost of shipping goods to and from the West decreased too. This reduced the economic isolation of westerners: they could eventually sell their goods on the large markets of the Atlantic coast. They also could purchase consumption and investment goods produced in the East at lower costs. An important consequence of the decrease in transportation costs is the convergence of regional real wages – see Figure 3.

The view that transportation matters suggests that other form of technological progress could also be important. In particular, technological progress in land-improvement techniques could have played a quantitatively important role. Productivity growth in the production of goods could also have affected the Westward expansion. For instance, improvement in total factor productivity raises the marginal product of land and labor in each location. Productivity growth could also have negative effects. In the East, for instance, technological progress allows wage and consumption growth, despite population growth and decreasing returns. Hence, technological progress slow down the Westward Expansion by reducing the need to increase the stock of land. The final effect of such changes is ambiguous a priori, and must be investigated quantitatively, using a formal model.

3 THE MODEL

How do population growth and the various forms of technological progress interact? What are their respective contributions to the Westward Expansion? To answer such questions, a model incorporating these mechanisms is developed. To clarify the exposition, the first version of the model is written in a static setting, and analyzed through a set of numerical examples. A dynamic version is then proposed for the purpose of the quantitative exercise conducted in Section 3.

3.1 The Static Model

All activity takes place in a single period of time. There are two locations called East (e) and West (w), and the list of commodities is as follows: labor, a consumption good, an intermediate good, eastern and western land. As will become clear later, the intermediate good serves the purpose of introducing a transportation cost for goods, in addition to a transportation cost paid by households.

Land exists in two states: raw and improved. Only the latter can be used for production. (Note that, in the static framework, raw land is worthless while in the dynamic model it may have value when agents foresee that it will be improved in the future.) It is assumed that all eastern land is improved. The fraction of western land which is improved, however, is determined in equilibrium. More specifically, a land-improvement sector, which exists only in the West, hires local workers to transform raw land into improved land. It then sells it to households who, in turn, rent it to the western consumption-good sector.

The consumption good is produced in both locations with labor, the intermediate good and improved land. Finally, the intermediate good is produced only in the East, with labor. There, it can be used at no other cost than its price. To be used in the West, however, a transportation cost has to be paid.

At this point, it is important to lay out the structure of ownership of land and firms. There is a mass p of identical agents, supplying inelastically one unit of time to the market. Each agent is endowed with an equal fraction of the property rights over eastern land and the various firms in the economy. Regardless of their location, households are also allowed to purchase property rights over western improved land, from the land-improvement sector.

Households choose their location and sector of activity. To summarize, they can work in the consumption good sector in the East or the West, in the western land-improvement sector or, finally, in the eastern intermediate-good sector. There are no costs associated with changing sector within a location. It is costly, however, to change location. Figure 4 summarizes the sectors, their inputs and locations.

3.1.1 Firms

Intermediate Good

A constant-returns-to-scale technology is used to produce the intermediate good from labor

$$x = z_x h_x^e.$$

The variable x denotes the total output of the sector, z_x is an exogenous productivity parameter and h_x^e is eastern labor. Let q_x denote the price of x . The eastern consumption-good sector purchases x at no other cost than q_x . The western consumption-good sector faces a transportation cost, though. More precisely, for one unit of the intermediate good, the western consumption-good sector faces a price $q_x(1 + \tau_x)$. The difference, $q_x\tau_x$, is lost during shipment – an iceberg cost. Thus, the marginal revenue of the firm is q_x , regardless of the final destination of the good. Its objective writes then

$$\max \{q_x x - w^e h_x^e\}, \quad (1)$$

where w^e denotes the eastern real wage rate.

Consumption Good

Labor, the intermediate good and improved land are used to produce the consumption good:

$$y^j = z_y (h_y^j)^\mu (x^j)^\phi (l^j)^{1-\phi-\mu}, \quad \mu, \phi \in (0, 1).$$

In this expression, the superscript j refers to location ($j = e, w$). The variable h_y^j refers to labor employed in the consumption-good sector in location j . Inputs of the intermediate good and improved land are denoted by x^j and l^j , respectively. The objective of the eastern sector is

$$\max \{y^e - w^e h_y^e - q_x x^e - r^e l^e\} \quad (2)$$

where r^e denotes the rental price of improved land. The western sector solves

$$\max \{y^w - w^w h_y^w - q_x(1 + \tau_x) x^w - r^w l^w\}. \quad (3)$$

Improved Land

The Land – By assumption eastern land is entirely improved. The land-improvement sector, therefore, exists only in the West. There, the total stock of land is fixed and represented by the unit interval and is, in equilibrium, partitioned between improved and raw land. The land-improvement sector decides this partition. At this point, it is important to distinguish between the stock of improved land itself and the production services it delivers to the consumption-good sector. The former is measured by the length of a subset of the unit interval, while the latter is measured in efficiency units. This distinction is used to introduce the notion that land is not homogenous. More precisely, the efficiency units obtained from improving an interval $I \subseteq [0, 1]$ is given by $\int_I \Lambda(u) du$, where Λ is a density function, assumed to be decreasing. Assume, further, that land is improved

from 0 to 1. Thus, a stock of improved land of size $l \in [0, 1]$ means that the interval $[0, l] \subseteq [0, 1]$ is improved and that the efficiency units of land used in production in the West amount to

$$l^w = \int_0^l \Lambda(u) du.$$

The function Λ is given the following particular form

$$\Lambda(u) = 1 - u^\theta, \quad \theta > 0.$$

One can interpret the assumptions that Λ is decreasing and that land is improved from 0 to 1, as a shortcut for modeling the fact that the “best” land is improved first. This modeling strategy also ensures an interior solution: land close to 1 delivers close to 0 efficiency units after improvement.

The Land-improvement Firm – The technology for improving land up to point l requires labor and is represented by

$$l = z_l h_l^w \tag{4}$$

where z_l is a productivity parameter and h_l^w is employment. Let q^w denote the price of an efficiency unit of western land. The optimization problem of the firm is

$$\pi = \max \left\{ q^w \int_0^l \Lambda(u) du - w^w h_l^w : l = z_l h_l^w \right\}, \tag{5}$$

and the first order condition is

$$q^w \Lambda(l) = \frac{w^w}{z_l}.$$

The left-hand side of this expression is the marginal benefit obtained from the last parcel of land improved, i.e., the efficiency units obtained from this parcel multiplied by their market price. The right-hand side is the marginal cost of improvement. Figure 5 represents the determination of the stock of improved land. Three variables affect it: the western wage rate, the productivity of the land-improvement technology and, finally, the price at which efficiency units of land are sold. Increases in the wage rate makes land improvement more costly and, therefore, affect it negatively. Productivity plays the opposite role. Finally, increases in the price of efficiency units of land raise the marginal revenue from land improvement and, thus, affect it positively.

3.1.2 Households

Households have preferences represented by $U(c)$, a twice continuously differentiable, increasing and strictly concave function. Imagine that, before any activity takes place, the population is located in the East. The optimization problem of a household deciding to remain there is given by

$$V^e = \max \left\{ U(c^e) : c^e = w^e + \frac{1}{p} (r^e l^e + \pi) \right\}$$

where c^e stands for consumption. As mentioned earlier, households are endowed with property rights over eastern land and the firms. Thus, they receive a fraction $1/p$ of the returns to eastern land, $r^e l^e$, and the profit of the land-improvement sector, π . (The consumption-good and intermediate-good sectors have zero profit in equilibrium.) A household deciding to live in west faces a similar problem:

$$V^w = \max \left\{ U(c^w) : c^w = w^w - \tau_h + \frac{1}{p} (r^e l^e + \pi) \right\}$$

where τ_h is the cost of moving from East to West.

Observe that western improved land does not appear in the budget constraint of households. The reason is the following: Suppose a household buys one unit of western improved land at price q^w

Technology	$\mu = 0.65, \phi = 0.25, \theta = 0.5$ $z_y = 1.0, z_l = 1.0, z_x = 1.0$
Population	$p = 10$
Eastern land	$l^e = 0.05$
Moving costs	$\tau_x = 0.1, \tau_h = 0.1$

Table 3: Parameter values

from the land-improvement sector, and rents it at rate r^w to the consumption-good sector. In equilibrium, households buy land up to the point where $r^w = q^w$. Thus, this operation does not appear in the budget constraint. Western land delivers income through the profit of the land-improvement sector, though.

The decision of a household is his location:

$$\max \{V^e, V^w\}. \quad (6)$$

Denote by h^w and h^e the number of agents who decide to live in the West and in the East, respectively.

3.1.3 Equilibrium

The equilibrium is a list of allocations for firms: $\{h_y^w, x^w, l^w\}$, $\{h_e^w, x^e, l^e\}$, $\{h_l^w\}$, $\{h_x^e\}$ and prices $\{q_x, r^w, r^e, w^w, w^e\}$ such that (i) problems (1), (2), (3), (5) and (6) are solved given prices; (ii) markets clear. The equilibrium equation on the eastern labor market is $h_y^e + h_x^e = h^e$, on the western labor market it is given by $h_y^w + h_l^w = h^w$, on the intermediate good market it is $x^w + x^e = x$ and, finally, it is $h^e c^e + h^w c^w + h^w \tau_h + q^x \tau_x x^w = y^e + y^w$ on the consumption good market.

3.1.4 Analysis

The mechanisms at work in the model can be understood through a set of numerical examples. First, parameters are chosen (see Table 3) and a baseline equilibrium computed. Additional equilibria are then computed, each of them associated with a change in a single exogenous variable at a time. For instance, the first experiment consists in increasing population from 10 to 15, holding other variables at their baseline level. In the second experiment, population is at its baseline level of 10, but the transportation cost for households, τ_h , is reduced from 0.1 to 0.05. Other experiments

	Ratio of westerners h^w/p	Stock of improved land l	Wage rates (w^w, w^e)	Return to western land r^w
Baseline	0.17	0.18	(0.42, 0.32)	0.73
$p = 15$	0.21	0.31	(0.41, 0.31)	0.92
$\tau_h = 0.05$	0.42	0.38	(0.39, 0.34)	1.02
$\tau_x = 0.05$	0.20	0.21	(0.42, 0.32)	0.78
$z_y = 1.5$	0.34	0.33	(0.60, 0.50)	1.40
$z_x = 1.5$	0.22	0.23	(0.46, 0.36)	0.88
$z_l = 1.5$	0.23	0.33	(0.42, 0.32)	0.67

Table 4: Numerical examples

consist in decreasing the transportation cost for goods, and increasing the productivity parameters, z_y , z_x and z_l . Table 4 shows that each experiment results in an increase of the percentage of population living in the West, and the stock of improved land.

When population increases, as in the first experiment, the demand for consumption goods increases, and the opening of more land in the West is justified to satisfy this demand. Land improvement

requires labor, so western population increases. Simultaneously, the larger stock of productive land implies a higher marginal product of labor in the west, and therefore the demand for western workers increases. Observe the drop in wages, due to increased labor supply. Note, finally, that the return to western land increases: On the one hand more land is used for production, so its marginal return tends to decrease. On the other hand more labor and intermediate goods are employed too, raising the marginal product of land.

Reduction in transportation costs have expected effects. First, the transportation cost for households dictates the East-West wage gap. As it declines, more households move to the West, reducing the wage rate there and increasing it in the East. Second, a reduction in the transportation cost for the intermediate good induces the western firm to use more of it. This results in an increase in the marginal product schedules for western land and labor and, in turn, raises the demand for labor and improved land.

Productivity growth, in each sector, also promotes the development of the west. Consider first the consumption good sector. When z_y increases, the return to western land rises inducing an increase in the stock of improved land. This, in turn raises the demand for labor. An increase in z_x tends to reduce the price of the intermediate good, making it cheaper for the western consumption-good sector to use it. Then, as in the case of a drop in the transportation cost, the marginal product, and therefore the demand, for labor and land increase. Finally, an increase in z_l directly promotes land improvement which attracts workers to the West.

3.2 The Dynamic Model

Consider a dynamic version of the model, where all the mechanisms described above are incorporated. Let time be discrete and indexed by $t = 1, \dots, \infty$. The new ingredients of this version are as follows. First, the land-improvement sector solves a dynamic problem: given that the stock of improved land at the beginning of t is l_t , what should l_{t+1} be? Second, a government is introduced as the owner of raw land. It sells it to the land-improvement sector which, as in the static version, improves it and sells it to households. The revenue from selling raw land is transferred to households. As will appear soon, this device is introduced to simplify the model. Third, the demography has to be laid out clearly. The choice, here, is to represent population as a set of overlapping generations, and to specify an exogenous mechanism for its growth. Within each age group one can find three types of agents: those who spend their life in a single location, East or West, and those who move from one location to the other. The latter are called “movers.” Fourth, there are economy wide markets for western and eastern improved land. Finally, the consumption-good and intermediate-good sectors solve static problems, hence they are still described by Equations (1), (2) and (3).

3.2.1 Improved-land

The physical description of land is the same as in the static version of the model. The stock of improved land, however, changes according to

$$l_{t+1} = l_t + z_{lt} h_{lt}^w.$$

In words, the stock of improved land increases, each period, by a quantity which depends on employment in the land-improvement sector. Hence, the equation above is the dynamic counterpart of Equation (4).

At the beginning of period t , the stock of improved land, l_t , is given. The land-improvement sector decides l_{t+1} and its profit is

$$\pi_t(l_t, l_{t+1}) = q_t^w \int_{l_t}^{l_{t+1}} \Lambda(u) du - \frac{w_t^w}{z_{lt}} (l_{t+1} - l_t) - \int_{l_t}^{l_{t+1}} q_t^r(u) du$$

The first two elements of the profit correspond to the total revenue net of the labor cost. They form the counterpart of Equation (5). The last part is the cost paid by the firm, to the government, for

raw land located in the interval $[l_t, l_{t+1}]$. The function $q_t^r(\cdot)$, represents the price of raw land set by the government. Its description is postponed to Section 3.2.3.

The value of the sector, at date t , is

$$J_t(l_t) = \max \left\{ \pi_t(l_t, l_{t+1}) + \frac{1}{i_{t+1}} J_t(l_{t+1}) \right\} \quad (7)$$

where i_{t+1} is the gross interest rate applying between date t and $t + 1$. The optimality condition associated with this problem is

$$q_t^w \Lambda(l_{t+1}) - \frac{w_t^w}{z_{lt}} - q_t^r(l_{t+1}) = \frac{1}{i_{t+1}} \left(q_{t+1}^w \Lambda(l_{t+1}) - \frac{w_{t+1}^w}{z_{l,t+1}} - q_{t+1}^r(l_{t+1}) \right).$$

The left-hand side of this equation is the marginal profit obtained from improving land up to point l_{t+1} , during period t . The right-hand side is the present value of the marginal profit the firm would realize, if it decided to improve this last “lot” during period $t + 1$, when prices and technology are at their period- $t + 1$ values. Along an optimal path, there should be no profit opportunities from changing the timing of land-improvement, thus the two sides of this equation have to be equal. This equation is an instance of the so-called Hotelling (1931) formula.

3.2.2 Households

Decision Problem

Households lives for 2 periods, and there are three types in each age group. First, there are those who spend their life in a single location. They are called “easterners” or “westerners.” Second, there are those who change location during their lives. They are called “movers.” Preferences are defined over consumption at age 1 and 2, c_1 and c_2 , and are represented by

$$\ln(c_1) + \beta \ln(c_2)$$

where β is a discount factor.

The decision to be a mover is made only once in life. Consider the case of an agent who wants to move from East to West. Moving takes place at the beginning of the first period of life, thus this agent works in the West throughout is life. He differs from a westerner who does not have to pay the cost of moving, τ_{ht} . As will become clear shortly, moving takes place only from East to West. Thus, in what follows, the term “mover” always refers to this particular direction.

Denote the consumption of an age- a household of type j ($j = e, w, m$) during period t by c_{at}^j and the value function of a type- j household of age 1 at t by V_t^j . One can write:

$$\begin{aligned} V_t^j &= \max \left\{ \ln(c_{1t}^j) + \beta \ln(c_{2,t+1}^j) \right\} \\ \text{s.t. } &c_{1t}^j + \frac{c_{2,t+1}^j}{i_{t+1}} = w_t^j + \frac{w_{t+1}^j}{i_{t+1}} + T_t \end{aligned} \quad (8)$$

for $j = e, w$, that is for households who do not move during their lives. The term T_t is a transfer received from the government at age-1. The motivation for having this transfer is explained in Section 3.2.3. Movers going from East to West solve the following problem

$$\begin{aligned} V_t^m &= \max \left\{ \ln(c_{1t}^m) + \beta \ln(c_{2,t+1}^m) \right\} \\ \text{s.t. } &c_{1t}^m + \frac{c_{2,t+1}^m}{i_{t+1}} = w_t^w + \frac{w_{t+1}^w}{i_{t+1}} + T_t - \tau_{ht} \end{aligned} \quad (9)$$

An age-1 agent in the East at date t must be, in equilibrium, indifferent between moving to the West or staying in the East. Hence,

$$w_t^w - w_t^e + \frac{w_{t+1}^w - w_{t+1}^e}{i_{t+1}} = \tau_{ht}. \quad (10)$$

In words, the present value of income, net of the moving cost, for an agent just settling down into the West must be the same as for an agent of the same age who stays in the East. Observe that Equation (10) implies that households move only in the westward direction. No household would pay to move from West to East, where the present value of income is lower.

Demography

Let p_t denote the size of the age-1 population, so that total population is given by $p_t + p_{t-1}$. Population growth has two sources: natural increase and international immigration. Denote the rates of natural increase in the West and the East by n^w and n^e , respectively. Those rates are location specific to capture the differences observed in the U.S. data – see Yasuba (1962). Denote the rate of international immigration by f . Finally, let p_t^w and p_t^e denotes the number of age-1 households located in the West and the East, respectively. Their laws of motion are

$$p_{t+1}^w = (n^w + f)p_t^w + m_t \quad (11)$$

and

$$p_{t+1}^e = (n^e + f)p_t^e - m_t. \quad (12)$$

where m_t is the number of age-1 households deciding to move to the West during period t . Define $\omega_t = p_t^w/p_t$, the proportion of age-1 households located in the West at date t . The law of motion for the age-1 population is then described by

$$\frac{p_{t+1}}{p_t} = n^w \omega_t + n^e(1 - \omega_t) + f. \quad (13)$$

3.2.3 Government

How does the government price unimproved land? Here, it is assumed that its policy is to sell it at the price that would prevail if unimproved land was privately owned and traded on a market.⁶ This dictates the following:

$$q_t^r(u) = \begin{cases} \text{undefined} & \text{for } u < l_t, \\ q_t^w \Lambda(u) - w_t^w/z_{lt} & \text{for } u \in [l_t, l_{t+1}], \\ q_{t+1}^r(u)/i_{t+1} & \text{for } u \geq l_{t+1}. \end{cases} \quad (14)$$

Observe first that, at the beginning of period t , all the land up to l_t has already been improved. Therefore, there is no such thing as unimproved land before that point. Second, note that integrating $q_t^r(u)$ over the interval $[l_t, l_{t+1}]$ returns a zero-profit condition. In other words, the difference between the value of improved and unimproved land is the cost of improvement. The last part of the definition of $q_t^r(u)$ is a no-arbitrage condition. Consider a lot, du , that is not improved during period t and remains as such at the beginning of period $t + 1$. This is the case for all u satisfying $u \geq l_{t+1}$. What would be the return on such lot, if it was traded on a market? By definition, unimproved land is not productive, the answer is therefore $q_{t+1}^r(u)/q_t^r(u)$. In equilibrium, this return must equal the gross interest rate, p_t/p_{t+1} .

Under this policy, the first order condition of the land-improvement sector now reads

$$q_t^w \Lambda(l_{t+1}) - \frac{w_t^w}{z_{lt}} = \frac{1}{i_{t+1}} \left(q_{t+1}^w \Lambda(l_{t+1}) - \frac{w_{t+1}^w}{z_{l,t+1}} \right).$$

In other words, when virgin land is priced competitively, the decisions of buying land and improving it can be separated. This should not be surprising: As long as the no-arbitrage condition described above holds, the firm cannot reduce the present value of its cost by reallocating its purchases of

⁶In an infinitely-lived representative agent model, this would mimic the equilibrium that would prevail if unimproved land was privately owned and traded on a market. In an overlapping generations model the equilibrium will be influenced by the timing of transfer payments to the agents or $\{T_t\}_{t=1}^{\infty}$.

raw land through time. The value of the land-improvement firm depends only on the timing of land-opening itself.

The revenue collected from selling virgin land is distributed via the transfer T_t to young households. The government's budget constraint is then

$$T_t p_t = \int_{l_t}^{l_{t+1}} q_t^r(u) du. \quad (15)$$

The introduction of the government allows one to avoid modeling explicitly the market for shares of the land-improvement firm. As the second line of equation (14) makes clear, the profit of the land-improvement sector is captured by the government and redistributed to the age-1 population.

3.2.4 Equilibrium

In equilibrium, the gross rate of return on improved land must be identical across locations. Hence, the gross interest rate is given by

$$i_{t+1} = \frac{r_{t+1}^j + q_{t+1}^j}{q_t^j}, \quad j = e, w. \quad (16)$$

Several market-clearing conditions have to hold: first, the eastern labor market must clear:

$$p_t^e + p_{t-1}^e = h_{yt}^e + h_{xt}^e. \quad (17)$$

The left-hand side of this equation represents the total eastern population at date t : the labor supply. The demand, on the right-hand side, comes from the consumption-good and the intermediate-good sectors. In the western labor market, a similar condition must hold:

$$p_t^w + p_{t-1}^w = h_{yt}^w + h_{xt}^w. \quad (18)$$

The market for the intermediate good is in equilibrium when

$$x_t^w + x_t^e = x_t \quad (19)$$

and, finally, the market for the consumption good clears when

$$c_t + m_t \tau_{ht} + q_{xt} \tau_{xt} x_t^w = y_t^w + y_t^e. \quad (20)$$

Total consumption, c_t , is given by the sum of consumption of all agents.⁷ A competitive equilibrium can now be formally defined.

Definition 1 *A competitive equilibrium is made of: (i) allocations for households $\{c_{at}^j\}$ for $j = e, w, m$ and $a = 1, 2$ and firms $\{h_{yt}^w, h_{yt}^e, h_{lt}^w, h_{xt}^e, x_t^w, x_t^e, l_t^e, l_t^w\}$; (ii) prices $\{w_t^j, r_t^j, q_t^j, q_{xt}, i_t, q_t^r(\cdot)\}$ for $j = e, w$; and transfers $\{T_t\}$ such that:*

1. The sequence $\{h_{xt}^e\}$ solves (1) given prices;

⁷To be precise, let m_t^j ($j = e, w, m$) be the number of age-1 agents of type j at date t :

$$\begin{aligned} m_t^w &= (n^w + f)p_{t-1}^w \\ m_t^e &= (n^e + f)p_{t-1}^e - m_t \\ m_t^m &= m_t. \end{aligned}$$

The number of age-1 spending their lives in the West are those born (or arrived from abroad) in the West (first equation); the number of age-1 in the East, spending their lives in the East, are those born there, minus the movers (second equation); the number of movers is defined as m_t . Total consumption is then

$$c_t = m_t^w c_{1t}^w + m_{t-1}^w c_{2t}^w + m_t^e c_{1t}^e + m_{t-1}^e c_{2t}^e + m_t^m c_{1t}^m + m_{t-1}^m c_{2t}^m.$$

2. The sequence $\{h_{yt}^e, x_t^e, l^e\}$ solves (2) given prices;
3. The sequence $\{h_{yt}^w, x_t^w, l_t^w\}$ solves (3) given prices;
4. The sequence $\{h_{it}^w\}$ solves (7) given prices;
5. The sequences $\{c_{at}^w\}$ and $\{c_{at}^e\}$ solve (8) given prices; the sequence $\{c_{at}^m\}$ solve (9); and household choose their location optimally, or (10) holds;
6. Population evolves in line with (11) and (12);
7. The government prices unimproved land according to (14), and its budget constraint (15) holds.
8. The equilibrium conditions (16)-(20) hold.

3.2.5 Balanced Growth

In the long-run, land becomes a fixed factor in the West as it is in the East. In other words, the land-improvement sector shuts down, and $l_t^w \rightarrow \int_0^1 \Lambda(u)du$, as $t \rightarrow \infty$. Suppose, in addition, that the rates of natural increase are the same across regions: $n^w = n^e = n$. Assume, finally, that the transportation costs, τ_{ht} and τ_{xt} are negligible. Then, the economy moves along a balanced growth path which can be described as follows. First population growth is constant and is the same across locations:

$$\gamma_p \equiv p_t^w/p_{t-1}^w = p_t^e/p_{t-1}^e = n + f.$$

Employment in each sector, h_{yt}^w , h_{yt}^e , and h_{xt}^e , grows at rate γ_p too. Thus, the production of intermediate goods is growing at the rate $\gamma_x = \gamma_p \gamma_{z_x}$. The production of the consumption good, is then growing at the same rate in each location, and this rate is given by

$$\gamma_y = \gamma_{z_y} \gamma_{z_x}^\phi \gamma_p^{\phi+\mu}.$$

The wage rate in each location is growing at rate γ_y/γ_p . The rental rate for land increases at rate γ_y as well as the price of land in each location. This implies, through Equation (16) a constant interest rate along the balanced growth path.

4 COMPUTATIONAL EXPERIMENT

4.1 Calibration

Let a model period correspond to 10 years. The exogenous driving forces are productivity variables: $\{z_{yt}, z_{lt}, z_{xt}\}$, and transportation costs: $\{\tau_{ht}, \tau_{xt}\}$. To choose these trajectories, one must pick initial conditions and rates of change. Gallman (2000, Table 1.4) indicates that the annual rate of growth of total factor productivity, z_{yt} , was 0.55% from 1800 to 1840 and 0.71% from 1840 to 1900. The growth rate of z_{xt} is set to the same values. The growth rate of z_{lt} is given by the calculations described in the Introduction: it is set to 0.6% from 1860 to 1900. Unfortunately, there are no data on technological progress in land-improvement during the antebellum period. The strategy, then, is to use labor productivity in agriculture as a proxy. Atack, Bateman, and Parker (2000) report that it grew at an annual rate of 0.3% per year from 1800 to 1860. O'Rourke and Williamson (1999, p. 36) mention a 1.5% annual rate of decline for transportation costs. This number is used for both transportation costs in the model. The initial value of the transportation cost for goods is set to 50%. This corresponds to the price difference between east and midwest, for wheat, at mid-century – see Herrendorf, Schmitz, and Teixeira (2006).

The labor and intermediate good shares are calibrated from Gallman (2000, Table 1.4). The labor share is $\mu = 0.2$ and the intermediate good share is calibrated to the capital share $\phi = 0.6$. The

rate of net migration, f , is set to 5.5%, its average level in the U.S. data for the period 1800-1900 – see Haines (2000, Table 4.1).

Yasuba (1962) reports information on the birth ratio by state and census year between 1800 and 1860.⁸ There is a great deal of variation in this data, but one clear pattern emerges: the larger birth ratio of western women. As discussed in the introduction, this difference does not imply a higher rate of natural increase in the West, though. Yet, for the purpose of the quantitative exercise conducted here, the rates of natural increase n^w and n^e are allowed to differ. This is a conservative choice, since it reduces the effects of all forces that might lead to an increase of the ratio of western to total population. How to pick n^w and n^e , then? First pick n^e . Yasuba indicates that the birth ratios observed in Vermont, Maine, New Hampshire, New York, New Jersey and Pennsylvania are about 2.0 in 1800. This implies a rate of natural increase $n^e = 1 + 2.0/10$. Given n^e , the values for n^w is chosen using Equation (13). More precisely, given $f = 0.06$, $n^e = 1.2$ and the observed ratio of western to total population, one can find the value of n^w such that total population would be multiplied by 13.6 in the model (as in the U.S. data between 1800 and 1900,) if it replicated perfectly the ratio of western to total population. This implies $n^w = 1.3$.

The rest of the parameters are computed in order to minimize a distance between the model and the U.S. data in a sense to be clarified. But, before describing this measure, one must first describe the nature of the trajectory computed here. Think of starting the economy off at date $t = 1$. Associate this date to the 1800 U.S. economy. At this point, the stock of improved land in the West, l_1 , is the result of past investment decisions and, thus, it is taken as given. More precisely, the value of l_1 is set to the actual ratio of the stock of western improved land in 1800 to its value in 1900: 6%. The initial old population is normalized to one. It is assumed that there are no households installed in the West at date 1. Thus, the initial young population is given by $p_1 = n^e + f$. From date 1 on, the driving variables are fed into the model for a length of 50 periods. Only the first 10 periods are of interest to the quantitative exercise, since they are taken to represent the U.S. from 1800 to 1900. Over the remaining 40 periods, the values of n^w and n^e are gradually reduced to capture the fact that, during the twentieth century, there has been no discernable differences in regional fertility rates.⁹ The rest of the driving variables are allowed to grow at the rates just described. Thus, the model economy converges to its balanced growth path in the long-run.

Define $a \equiv (\beta, \theta, l^e, \tau_{h1}, z_{y1}, z_{x1}, z_{l1})$, which is the list of remaining parameters: the discount factor, the curvature parameter (of the density of efficiency units of land), the stock of improved land in the east, and the initial values for the transportation cost for households and productivity paths. For a given a the model generates times series for the ratio of westerners, the stock of improved land and the ratio of western to eastern wages. Namely, define

$$\begin{aligned}\hat{P}_t(a) &= \frac{p_t^w + p_{t-1}^w}{p_t^w + p_{t-1}^w + p_t^e + p_{t-1}^e} \\ \hat{Q}_t(a) &= l_t \\ \hat{R}_t(a) &= w_t^w / w_t^e\end{aligned}$$

Let P_t , Q_t and R_t be the empirical counterparts of \hat{P}_t , \hat{Q}_t and \hat{R}_t . The sequence Q_t is built by normalizing the stock of western improved land (Figure 2) by its 1900 value. The sequence P_t and R_t are displayed on Figures 1 and 3.

The choice of a is the result of a grid search to solve

$$\min_a \sum_{t \in \mathcal{T}} (\hat{P}_t(a) - P_t)^2 + \sum_{t \in \mathcal{T}} (\hat{Q}_t(a) - Q_t)^2 + \sum_{t \in \mathcal{T}} (\hat{R}_t(a) - R_t)^2 + (i_{1900}(a) - 1.07^{10})^2$$

⁸The birth ratio is the number of children under 10 years of age, per women aged 16-44.

⁹To be precise, n_w is given the following values: {1.3, 1.25, 1.2, 1.05} for the following periods: {1...19, 20...34, 35...44, 45...50}. Likewise, n^e is given the following values: {1.2, 1.15, 1.05} on {1...35, 35...44, 45...50}.

where $\mathcal{T} \equiv \{1800, 1810, \dots, 1900\}$.¹⁰ The first and second terms of this distance involve the sum of square differences between the actual and predicted stock of land and ratio of westerners. The third term involves the wage ratio. It is important for the determination of the initial value τ_{h1} . The last term involves i_{1900} , the real interest rate at the end of the period. It is important for the determination of the discount factor β . The value 1.07^{10} correspond to a 7% annual interest year over a ten year period.¹¹ Figures 6, 7 and 8 indicate the performance of the model at matching the U.S. data. The baseline parameters are indicated in Table 5.

4.2 Counterfactuals

The results of six counterfactual experiments are described by Figures 9 and 10. Each experiment consists in shutting down one of the exogenous driving forces at a time. In the first one, the equilibrium path of the economy is computed without any population growth. More precisely, n^w and n^e are set to unity and $f = 0$. The only forces driving the Westward Expansion are then the technological variables in production and transportation. In the second experiment, population grows as in the baseline model, but productivity growth in the consumption good sector is shut down: $\gamma_{z_y} = 1.0$. In the third experiment, productivity growth in the land-improvement technology is shut down: $\gamma_{z_l} = 1.0$. In the fourth experiment, it is the productivity variable in the intermediate good production which is not growing: $\gamma_{z_x} = 1.0$. Finally, experiment five and six correspond to shutting down the decline in transportation costs for households ($\gamma_{\tau_h} = 1.0$) and goods ($\gamma_{\tau_x} = 1.0$), respectively.

The central message from Figures 9 and 10 is that there are two main forces driving the Westward Expansion: the decline in transportation costs (applied to households, that is τ_{ht}) and population growth. The decline in the cost of transportation for households affects mostly the distribution of population, but it has a lesser effect on the accumulation of Western land. Population growth, on the other hand, affects mostly the accumulation of land, and has a small effect of the distribution of population.

Such results can be interpreted along the same lines as those exemplified with the static model of Section 2.1. The importance of population growth for the accumulation of western land comes from the fact that eastern land is fixed. As the demand for the consumption good increases, because of population growth, the decreasing returns faced by the Eastern production sectors makes it more expensive to satisfy it. The opening of western land is then optimal to overcome the decreasing returns. The effect of τ_{ht} on the movement of population is straightforward. The fact that it does not affect the development of western land as population growth does is another indication of the importance of the decreasing returns in the East.

Technology variables such as z_{yt} , z_{lt} and z_{xt} have little effects on the accumulation of western land. As far as the distribution of population across region is concerned, however, the growth of z_{yt} plays a noticeable role, although it is quantitatively smaller than the role played by τ_{ht} . Without growth in z_{yt} , that is with no total factor productivity growth, the ratio of western to total population is uniformly below its baseline trajectory. The reason is that land becomes less productive in each location. A priori this affects labor demands in each location, but quantitatively the effect on western labor demand is the largest. Remark, finally, that the decrease in τ_{xt} , the transportation cost for intermediate goods, has a small effect on the distribution of population. With no decrease in this cost, the ratio of westerners lies below its baseline trajectory. As far as the accumulation of western land is concerned, this variables plays a negligible role.

Figure 11 indicates the effect of international immigration. The question asked is: if no immigrants from the rest of the world entered the U.S. during the nineteenth century, and if the rate of natural increase remained unchanged, how different would the U.S. be in 1900? Technically, this amounts to

¹⁰Note that there is no data for the stock of improved land in 1820 and 1830, and that the data for the wage ratio are 1830-1880.

¹¹This value corresponds to the interest rate used by Cooley and Prescott (1995) for the second half of the twentieth century.

computing the equilibrium trajectory of the economy with $f = 0$, but n^w and n^e at their baseline levels. The lesson from this experiment is that international immigration played a small role, quantitatively. Under the assumption that immigrants did not affect the rate of natural increase, population grows by a factor 8.8 between 1800 and 1900 (vis à vis a factor 13.6 in the baseline case). Quantitatively, population growth is then still high enough to warrant a significant westward movement.

5 CONCLUDING REMARKS

The nineteenth century Westward Expansion in the United States is one of the processes that shaped the United States as we know them today. In particular, it determined the geographic distribution of population and economic activity. This paper presented an attempt at identifying the quantitatively relevant forces driving this phenomenon. Population growth and the decrease in transportation costs are found to be the most important forces. More precisely, the decrease in transportation costs induced the westward migration, while population growth is mostly responsible for the investment in productive land.

International immigration and natural increase have been treated exogenously. It has been shown that natural increase was high enough to warrant the Westward Expansion, even if no immigrants came from the rest of the world. Future work could investigate the causes of population growth in the United States during the nineteenth century, and its link to the expansion. One can make two observations here. First, international immigration from the rest of the world is essentially the same phenomenon as the one studied here, within the United States. Hence, a similar model, calibrated to different data, could shed some light on the pace of international immigration during the nineteenth century. Second, and regarding natural increase in the United States, one faces the challenge of explaining the highest fertility of westerners relative to easterners.

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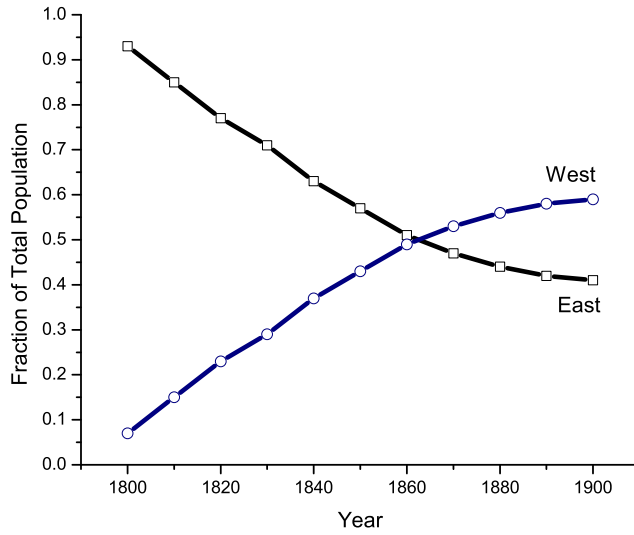


Figure 1: Regional Shares of Total Population, 1790–1910.

Note – The source of data is Mitchell (1998, Table A.3, p. 34). The “East” is arbitrarily defined as the New-England, Middle-Atlantic and South Atlantic regions. The list of states in these regions are Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Florida. The West consists of all other states in the continental U.S.

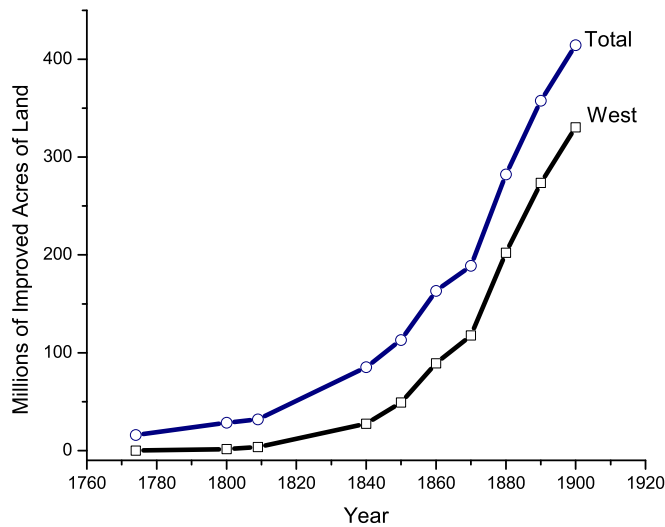


Figure 2: Stock of Improved Land, 1774–1900.

Note – The source of data is Gallman (1986, Table B-5).

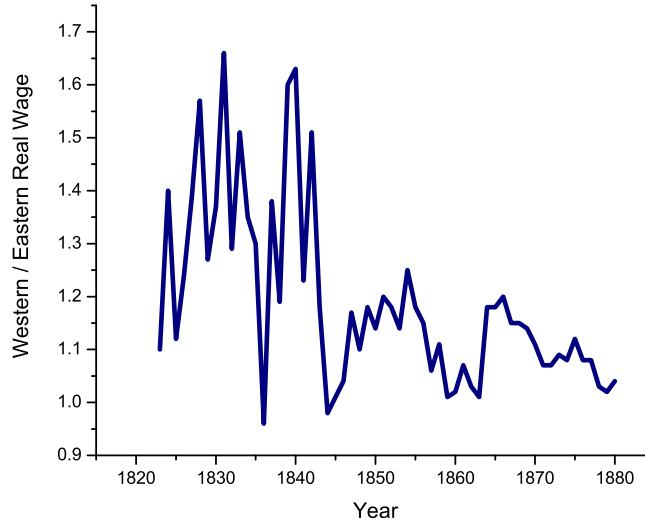


Figure 3: Ratio of Western to Eastern Real Wages, 1823–1880.

Note – The source of data is Coelho and Shepherd (1976) and Margo (2000). Only northern regions, which used free labor throughout the entire period, are considered. The average of New-England and Middle Atlantic’s real wages reported by Coelho and Shepherd (1976) are spliced with Margo (2000)’s Northeastern real wages. The average of Eastern North Central and Western North Central real wages from Coelho and Shepherd (1976) are spliced with Margo (2000)’s Midwest real wages.

	1860	1900
(1) man-days required to clear an acre of forest	32	26
(2) man-days required to clear an acre of prairie	1.5	0.5
(3) % of acre initially under forest	66	36
(4) % of acre initially under prairie	34	64

Source: Lines (1) and (2): Primack (1962a), Table 6, p. 28. Lines (3) and (4): *ibid.*, Tables 1, 3 and 4 pp. 11, 13 and 14, the number for 1860 is obtained by averaging the data for the 1850’s and the 1860’s. Likewise for 1900.

Table 1: Land-Clearing Statistics, 1860 and 1900.

	1860	1900
(1) man-days required to build a rod of wooden fence	0.31	0.31
(2) man-days required to build a rod of stone fence	2.0	2.0
(3) man-days required to build a rod of wire fence	0.09	0.06
(4) % of wooden fence	93	0
(5) % of stone fence	7	0
(6) % of wire fence	0	100

Source: Lines (1)-(3): Primack (1962a), Table 25, p. 82. Lines (4)-(6): *ibid.*, Table 22, p. 202, panel 2 and 6.

Table 2: Fencing Statistics, 1860 and 1900.

West	East
<u>Consumption-good sector</u>	<u>Consumption-good sector</u>
Inputs: western labor intermediate good western improved land	Inputs: eastern labor intermediate good eastern improved land
<u>Land-improvement sector</u>	<u>Intermediate-good sector</u>
Input: western labor	Input: eastern labor

Figure 4: The sectors of production.

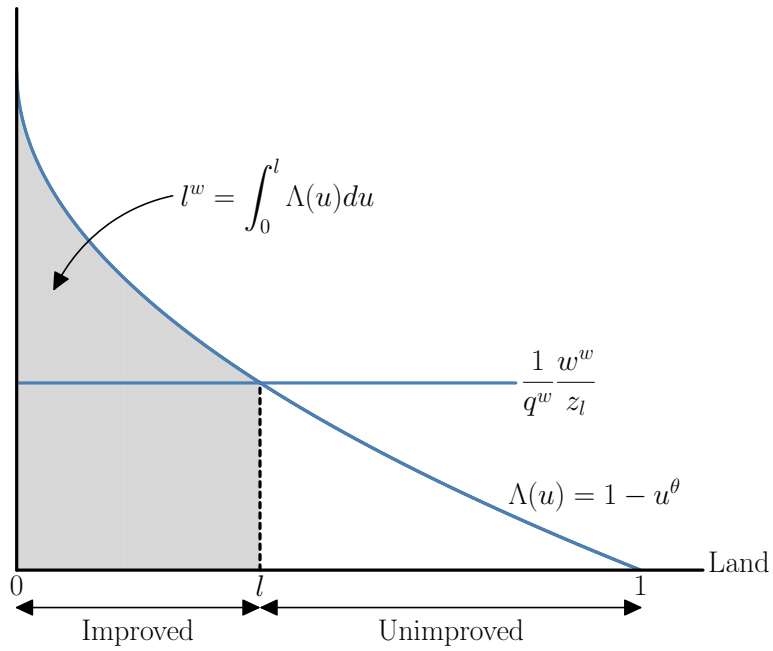


Figure 5: The determination of the stock of improved land.

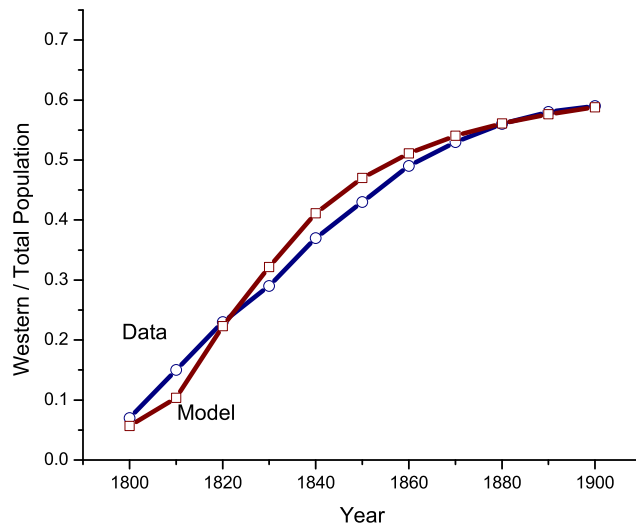


Figure 6: Ratio of Western to Total Population, U.S. Data and Model.

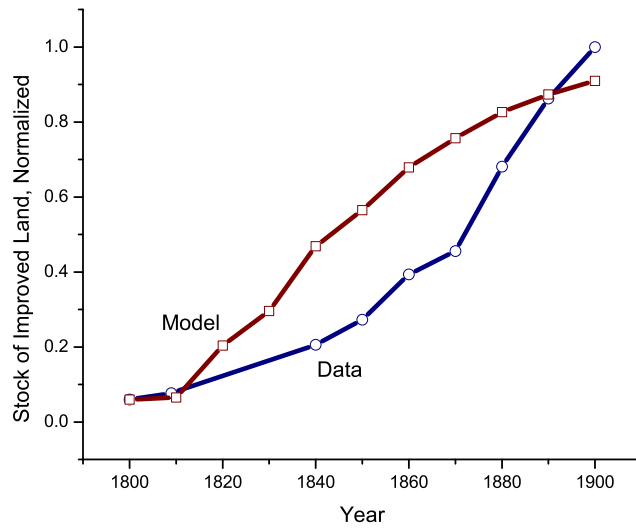


Figure 7: Stock of Western Improved Land, U.S. Data and Model.

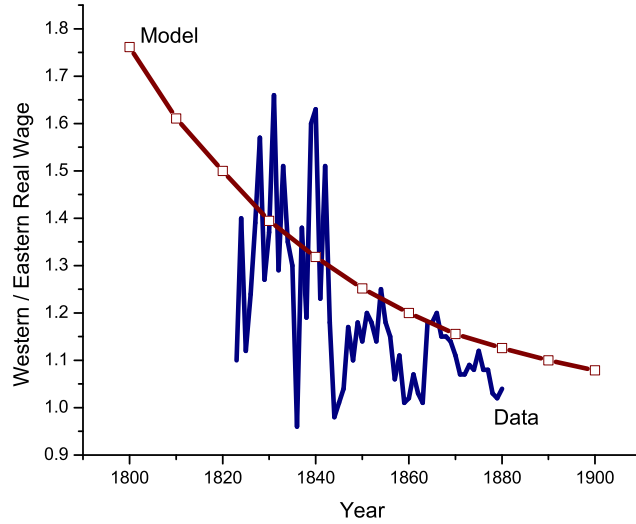


Figure 8: Ratio of Western to Eastern Real Wage, U.S. Data and Model.

Preference	$\beta = 0.99$
Technology	$\phi = 0.6, \mu = 0.2, l^e = 0.01, \theta = 0.1$
Demography	$n^w = 1.3, n^e = 1.2, f = 0.05$
Driving forces	$z_{y1} = 2.0, \gamma_{z_y} = 1.05$ (1800-1840), $\gamma_{z_y} = 1.07$ (1840-1900)
	$z_{x1} = 1.0, \gamma_{z_x} = 1.05$ (1800-1840), $\gamma_{z_x} = 1.07$ (1840-1900)
	$z_{l1} = 0.6, \gamma_{z_l} = 1.03$ (1800-1860), $\gamma_{z_l} = 1.06$ (1860-1900)
	$\tau_{h1} = 0.3, \gamma_{\tau_h} = 0.84$
	$\tau_{x1} = 0.5, \gamma_{\tau_x} = 0.84$

Table 5: Calibration.

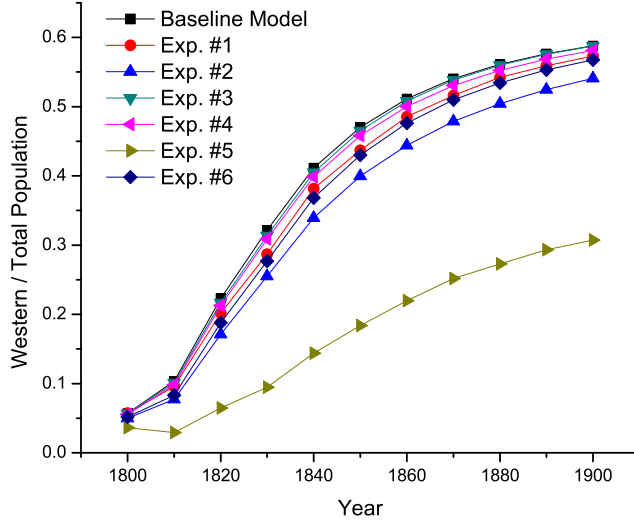


Figure 9: Ratio of Western to Total Population – Counterfactual Experiments.

Experiment 1 – No population growth, Experiment 2 – No growth in z_{yt} , Experiment 3 – No growth in z_{lt} , Experiment 4 – No growth in z_{xt} , Experiment 5 – No decline in τ_{ht} , Experiment 6 – No decline in τ_{xt} .

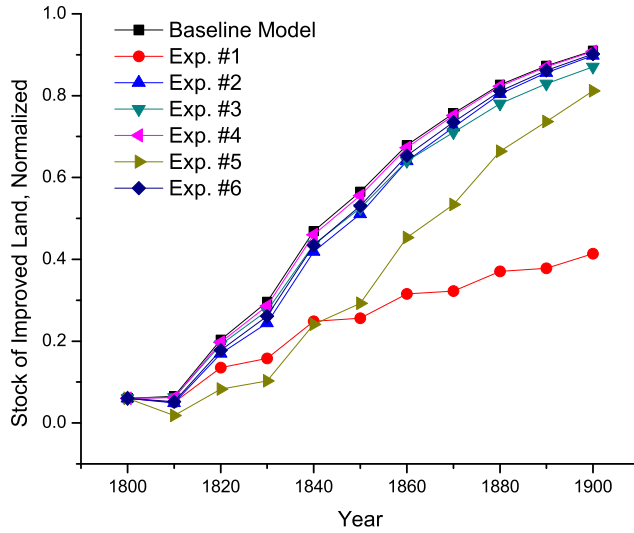


Figure 10: Stock of Western Improved Land – Counterfactual Experiments.

Experiment 1 – No population growth, Experiment 2 – No growth in z_{yt} , Experiment 3 – No growth in z_{lt} , Experiment 4 – No growth in z_{xt} , Experiment 5 – No decline in τ_{ht} , Experiment 6 – No decline in τ_{xt} .

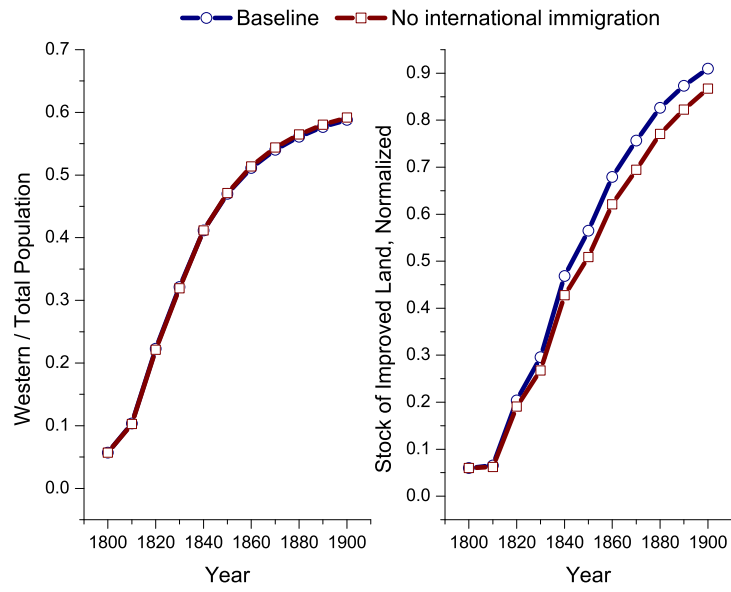


Figure 11: Counterfactual Experiment: The Effect of International Immigration.