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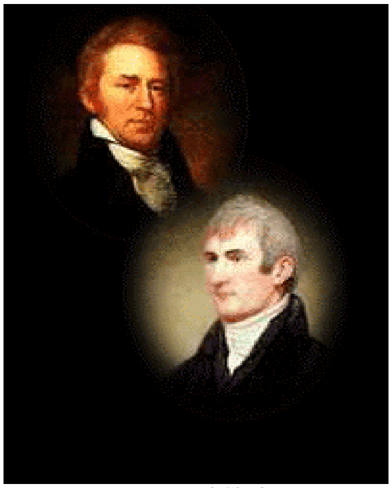

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THE U.S. WESTWARD EXPANSION

by

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The U.S. Westward Expansion*

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Abstract

Some facts characterizing the U.S. economic development in the 19th century are: (i) the westward movement of population; (ii) the accumulation of productive land; and (iii) the wage gap in favor of the West. An overlapping-generations model is developed, to account for these facts. The model's novelty is the presence of a fixed amount of land, initially unsuitable for production, but that can be improved. Historical evidence on productivity in land-improvement activities is used to calibrate the model's parameters. The model accounts for the regional distribution of population and the path of the stock of developed land. The main factor driving the Westward Expansion is population growth. International immigration is found to contribute little to the opening of the West.

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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 867,980 square miles in 1800, the nation encompassed 2,974,159 in 1900. Second was the geographic distribution of the population. Less than 7% of the populace lived west of the Appalachians in 1800. By 1900 this number is about 60%.

1.1 Territorial Expansion

In 1800 the nation's most western territories consisted of today's Wisconsin, Illinois, Kentucky, Tennessee and Mississippi. West of that line were mainly territories owned by France and Spain. In 1803 France offered to sell the Louisiana territory to the United States. This transfer, completed within a year, doubled the area of the country (see Figure 1). The next acquisition, Florida, was bought from Spain in 1819. Later on, in 1845, Texas was annexed as a state and, in 1846, the Oregon territory was annexed through a treaty with Great Britain (see Figure 2). In 1848, as a result of the Treaty of Guadalupe Hidalgo signed with Mexico, the United States gained even further western territories: the Mexican acquisition depicted in Figure 2. The last continental acquisition consisted of the southern part of Arizona, through the Gadsden Purchase from Mexico in 1853.

In an economy mostly dominated by agriculture land is a critical input. Yet, in general, it cannot be used for production without being improved. Virgin land must first be cleared and broken by the plow. It needs to have fencing to contain livestock and to preserve crops. It also, sometimes, needs to be drained and/or irrigated. With the vast areas of land acquired by the U.S. during the 19th century, settlers were bound to devote much effort and resources to these activities. By doing so, they actually built an important part of the country's capital stock. Table 1 below reports the share of total gross investment represented by land-clearing and first-breaking.[1] The decline of investment in improved land can be given two interpretations. The

1834/43	1844/53	1869/78	1879/88	1889/98	1899/08
41	15	8	4	2	1

Table 1: Share of land-clearing and first-breaking in total gross investment (%), U.S.

first, and probably the most obvious, is the industrialization of the U.S. economy. But other factors had their role. As the 19th century reached an end and the West got settled, there was less virgin land to open. Moreover, prairies, which are easy

[1] The source for Table 1 is Gallman (2000), Table 1.12, p. 40.

to clear, rose in importance relative to forest-land. The picture of the U.S. capital stock during the 19th century is significantly affected by the value of accumulated improved land. Gallman (1992) values it at the clearing cost and reports its share of the total capital stock. Figure 3 portrays it together with the share of industrial structures.[2] Here again, there is strong evidence that improved land played a major role in the growth of the U.S. economy during the 19th century. From a share of 56% of the total U.S. capital stock in 1774, improved land fell to 8% in 1900. In the meantime, industrial structures rose from 21% to 70%. The stock of improved land, accumulated by clearing and breaking virgin land, is represented in Figure 4.[3] The surface of cleared land is normalized to unity in 1900. A similar approach is used by Easterlin (1976). He proposed to measure the extent of settlement of a state by the number of improved acres as a percentage of the value attained in 1930. He then reports that out migration towards more western states set in when the settlement process was between 75% and 80% through.

1.2 Population movement

At the same time that the Louisiana territory was bought, President Thomas Jefferson sent a small U.S. army unit, lead by Meriwether Lewis and William Clark, 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, after having explored 8,000 miles of territory. Their findings concerning the land, its natural resources, and its native peoples became most valuable for migrants that, throughout the rest of the 19th century, settled the continent.

Most studies of internal migration in the United States use the Census data on population by state of birth and state of residence. Unfortunately, this data is not available before 1850. Therefore, in order to represent the westward movement of population, Figure 5 plots the ratio of regional to total population, from 1790 to 1910.[4] Notice that the westward movement, so represented, appears to have ended by the eve of the 20th 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 claimed[5]:

> 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]The source for Figure 3 is Gallman (1992), Table 2.8, Panel B, p. 94.

[3]The source for Figure 4 is Gallman (1986), Table B-5.

[4]The source for Figure 5 is Mitchell (1998), Table A.3, p. 34. The 'East' consists of New-England, Middle-Atlantic and South Atlantic. The 'West' consists of all other regions, that is East-North-Central, West-North-Central, East-South-Central, West-South-Central, Mountains and Pacific.

[5]Quoted from Turner (1894).

There was a fertility differential, in favor of western regions, during the 19th century.[6] Hence, even without westward migration would the ratio of Westerners have increased. Yet, there is little doubt about the existence of significant internal migration movements. Gallaway and Vedder (1975), for instance, estimate the components of population growth for the Old Northwest, for the period 1800-1860. Their calculations, represented in Figure 6, are based on a basic demographic accounting equation, which states that the rate of population growth is the sum of the rate of natural increase and the rate of net migration.[7] One can see that net migration drives most of the northwestern population growth during the early 19th century. For instance, from 1800 to 1820, 80% of the growth rate of population in this region is accounted for by positive net migration. Along the same line of argument, Oberly (1986) reports that a third of the veterans of the war of 1812 lived as old men in a different state as the one where they volunteered to serve. The decrease in the rate of net migration, exhibited in Figure 6, is not an indication of diminishing migration flows. As Gallaway and Vedder (1975) point out, the Old Northwest was no more a 'Frontier' area in the middle of the century and, therefore, there was increasing out-migration toward more western states. Notice that the redistribution of population in favor of the West was already started when, in February 1848, gold was found in California. The gold rush, although an important event in size, seems marginal when considered in perspective of the previous and subsequent movements. Finally, a notable feature of the westward migration is that it really was westward! In other words, there is abundant evidence that settlers moved along lines of latitudes. Steckel (1983) shows that, from 1850 to 1880, more than 80% of those living outside their states of birth lived in a state within the latitudes of their state of birth.[8] Oberly (1986) and Atack and Bateman (1987) provide similar evidence.[9]

1.3 Theories of the Westward Expansion

Why would people go west? Turner (1894) proposed the most famous explanation of the Westward expansion. His theory, known as the 'safety valve' hypothesis, states that the Westward movement of population is a response to the growing discontent with economic and social conditions in the East, and to the opportunities of the West. Steckel (1983) emphasizes the importance of human capital which, in agriculture, is latitude specific, in shaping western migration. Migrants tended to settle on lands with soils similar to those with which they were familiar. Coelho and Shepherd (1976) document regional differences in real-wages that can account for the westward

[6] See Yasuba (1962).

[7] The source for Figure 6 is Gallaway and Vedder (1975), Table 1, p. 161. The Old Northwest corresponds to today's East North Central states: Ohio, Indiana, Illinois, Michigan and Wisconsin.

[8] See Steckel (1983), Table 3, p. 19.

[9] See Oberly (1986), p. 433 and Atack and Bateman (1987), Table 5.1, p. 74.

movement of the American labor force. Their estimates, for the period 1851-1880, show that the Midwest consistently remained a high real wage area relative to the Northeast. More recently Margo (2000) reports real wage indices by region and categories of workers for the period 1823-1860. Using these two sources one can build series of regional real wages for common laborers, for the period 1823-1880. In doing so, several points are worth noting. First, slave labor was used in southern states during the antebellum period but not after. To obtain the most homogenous possible series only northern regions, which used free labor throughout the entire period, are considered. Second, 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. Finally, 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. The ratio of Midwestern to Northeastern real wages obtained that way is plotted in Figure 7. An inspection of Figure 7 reveals that Western real wages exceeded Eastern real wages by a factor 1.3 during the first half of the century. This ratio fell below 1.2 around 1850.

1.4 Contribution

The analysis here focuses on providing a unifying framework to account for the opening of new land (see Figure 4) *and* the westward movement of population (see Figure 5). Such a framework is provided by general equilibrium theory. An overlapping-generations model with two locations, East and West, and a land-improvement sector in the West is developed. The land-improvement sector is the novelty of the model. Land differs from other forms of physical capital in various respects. First, raw land is in fixed supply, but it cannot be use to produce goods. Second, in order to be used it must be developed, hence land is not a fixed factor in the West. Third, developed land is assumed not to depreciate. Finally, some land is more productive than other land. Agents choose the location in which they want to live at the beginning of their life. This decision is irreversible, therefore sequential migration is not allowed. In each location a consumption-good sector produces a single good. The mechanisms driving the westward expansion are as follow: First, population growth implies an increasing demand for the consumption good, and hence resources. Land being fixed in the East, agents have an incentive to move westward to open new territories and produce more. Second, as more western territories are being settled, western labor becomes more productive than Eastern labor, because there is more land per worker in the West. This, and the need to compensate settlers for the cost of moving westward, rationalize the wage gap in favor of the West and the fact that migration is westward.

1.5 Related models

A model with sequential migration between two locations, allowing agents to move in both directions can be found in Hercowitz and Pines (1997). A number of authors have included land in their models. Recently Hansen and Prescott (2002) use a model with fixed land to account for very long run growth facts. Eckstein et al. (1988) also include fixed land in their model and address Malthus's prediction about population growth and standards of living. But models with investment in land are rare, although, as the previous discussion suggests, some important facts of the U.S. economic growth involved significant investment in land.

1.6 Findings

Most of the parameters of the model are calibrated to the U.S. economy in the 19th century. Given this calibration, the findings are as follows: The model accounts fairly well for the time paths of the distribution of population between East and West, and the stock of improved land. In particular, the timing of migration is in line with the data, as well as the timing of land-opening. The model displays a wage gap in favor of the West, the ratio of regional real wages is in line with its average value in the data. Yet, the model does not display a significant decline in the wage gap, as is observed in the data. Productivity affects the results only marginally so that the bulk of the explanation for land opening *and* migration is due to population growth. Therefore, the model is consistent with the conventional view that the abundance of unsettled land and the increasing population size are key factors in shaping the Westward Expansion. More precisely, the abundance of land explains the Westward Expansion to the extent that it explains the wage differential between the East and the West. It is, therefore, not cheap land per se that attracts settlers to the West, but high real wages. The same argument holds, unchanged, if one considers the international immigration to the United States instead of the internal migration within the United States. Finally, a counterfactual experiment suggests that the flow of international immigration to the U.S., during the nineteenth century, contributed little to the opening of the West. Most of redistribution in the population was driven by natural increase.

The remaining of the paper is organized as follows: In the next section the model is developed and its competitive equilibrium defined. Section 3 presents the data and the method used for calibrating some of the non-standard parameters of the model. In Section 4 the ability of the model to account for the main feature of the westward expansion is assessed through a set of computational experiments. Section 5 concludes.

2 The Model

The economy is described by a discrete-time overlapping-generations model. Agents live for S periods. There are two locations called East (e) and West (w). In each location the same technology is used to produce a single consumption good using capital, labor and improved local land. The market for the consumption good is economy-wide and there are no transportation costs. Capital depreciates at rate $1-\delta$ but land does not. All the available land in the East has already been improved. Hence, the services delivered by land to the eastern consumption-good sector are in fixed supply $l_t^e \equiv l^e$. In contrast, the existing land in the West, initially owned by a government, is unsuitable for productive use. However, a land-improvement sector can, each period, buy parcels of raw land and improve them. The land-improvement technology requires only labor. At the end of each period, the newly improved land is sold to the households who rent it to the consumption-good sector in subsequent periods. There is no land-improvement sector in the East. In what follows, the terms 'improved,' 'cleared' and 'settled' are equivalent in reference to western parcels of land suitable for use in the production of the consumption good.

Agents work throughout their life and are remunerated at the wage rate w_t^j during period t in location j. They can move freely within their location but moving from East to West is costly. Agents can buy various assets on economy-wide markets. First, there are bonds that backup the capital stock. The rental rate for capital between period t and $t+1$ is denoted by $i_{t+1}-\delta$. Second there are assets representing the stock of eastern and western improved land, respectively. The rental rate for improved land in location j is denoted r_{t+1}^j. Observe that the rental rate for capital is not location specific because capital can move freely from one location to the other. It is not the case for labor and improved land.

2.1 Technologies

2.1.1 Consumption-good sector

The consumption-good technology is described by the constant-returns-to-scale production function F. Output in location j is

$$y_t^j = F\left(z_t, k_t^j, h_t^j, l_t^j\right) = z_t \left(k_t^j\right)^{\phi} \left(h_t^j\right)^{\mu} \left(l_t^j\right)^{1-\phi-\mu},$$

where z_t is total factor productivity, k_t^j, h_t^j and l_t^j are inputs of capital, labor and land services respectively. Total factor productivity is constant across locations. The optimization program of a firm in location j is

$$\max_{k_t^j, h_t^j, l_t^j} \left\{F\big(z_t, k_t^j, h_t^j, l_t^j\big) - (i_t-\delta)k_t^j - w_t^j h_t^j - r_t^j l_t^j\right\}. \tag{2.1}$$

Factors demand are derived from the optimality conditions associated with the above problem:

$$
\begin{aligned}
i_t - \delta &= \phi z_t \left(\mathbf{k}_t^j\right)^{\phi-1} \left(\mathbf{l}_t^j\right)^{1-\phi-\mu}, \\
w_t^j &= \mu z_t \left(\mathbf{k}_t^j\right)^{\phi} \left(\mathbf{l}_t^j\right)^{1-\phi-\mu}, \\
r_t^j &= (1-\phi-\mu) z_t \left(\mathbf{k}_t^j\right)^{\phi} \left(\mathbf{l}_t^j\right)^{-\phi-\mu},
\end{aligned}
$$

where $\mathbf{k}_t^j$ denotes the stock of capital per worker, defined by $\mathbf{k}_t^j \equiv k_t^j/h_t^j$. Likewise, the variable $\mathbf{l}_t^j \equiv l_t^j/h_t^j$ is the amount of land-services per worker. The first order conditions with respect to k_t^j imply

$$
\left(\frac{\mathbf{k}_t^w}{\mathbf{k}_t^e}\right)^{1-\phi} = \left(\frac{\mathbf{l}_t^w}{\mathbf{l}_t^e}\right)^{1-\phi-\mu}.
$$

Hence, if there is more land per worker in the West, i.e. if the right-hand side of the above is greater than 1, there must be more capital per worker too. In such a case, there would be a wage gap in favor of the West, a fact visible from the first order conditions with respect to h_t^j. Combining the first order conditions for k_t^j and h_t^j, one finds that the ratio of western to eastern real wages satisfies

$$
\frac{w_t^w}{w_t^e} = \left(\frac{\mathbf{l}_t^w}{\mathbf{l}_t^e}\right)^{(1-\phi-\mu)/(1-\phi)}.
$$

Suppose that the amount of land services in the West is fixed. This situation eventually happens, as the discussion of the land-improvement sector will show. Then, the wage gap is driven by population growth. If western population grew at a faster rate than eastern population, it would eventually decline.

2.1.2 Land-improvement

Parcels of western land are indexed by l on the unit interval and differentiated by their efficiency $\Lambda(l)$, $l \in [0,1]$. At each efficiency level l, there is a continuum of land of size 1. At the beginning of period t, the amount of improved western land is measured by the length of the interval $[0, l_t] \subseteq [0,1]$. The flow of services associated with this stock is

$$
l_t^w = \int_0^{l_t} \Lambda(l)dl, \quad \text{with} \quad \Lambda(l) = 1 - l^\theta, \theta > 0.
$$

The function Λ reflects the quantity of services provided by a lot dl. At the beginning of period t, all land on the interval $[0, l_t]$ has been improved and likewise on $[0, l_{t+1}]$ at the beginning of the next period. It is assumed that $l_{t+1} \geq l_t$. The total amount of additional land services, created during period t, is then $\int_{l_t}^{l_{t+1}} \Lambda(l)dl$. Best lots are assumed to be improved first: The function Λ is, therefore, decreasing.

The land-improvement technology is described by a linear production function where western labor is the only input. Let h_t^c be the total labor force used to improve new parcels during period t. The law of motion for opened parcels is given by

$$l_{t+1} = l_t + z_t^c h_t^c,$$

where z_t^c is a productivity parameter. Entry into the sector is free, and it is assumed that the number of firms does not matter: If n firms employed h_t^c/n units of labor each, the output of the sector would be the same as if one firm employed h_t^c. One could imagine that each firm improves a rectangle of width $1/n$ with length from l_t to l_{t+1}, and hence creates $n^{-1}\int_{l_t}^{l_{t+1}} \Lambda(l)dl$ efficiency units.

Each period the land-improvement firm decides how much land to improve. Suppose that the decision is made at date t to open land on the interval $[l_t, l_{t+1}]$. First, unimproved land must be bought at the government's price $q_t^u(\cdot)$. The total cost of raw land on this interval is then $\int_{l_t}^{l_{t+1}} q_t^u(l)dl$. Second, labor must be hired. The western wage rate applies, hence the labor cost is $w_t^w(l_{t+1} - l_t)/z_t^c$. The revenue is obtained from selling the newly improved land at the end of the period. Improved-land's services are priced at q_t^w. The revenue is then $q_t^w \int_{l_t}^{l_{t+1}} \Lambda(l)dl$. The profit of the land-improvement sector can now be written:

$$\pi_t(l_t, l_{t+1}) = q_t^w \int_{l_t}^{l_{t+1}} \Lambda(l)dl - \frac{w_t^w}{z_t^c}(l_{t+1} - l_t) - \int_{l_t}^{l_{t+1}} q_t^u(l)dl.$$

The value of the land-improvement sector at date t is

$$\max_{\{l_{t+s+1}\}} \frac{1}{p_t} \sum_{s=0}^{\infty} p_{t+s}\pi_t\left(l_{t+s}, l_{t+s+1}\right), \tag{2.2}$$

where p_t is the date-1 present value price defined by $p_1 = 1$ and $p_t = p_{t-1}/i_t$. The first-order condition for l_{t+1} is

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

The left-hand side of the above equation is the marginal profit of opening l_{t+1} (i.e. the last lot) in t. The right-hand side is the present value of the marginal profit if the same lot was open in $t+1$. Along an optimum path there must be no benefits from postponing (or rushing) land clearing. This equation is an instance of the so-called Hotelling (1931)'s formula.

In a steady state, all the land that remains unimproved has no value. Let l_{ss} be the amount of cleared land in a steady state. Then $q_{ss}^u(l) = 0$ for $l \geq l_{ss}$. The marginal benefits of opening the last lot must equal its marginal cost:

$$q_{ss}^w \Lambda\left(l_{ss}\right) = \frac{w_{ss}^w}{z_{ss}^c}.$$

The stock of improved-land, in a steady-state, is then given by

$$l_{ss} = \Lambda^{-1}\left(w_{ss}^{w}/(q_{ss}^{w} z_{ss}^{c})\right).$$

2.2 Households

2.2.1 Consumption plan

The lifetime utility function of an age-1 agent living in location j is

$$\sum_{s=0}^{S-1} \beta^s U\left(c_{t+s}^{s+1,j}\right), \text{ with } U(c) = \frac{c^{1-\sigma}-1}{1-\sigma},$$

where $\beta \in (0,1)$ is the subjective discount factor and $c_{t+s}^{s+1,j}$ denotes age-$(s+1)$ consumption in period $t+s$. His wealth is given by

$$m_t^j = \frac{1}{p_t}\sum_{s=0}^{S-1} p_{t+s} w_{t+s}^j + \tau_t.$$

Notice that the transfer τ_t is received only during the first period of life. His maximization problem is given by

$$V_t\left(m_t^j\right) = \max_{\{c_{t+s}^{s+1,j}\}} \sum_{s=0}^{S-1} \beta^s U\left(c_{t+s}^{s+1,j}\right), \tag{2.3}$$

subject to

$$\frac{1}{p_t}\sum_{s=0}^{S-1} p_{t+s} c_{t+s}^{s+1,j} = m_t^j. \tag{2.4}$$

Associated with the optimal consumption plan, there is an optimal saving plan. Let $a_{t+1}^{s+1,j}$ denotes the optimal level of saving chosen at age s in period t, for period $t+1$ when the agent will be of age $s+1$.

2.2.2 Migration decision

The decision about moving westward is made once and for all at the beginning of life. It takes an agent a fraction γ of his time to move and settle down in his new location. The value of moving from East to West at the beginning of period t is, therefore, $V_t\left(m_t^w - \gamma w_t^w\right)$. The value of staying in the East is $V_t\left(m_t^e\right)$. Agents choose their location optimally, hence given prices they must be indifferent between moving or not:

$$V_t\left(m_t^w - \gamma w_t^w\right) = V_t\left(m_t^e\right). \tag{2.5}$$

Equation (2.5) implies that the total cost of migration, γw_t^w, equals the difference between the wealth of a Westerner and that of an Easterner.

2.3 Population dynamics

Let $h_t^{s,j}$ be the number of age-s agents living in location j. The variable $h_t^{s,j}$ must obey the following law of motion,

$$h_t^{s,j} = h_{t-1}^{s-1,j} \quad \text{for} \quad j = e, w \quad \text{and} \quad s = 2, \ldots, S, \tag{2.6}$$

which simply sates that agents do not change location in the course of their life. Hence an age-$(s-1)$ individual during period $t-1$ in location j, remains in the same location next period, when he is one period older. Total population in location j is given by $\sum_{s=1}^{S} h_t^{s,j}$.

2.4 Government and the price of unimproved-land

How does the government price unimproved land? Here, it is assumed that its policy is to sell it at the price $q_t^u(\cdot)$ that would prevail in a competitive equilibrium.[10] This dictates the following:

$$q_t^u(l) = \begin{cases} \text{undefined} & \text{for} \quad l < l_t, \\ q_t^w \Lambda(l) - \frac{w_t^w}{z_t^c} & \text{for} \quad l \in [l_t, l_{t+1}], \\ \frac{p_{t+1}}{p_t} q_{t+1}^u(l) & \text{for} \quad l \geq l_{t+1}. \end{cases} \tag{2.7}$$

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 a price for unimproved-land before that point. Second, note that, integrating $q_t^u(l)$ 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 $q_t^u(l)$ is a no-arbitrage condition. Consider a lot, dl, that is not improved during period t and remains as such at the beginning of period $t+1$. This is the case for all l satisfying $l \geq l_{t+1}$. What would be the return on such a lot, if it was traded on a competitive asset market? By definition, unimproved-land is not productive, the answer is therefore $q_{t+1}^u(l)/q_t^u(l)$. Absence of arbitrage dictates then that this return must equal the return on a bond: p_t/p_{t+1}.

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

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

[10] In 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 $\{\tau_t\}_{t=1}^{\infty}$.

In other words, when virgin land is priced competitively, the decisions of buying land and improving it can be separated. This should not be a surprising result: 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 raw land through time. The value of the land-improvement firm depends only on the timing of land-opening itself.

Each period the revenue collected from selling virgin land is distributed via a transfer τ_t to the young households. The government's budget constraint is

$$\tau_t \sum_{j=e,w} h_t^{1,j} = \int_{l_t}^{l_{t+1}} q_t^u(l)dl. \tag{2.8}$$

2.5 Equilibrium

2.5.1 Asset Pricing

One unit of consumption invested in bonds yields a gross return i_{t+1}. If, instead, it is invested in efficiency units of j-land, the return is $(r_{t+1}^j + q_{t+1}^j)/q_t^j$. In equilibrium these returns must be equal otherwise an agent could realize infinite profits. Thus,

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

The equation above can be solved forward for q_t^j:

$$q_t^j = \frac{1}{p_t} \sum_{s=1}^{\infty} p_{t+s} r_{t+s}^j, \quad \text{for} \quad j = e, w. \tag{2.9}$$

2.5.2 Market clearing

In a competitive equilibrium several market-clearing conditions must hold. First, the eastern labor market must clear,

$$\sum_{s=1}^{S} h_t^{s,e} = h_t^e, \tag{2.10}$$

as well as the western labor market,

$$\sum_{s=1}^{S} h_t^{s,w} = h_t^w + h_t^c. \tag{2.11}$$

The left-hand sides of (2.10) and (2.11) are total labor supplies in the East and in the West respectively. The right-hand sides are labor demands. Notice that total labor demand in the West has two components: the consumption-good sector and the land clearing sector.

Second, period-t savings must fund period-$(t+1)$ capital and land. This results in the following market-clearing condition for savings:

$$\sum_{s=1}^{S-1} \sum_{j=e,w} h_t^{s,j} a_{t+1}^{s+1,j} = k_{t+1}^e + k_{t+1}^w + q_t^e l^e + q_t^w l_{t+1}^w. \tag{2.12}$$

Here the left-hand side, aggregate saving, is the sum of individual savings across cohorts of agents of age 1 to age $(S-1)$ living in the East and the West.

Finally, the economy's resource constraint is

$$c_t^e + c_t^w + k_{t+1}^e + k_{t+1}^w = y_t^e + y_t^w + \delta \left(k_t^e + k_t^w\right) \tag{2.13}$$

where c_t^j is aggregate consumption in location j.

2.5.3 Initial Conditions

At date 1 the regional partition of cohorts of age 2 and above is predetermined. The age-1 cohort, though, chooses its location at the beginning of the period. Hence, the initial population structure is given by the size of the age-1 cohort $h_1^{1,e} + h_1^{1,w}$ and the two vectors $\left(h_1^{2,j}, \ldots, h_1^{S,j}\right)$ for $j = e, w$.

Recall that there are three assets. Bonds, shares of improved western land, and shares of improved eastern land. An agent can hold any of them, regardless of his location. Therefore, one needs to specify the holdings of agents of age 2 and above, in each location, for each of the three assets.

Bonds – Define $\left(b_1^{2,j}, \ldots, b_1^{S,j}\right)$ to be the initial bond-holdings of agents of age 2 and above in location j. The initial capital stock, $k_1^e + k_1^w$, is then given by:

$$\sum_{s=2}^{S} \sum_{j=e,w} h_1^{s,j} b_1^{s,j} = k_1^e + k_1^w. \tag{2.14}$$

Western Land – Let $\left(d_1^{2,j}, \ldots, d_1^{S,j}\right)$ be the initial holdings of improved western land by agents of age 2 and above, living in the East $(j = e)$ **and** in the West $(j = w)$. The initial stock of improved land in the West, l_1^w, must satisfy

$$\sum_{s=2}^{S} \sum_{j=e,w} h_1^{s,j} d_1^{s,j} = l_1^w. \tag{2.15}$$

Eastern Land – Likewise, let $\left(\bar{d}_1^{2,j}, \ldots, \bar{d}_1^{S,j}\right)$ be the initial holdings of improved eastern land. Recall that $l_t^e \equiv l^e$. Thus, the following must hold:

$$\sum_{s=2}^{S} \sum_{j=e,w} h_1^{s,j} \bar{d}_1^{s,j} = l^e. \tag{2.16}$$

2.5.4 Competitive Equilibrium

A competitive equilibrium can now be formally defined.

Definition 1 *A competitive equilibrium is a time path for wage rates* $\{w_t^j\}$*, rental rates for land* $\{r_t^j\}$ *and capital* $\{i_t\}$*, prices* $\{q_t^j, q_t^u(\cdot)\}$*, allocations for the households* $\{c_t^{s,j}\}$*, factor inputs in the consumption-good sectors* $\{k_t^j, h_t^j, l_t^j\}$*, the stock of improved land* $\{l_{t+1}\}$*, and transfers* $\{\tau_t\}$*, such that, given the initial conditions* (2.14)-(2.16)*:*

1. *The sequence* $\{k_t^j, h_t^j, l_t^j\}$ *solves problem* (2.1) *given* $\{w_t^j\}$*,* $\{r_t^j\}$ *and* $\{i_t\}$*.*

2. *The sequence* $\{l_{t+1}\}$ *solves problem* (2.2) *given* $\{w_t^w\}$*,* $\{q_t^w\}$ *and* $\{q_t^u(\cdot)\}$*.*

3. *The sequence* $\{c_t^{s,j}\}$ *solves problem* (2.3) *subject to* (2.4) *given* $\{w_t^j\}$*,* $\{i_t\}$ *and* $\{\tau_t\}$*.*

4. *Agents choose to live in the location that maximizes their welfare, or* (2.5) *holds.*

5. *The population obeys the law of motions* (2.6)*.*

6. *The government prices unimproved land according to* (2.7)*, and its budget constraint* (2.8) *holds.*

7. *There are no arbitrage opportunities, or* (2.9) *hold.*

8. *The market clearing conditions* (2.10)-(2.13) *hold.*

3 Calibration and Estimation

Historical evidence is available to pin down sensible values for most of the parameters of the model, including the cost of migration and the productivity in the land-improvement sector. The remaining parameters are selected to minimize the distance between the model's output and its empirical counterpart. Notice that there is no statistical model here, therefore this 'estimation' procedure is not the basis for any inference.

3.1 Demographics

Let the length of a period in the model be 10 years. Set S, the length of (adult) life, to 4 periods. An individual lives then for 40 years. There will be 10 model-periods over the course of the 19th century. Population must obey the law of motion (2.6). Hence, only the process for the age-1 population needs to be chosen. Mitchell (1998), Table A2, reports the size of the white population for the United Sates by age groups. His numbers are inputted into the model in the following way: For the years 1800, 1810 and 1820, the 16-25-years group is used.[11] For the years 1830-1900, the 20-29-years group is used. The resulting pattern of population size is depicted in Figure 8.

3.2 Total Factor Productivity, $\{z_t\}$

The annual growth rate of total factor productivity, reported by Gallman (2000), was 0.55% for the period 1800-1840 and 0.71% for the period 1840-1900.[12] The process $\{z_t\}$ is built to match such a pattern, with z_1 normalized to 1. The resulting path of total factor productivity is depicted in Figure 8.

3.3 Productivity in the Land-Improvement Sector, $\{z_t^c\}$

The transformation of virgin land into improved farm land requires different tasks than those implied by daily farm work. Primack (1962a) points out that farm capital is built from land-clearing and first-breaking, farm buildings, farm fencing, drainage and irrigation.[13] For the purpose here, buildings are not considered since they do not correspond to improvement to the land itself. The work of Primack (1962a) is directly aimed at measuring the labor productivity in each of these activities, for the period 1860-1910.

3.3.1 Land-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? It is clear that productivity, here, depends heavily on the nature of the initial coverage of the land: clearing an acre of forest or an acre of grassland are two very 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 trees down and then burning the wood or using it to build fences. Two firings were often needed. The Indian method consisted in girdling the trees by stripping the bark

[11] There is no data for the 20-29-years group for these years.

[12] See Gallman (2000), Table 1.7, Panel B, columns (5), p. 23.

[13] Primack (1962b, 1965, 1969) addresses the same issue and provide additional measurements.

from a section around it. If done during the winter, the tree would die and start loosing 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 does not need to learn and do everything by himself. Where the Yankee method was in use, the re-piling of wood, for the second burning, became the occasion of such a gathering, called 'log-rolling'. Grassland clearing was much easier. Yet, the prairie sod 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, is the main source of productivity increase in grassland clearing.

Table 2 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. The labor requirement to clear one acre of 'average' land is then 21.6 man-days in 1860 and 9.7 man-days in 1900 (see Table 2).

Settlers had control, at least partially, over the type of land they wanted to clear. Hence, the change in the labor required to clear an 'average acre' not only captures technological progress, but also a substitution effect from forest toward prairie. A Tornqvist index is then used to measure the change in the labor needed to clear an acre of land.[14] This index is

$$\frac{\omega_{1860} + \omega_{1900}}{2} \log\left(\frac{32}{26}\right) + \left(1 - \frac{\omega_{1860} + \omega_{1900}}{2}\right) \log\left(\frac{1.5}{0.5}\right)$$

[14]Let 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

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

where ω_{1860} is the cost-share of forest-clearing in 1860:

$$\omega_{1860} = \frac{32 \times .66}{32 \times .66 + 1.5 \times .34} = 0.97.$$

Likewise, the cost-share of forest-clearing in 1900 is

$$\omega_{1900} = \frac{26 \times .36}{26 \times .36 + 0.5 \times .64} = 0.96.$$

Note that, despite the increase in the share of prairie-clearing between 1860 and 1900, forest-clearing represents an almost constant fraction of the total cost of land-clearing. The value of the Tornqvist index resulting from this calculation is 0.23. The average annual growth rate of productivity in land-clearing, for the period 1860-1900, is then about 0.6%.

3.3.2 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 century, farmers have been seeking for better fencing devices. Indeed, 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. For instance, 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 3 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

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

$$\log T = \frac{\omega_0 + \omega_T}{2} \log\left(\frac{h_0^f}{h_T^f}\right) + \left(1 - \frac{\omega_0 + \omega_T}{2}\right) \log\left(\frac{h_0^p}{h_T^p}\right).$$

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 requires about 0.09 man-days per rod. This requirement dropped to 0.06 man-days in 1900, thanks to the use of barbed wire.[15] The shares of wood, stone and wire fences in total fencing are also reported in the table.

In line with the calculations conducted above for land-clearing, a Tornqvist index is computed to measure the change in the labor requirement in fencing. [16] The average annual growth rate of productivity, resulting from this calculation is 0.5%.

3.3.3 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.[17]

3.3.4 Productivity growth

It is time to summarize the evidence given above. For the post-civil war period, the average annual growth rate of productivity was 0.6% in land-clearing and 0.5% in fencing. There was no noticeable productivity growth in draining and irrigating. According to Primack (1962a), less than 1% of the agricultural labor force engaged in farm improvement activities was actually draining and irrigating the land.[18] Likewise, fencing occupied less than 10% of the labor force engaged in farm improvement. Therefore, the choice here is to use 0.6% per year, as the growth rate of productivity in the land-improvement sector, for the period 1860-1900.

Evidence of technological progress in land-improvement, for the antebellum period, are not available. The strategy chosen is to use agricultural output per worker as a proxy. Atack et al. (2000b) report that agricultural output per worker grew at the average annual rate of 0.3% between 1800 and 1860.

The path for z_t^c is built as follows. For a given initial condition, z_{1800}^c, a growth rate of 0.3% per year is applied to build the sequence $\{z_{1810}^c, \ldots, z_{1860}^c\}$. For the years $\{z_{1870}^c, \ldots, z_{1900}^c\}$, a growth rate of 0.6% per year is used. The choice of z_{1800}^c is

[15]Source: 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.

[16]Since there is no improvement in wood and stone fencing productivity, the index is $0.5 \log(0.09/0.06) = 0.2$.

[17]See Primack (1962a), p. 114 and p. 130.

[18]See Primack (1962a), Table 37, p.138.

discussed below. The resulting path of productivity in the land-improvement sector, normalized to 1 in 1800, is depicted in Figure 8.

3.4 Cost of migration, γ

The amount of time required to move and settle in the West is not easily observed. Part of this time was devoted to land improvement. Productivity changes in this activity were discussed previously. But settlers had to face other costs like buying a parcel of land, livestock, the materials to build a house as well as furniture and provisions. They also had to physically move, a long and sometimes dangerous journey.

Danhof (1941) provides estimates of the cost of farm making in the West. He shows, using information provided by contemporary observers, that the cost of farm making is a function of the location and, of course, the size of the farm. For instance, the total cost of setting up a 40-acre farm in the 1850's is about \$550 in Illinois, \$277 in Michigan, \$440 in Iowa and \$700 in Texas. For an 80-acre farm, the total cost ranges from \$700 to \$2,000 in Illinois, \$1,000 to \$1,500 in Iowa and \$500 in Texas.[19] Danhof (1941) concludes that 'in any case the farm maker's wealth could not fall much short of \$1,000'. This number includes, as a significant part, the cost of clearing and first breaking the land and the cost of fencing. In Atack et al. (2000a), it is reported that, in 1860, The Minnesota Commissioner of Statistics advised would-be settlers to have an amount ranging from \$500 to \$1,000 on their arrival. This, again, includes the cost of first breaking. Another piece of information is provided by Goddard (1869):

> The pioneers who settled Ohio, Indiana, Illinois, Michigan, Wisconsin, Iowa, Minnesota and Kansas, averaged a good deal less than seven hundred dollars each as their outfit. With seven hundred dollars, a man may take up a quarter section of homestead land, buy a team and cow, build a cabin and cattle-shelter, get a few implements, break-up and sow or plant twenty acres of prairie, and have a crop growing.
>
> At the end of five years he should, with fair luck, have forty acres under good cultivation, as many more fenced in for hay and pasture, and a fair stock of young cattle. After that, he may pass an Eight-Hour law for himself and wife, and live in substantial independence and comfort.

Note that these numbers refer mainly to settlers arriving from the East. They are likely to overstate the cost faced by a farmer, already living in the West, and willing to move to even more western territories.

In order to choose a value for γ, the \$700 advocated by Goddard (1869) is used as a reference. Margo (2000) estimates that the money wage in 1860 in the midwest

[19]See Danhof (1941), Table 1, p. 327.

is \$1 per day for a common laborer.[20] Seven hundred dollars represent then 700 days of work or about 20% of a ten-years period. The value for γ is then 20%.

3.5 Factor shares, discount factor and depreciation, $(\phi, \mu, \beta, \delta)$

From Gallman (2000) one can compute capital and labor's share of income, ϕ and μ, to be respectively 0.28 and 0.68. The resulting share for land is then $1 - \phi - \mu = 0.04$.[21] The subjective discount factor, β, and the depreciation factor for capital, δ, are common in macroeconomic models. They are set to 0.95^{10} and to 0.90^{10} respectively, following closely the values used by Prescott (1986).

3.6 Remaining Parameters

The following must be assigned values: the initial productivity in the land-improvement sector z^c_{1800}, the parameters governing land efficiency θ, the amount of services delivered by Eastern land l^e and the utility parameter σ. The strategy chosen here is similar to that used by Andolfatto and MacDonald (1998), and Greenwood et al. (2002). Define $\alpha \equiv (z^c_{1800}, \theta, l^e, \sigma)$. For a given α, the model generates time series for the ratio of Westerners and for the number of developed acres. Let the function $\mathbf{W}(\alpha, t)$ describe the mapping from the parameters to the predicted ratio of Westerners at date t:

$$\mathbf{W}(\alpha, t) = \frac{\sum_{s=1}^{S} h_t^{s,w}}{\sum_{s=1}^{S} \sum_{j=e,w} h_t^{s,j}}.$$

Likewise, let $\mathbf{D}(\alpha, t)$ be the mapping from α to the predicted amount of developed land at t. More precisely,

$$\mathbf{D}(\alpha, t) = l_t$$

where l_t is the solution to the maximization problem of the land-improvement sector at date $t-1$. Let $\{\mathbf{w}_t\}$ and $\{\mathbf{d}_t\}$ be the corresponding U.S. data obtained from Mitchell (1998) and Gallman (1986) for $t = 1800, 1810, \ldots, 1900$ and portrayed in Figures 4 and 5. The average relative difference between the computed and actual ratio of Westerners is $(1/11) \sum_{t=1800}^{1900} \ln\left(\mathbf{W}(\alpha, t)/\mathbf{w}_t\right)$. For the stock of improved land,

[20] See Margo (2000), Table 3A.5, p. 67.

[21] Gallman (2000), Table 1.4, Panel A, columns (2)-(4) and Panel B, columns (1)-(3), p.15 reports the contribution of capital, labor and land to the U.S. economic growth during the years 1800-1840 and 1840-1900. The growth rate of labor supply was 3.09 during the first period. Once weighted by the labor share Gallman (2000) obtains 2.10. An estimate of the labor share is then 2.10/3.09=0.68. During the second period these numbers are 2.72, 1.85 and 0.68 respectively. Likewise, the growth rate of the capital stock for the period 1800-1840 was 3.98 and its weighted growth rate was 1.15. Hence the estimated capital share for the period is 0.28. The same figures, for the period 1840-1900, are 4.96, 1.44 and 0.29 respectively.

two observations are missing for the years 1820 and 1830. Thus, the corresponding average is computed using 9 data points. The final set of parameters must solve

$$\min_{\alpha} \left\{ \frac{1}{2} \left| \frac{1}{11} \sum_{t=1800}^{1900} \ln \left(\frac{\mathbf{W}(\alpha, t)}{\mathbf{w}_t} \right) \right| + \frac{1}{2} \left| \frac{1}{9} \sum_{t=1800}^{1900} \ln \left(\frac{\mathbf{D}(\alpha, t)}{\mathbf{d}_t} \right) \right| \right\}.$$

The minimization is done by grid search.

4 Computational experiments

Two sets of experiments are now discussed. First, the model is used to address the question: Can the Westward expansion be accounted for by productivity and population growth, in the context of general equilibrium theory? Second, through a few counterfactual experiments, the model is used as a device to assess the respective contribution of each factor.

4.1 Baseline model

The baseline calibration of the model, including parameters obtained from the minimization procedure, is given in Table 4. Figures 9 and 10 plot the actual path for the ratio of Westerners and the stock of improved land together with their model counterparts. Both pictures suggest that the model is in line with the facts along these two dimensions. Table 5 reports the average relative difference between the model and the data.[22] On average, the baseline model overstates the actual ratio of Westerners by 0.5% per period and understates the actual stock of improved land by 4%.

In the baseline model, 2.2% of available western land has already been improved at the beginning of the initial period. This share rises up to 81.2% in 1900. Such an increase in the stock of improved-land represents 84% of the actual increase. In addition, notice, from Figure 10, that the timing of land opening is reasonably consistent with the data. As for the distribution of population, the model predicts that, initially, 7.2% of the population lives in the West. This ratio is 56.7% in 1900. In comparison with the data, 95% of the total change in the ratio of Westerners is accounted for by the model. The timing, here again, is correct. With 2.2% of the land improved and 7.2% of total population during the initial period, land per worker is higher in the western than in the eastern consumption-good sector. Hence, as discussed in Section 2, there is also more capital per worker in the West. Along the transition paths, displayed in Figures 9 and 10, the stock of land per worker decreases in both locations.

[22]More precisely, the last two columns of Table 5 are, respectively, $\frac{1}{11}\sum_{t=1800}^{1900} \frac{\mathbf{W}(\alpha,t)}{\mathbf{w}_t}$ and $\frac{1}{9}\sum_{t=1800}^{1900} \frac{\mathbf{D}(\alpha,t)}{\mathbf{d}_t}$.

In the East, this is due to the increasing population size, in face of a constant amount of improved-land. In the West, this reveals that the stock of improved-land grows at a lower rate than western population. A result due to the fact that western parcels of land are less profitable to the land-improvement sector, as the economy moves westward. The stock of improved-land per worker remains higher in West than in the East throughout the transition.

Quite naturally, the price of improved-land is higher in the East than in the West. Notice, however, that it is not cheaper western land that causes population to settle the West. The market for improved-land is economy-wide, therefore an Easterner can buy shares of western land without having to move. On the other hand, he needs to move to benefit from the fact that, as a worker in the West, he would use more capital and land than in the East and, hence, receive a higher wage.

The wage gap between the East and the West, measured as the ratio of western to eastern real wage rates, is portrayed in Figure 11 together with its empirical counterpart. Notice that the model is in line with the average of the actual ratio of regional real wages. However, the downward slopping trend one can see in the data is not matched by the model. The reason here is that the time cost of settling down in the West is constant. Therefore, the cost and benefit of moving westward grow approximately at the same rate. It is quite natural to associate the observed decrease in the wage gap to increasing labor force mobility. As a matter of fact, transportation means improved substantially during the 19th century.[23] For instance, the steamboat was first used in the West in 1811-1812, from Pittsburgh to New-Orleans.[24] The Erie canal was completed in 1825 and the transcontinental railroad in 1869. Not only did these developments reduce the cost of physically reaching western locations, but they also reduced the economic isolation of Westerners. Goods initially available only to Easterners, became available to Westerners at a decreasing cost. Therefore, the opportunity cost of settling down in the West decreased. To account for this effect in the framework of the model proposed here, the time cost of migrating and settling down in the West can be modelled as $\gamma_t = z_\gamma \gamma_{t-1}$. In such a case, the quantity $z_\gamma - 1$ is the growth rate of the cost of migration. In Figure 12, the wage gap is portrayed for an economy similar to the baseline model, but where γ_t decreases at the arbitrary rate of 10% per period ($z_\gamma = 0.9$). One can see that, as expected, the ratio of western to eastern real wages declines. This result, though, does not come for free. In face of a decreasing cost of migration, settlers flow into the West more rapidly than in the baseline case. Hence, under this specification, the model overstates the ratio of Westerners: It predicts that 88% of the population lives in the West in 1900. (vis à vis 59% in the data.)

[23]See, for instance, Haites et al. (1975) and Fishlow (2000).

[24]See Ridge (1980).

4.2 *Counterfactual experiments*

How does each of the driving forces of the model contribute to the westward expansion? To answer this question three counterfactual experiments are conducted. In each, one of the driving forces of the economy is shut down. More precisely, the first experiment asks what does the model predict in the absence of total factor productivity growth? The second evaluates the impact of having no productivity gains in the land-improvement sector. In the last experiment, population does not grow. Figures 13 and 14 plot the path of each variable.

4.2.1 *Population growth*

The first conclusion to draw from these experiments is that the bulk of the explanation of the westward expansion comes from population growth. When population remains constant at its 1800's level, the model understates both the stock of improved land and the ratio of Westerners. On average, the model accounts for 70% of the actual ratio of Westerners and 32% of the actual stock of improved land (see Table 5). The model now predicts that 31% of the population lives in the West by 1900, and only 14% of the available land has been improved. This represent only 44% of the actual increase in western population and 12% of the actual increase in the stock of improved land. The explanation, here, is rather natural. In the baseline model, there is an increasing demand for goods, due to the growing population size. This demand can be satisfied by accumulating factors like capital and land. Since land cannot be accumulated in the East, the population has an incentive to move westward and to open new territories. This incentive disappears when population does not increase.

4.2.2 *Productivity growth*

How do total factor productivity growth and technological progress in the land-improvement sector affect the westward movement? Consider first total factor productivity. When it remains constant at its 1800's level, real wages do not grow as in the baseline case. A direct consequence of this is that the cost of opening new territories is lower than in the baseline case. Notice that the stock of improved land, in experiment (i), is uniformly above the baseline case (see Figure 14). From Table 5, one can see that the computed stock of improved land overstate the observed value by 3.7% on average. Accumulation of improved land in the West makes western labor more productive in the consumption-good sector, relative to eastern labor: a fact already discussed. To reach an equilibrium, more settlers have to flow in the Western territories. Consequently, the path of the ratio of Westerners in experiment (i) lies uniformly above the baseline case (see Figure 13). On average, the actual ratio of Westerners is overstated by 9.4%. Productivity in the land-improvement sector has the opposite effect. When it does not grow, new territories are more costly to improve (relative to the growing productivity case). As a consequence, the stock of improved land lies uniformly below the baseline case here (see Figure 14). On average, the model understates the data by 11.5% along this dimension (see Table 5). Less opened land in the West makes it less attractive to eastern workers. In other words, real wages are lower in that case than in the baseline case, although they grow at the same pace. Therefore, people move westward at a slower pace (see Figure 13). In that case, the model understates the actual ratio of Westerners by 1.5% on average.

4.2.3 International immigration

Can one conclude, from the results of the experiments conducted above, that the Westward Expansion was caused by U.S. population growth? In fact one could argue the opposite: That it was the possibility of opening new territories in the West that caused population growth, partly by attracting to the United States immigrants from the rest of the world. This issue is now addressed and two points are argued: First, the mechanisms driving international and internal migration are essentially the same. Hence, the mechanisms at work to explain migration in the model presented here, would be essential ingredients in a model with endogenously determined international immigration. Second, the contribution of immigration to the Westward Expansion is measured: it is small.

What are the forces that actually propelled millions of immigrants (see Figure 15) to the new world? [25] The surge of immigration, observed during the 1840's and early 1850's, coincides in time with the Irish potato famine (1845-1850) and the German 'failed' revolution (1848-1849). This was, also, a period of relative economic prosperity in the U.S.: The gross national product per capita grew, on average, at a rate of 2.3% per year for the period 1845-1855, vis à vis 1.5% for the entire 19th century.[26] Note that the decline in immigration, observed during the years leading to the civil war, coincides with a recession started in the late 1850's.[27] Observe finally that, during the civil war period (1861-1865), immigrants continued to arrive, regardless of the recession and despite the war. The long-run trend in immigration is easier to rationalize than yearly fluctuations. Williamson (1995), for instance, documents international real wage dispersion during the nineteenth century. He concludes that most of it is due to a wage gap, favoring the United States vis à vis European countries.

[25] The source for Figure 15 is U.S. Bureau of the Census (1975), series C 89.

[26] Calculation are based on: (i) The gross national product series from Mitchell (1998), Table J1, pp. 761-787. (ii) The population series from Haines (2000), Table 4.2, p. 156.

[27] In 1857, the U.S. economy entered into a recession. Gross national product per capita remained below its 1856 value until 1870. The trough of this recession can be dated in 1864, when gross national product per capita was 30% below its 1856 value.

Figure 16 plots the ratio of U.S. to foreign real wages, for a set of European countries.[28] For each of them, this ratio remains above one during the entire period. Consider in particular the European leader: Great Britain. During the antebellum years, the gap was 62% on average. Then, despite the sharp decline in U.S. wages during the war, the gap still averaged 48% over the period 1865-1900. The bottom line of this discussion is that the forces at work behind immigration to the United States, are the same than those who drove the westward migration within the United States: Land availability can explain the immigration flow, to the extent that it can account for the wage differential between the U.S. and the rest of the world. Hence, there would be no essential differences between the model proposed here and a model where immigration to the United States would be endogenously determined. Note that the idea that land availability was attracting people to the new world is not a new one. The model proposed here emphasized a particular mechanism however: It is not cheap land per se which is attractive, but the high real wage rate that the abundance of physical capital, and land in particular, delivers.

To argue that high real wages were at least as important as cheap land as a factor explaining immigration, consider Figure 17 and Table 6.[29] There, the fraction of foreign born population, by region, is represented for the period 1850-1900 and for the two years 1820 and 1860. Observe that, if immigrants came to the United States only to settle the West and benefit from the low price of land, the ratio of foreign-born would not have increased in the Northeast, as it actually did. The model predicts that along an equilibrium path, immigrants arriving from, say Europe, must be indifferent between settling down on the East coast or moving further into the West of the country. In line with this prediction, the data do not show a clear pattern of regional settlement by immigrants. The opportunities offered by the U.S. to the rest of world were not specific to the East or the West.

How did international immigration contribute to total population growth in the U.S.? Consider a simple demographic accounting equation:

$$P_{t+1} = P_t + N_t + I_t :$$

Here, P_t is total population at the beginning of period t. The variable N_t represent the net natural increase during period t; that is, the difference between births and deaths. The variable I_t stands for net migration; i.e., in-migration minus out-migration. The rate of total population growth is given by

$$\frac{P_{t+1} - P_t}{P_t} = \frac{N_t}{P_t} + \frac{I_t}{P_t},$$

[28]The source for Figure 16 is Williamson (1995), Table A2-1, pp. 178-180.

[29]The source for Figure 17 is U.S. Bureau of the Census (1975), series A 190-192. The source for Table 6 is Yasuba (1962), Table V-17, p. 182.

or the sum of the rate of natural increase and the rate of net migration. Figure 18 represents the growth rate of total population and its decomposition.[30] As one can see, most of the increase in total population is driven by natural increase. In the second part of the century, the share of net immigration increases, but still remains smaller than the share of natural growth.

The following thought experiment can be designed: What would have total population growth been, if no international immigration occurred during the 19th century? Let $\hat{P}_t$ be such a hypothetical population. Then set $\hat{P}_{1790} = P_{1790}$ and

$$\hat{P}_{t+1} = \hat{P}_t \exp\left(\frac{N_t}{P_t}\right).$$

That is, set the counterfactual population path equal to actual population for the initial period, 1790. Then, iterate using only the actual rate of natural increase. Note, immediately, that this experiment assumes that the rate of natural increase remained the same in the absence of immigration. There is, however, evidence that the foreign born population had higher fertility. Hence, $\hat{P}_t$ is an upper bound for the counterfactual population built here. Keeping this restriction in mind, the path of actual and counterfactual populations are portrayed in Figure 19. Total population in 1900 would not be above 54% of what it actually was. What are the implications for the Westward Expansion? To answer this, the counterfactual population just described is inputted into the model, and the transition recomputed. The upshot of this experiment is that international immigration contributed little to the opening of the West. More precisely, the stock of improved-land, obtained in this experiment, is compared to the one obtained in the baseline case in Figure 20. Not surprisingly, this stock is lower now than in the baseline case, due to slower population growth. Compared with the data, the model understates the stock of improved-land by 15% on average. Consistent with this finding, the ratio of Westerners is lower than in the baseline case too. The model, on average, understates it by 0.1% per period. Remember that, in the baseline case, the model slightly overstates this ratio. Figure 21 compares the ratio of Westerners obtained in this experiment to the baseline model. Note that the departure from the baseline case, and hence from the data, is arguably small.

5 Concluding remarks

The 19th century Westward Expansion in the United States is a one-time phenomenon. It combined, within a century, a massive redistribution of the population

[30]The source for Figure 18 is Haines (2000), Table 4.1, p. 153.

and a significant investment in improving newly acquired land. Much work has been devoted to the history, and the political meaning and implications, of the westward movement.[31] But it is also of great importance to the understanding of the U.S. economy during that period. It is shown here that standard general equilibrium theory provides a unifying framework to understand both the movement of population and investment in land. The model is consistent with the conventional view that population growth and the abundance of unsettled land are key factors, and it emphasizes the economic mechanisms at work. The model is also consistent with the U.S. data, as far as the existence and the magnitude of a real wage gap in favor of the West is concerned. Yet, the convergence of real wages exhibited by the data is not matched. This leaves the door open to further research, mainly regarding the modelling and the calibration of migration and its cost.

The question of international immigration to the United States is similar to the question of the Westward movement: the opportunities offered by the West to eastern workers are the same as those offered by the U.S. as a whole, to workers in the rest of the world. Hence the model provides a framework to explain international immigration to the United States during the 19th century. Abundance of land is, indeed, a factor attracting migrants from all over the world because it causes real wages to be high.

It has been documented [see Yasuba (1962)] that Westerners had higher fertility than Easterners. Moreover it has been argued that this could be due to the abundance of land in the West, compared to the East. Including the fertility decision into the framework of the model proposed here would allow one to address this question. In addition, this would allow one to analyze both components of changes in the population: migration and natural increase.

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[31] The leading work being that of Turner (1894).

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Figure 1: The United States in 1810.

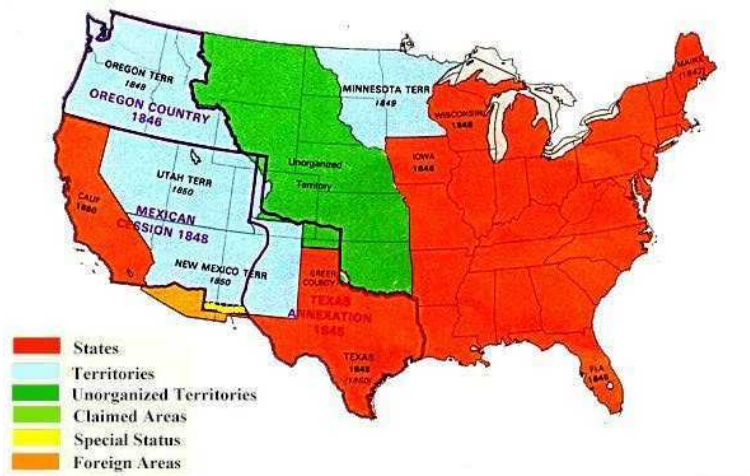

Figure 2: The United States in 1850.

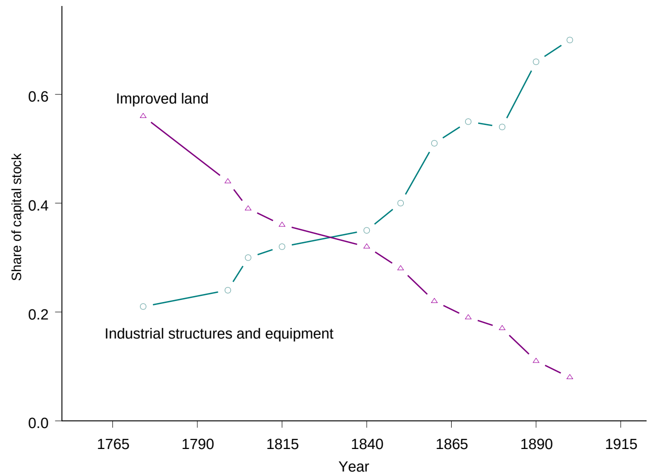

Figure 3: Shares of the domestic capital stock, U.S., 1774–1900.

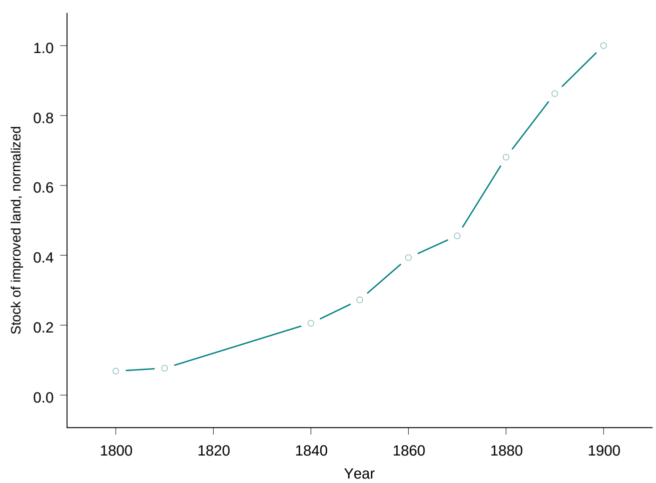

Figure 4: Stock of improved land, U.S., 1800–1900.

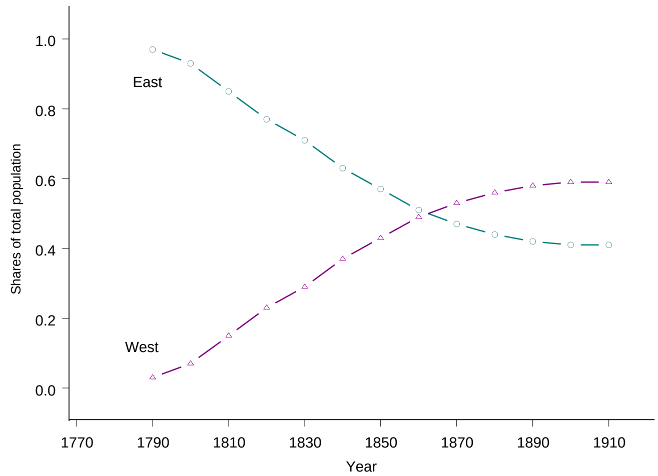

Figure 5: Regional shares of total population, U.S., 1790–1910.

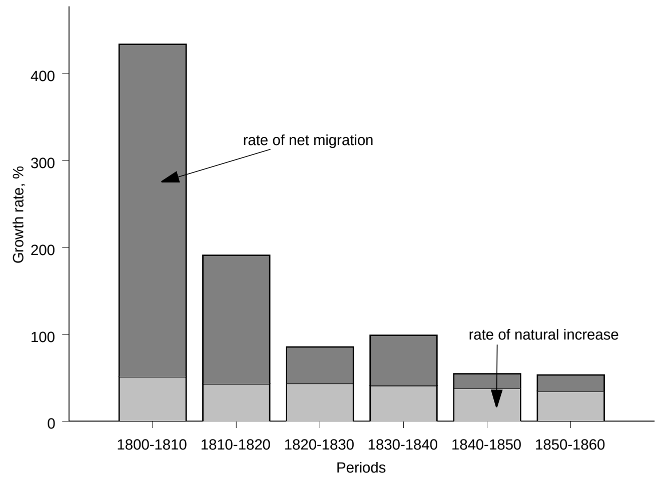

Figure 6: Growth rate of population, the Old Northwest, 1800-1860.

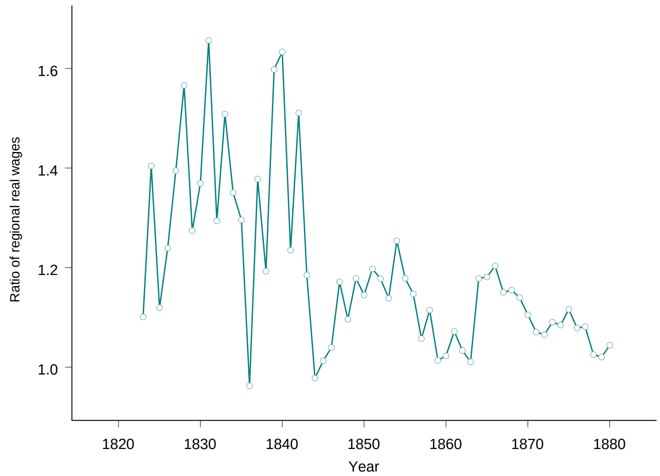

Figure 7: Ratio of western to eastern real wages (common laborers), U.S., 1823–1880.

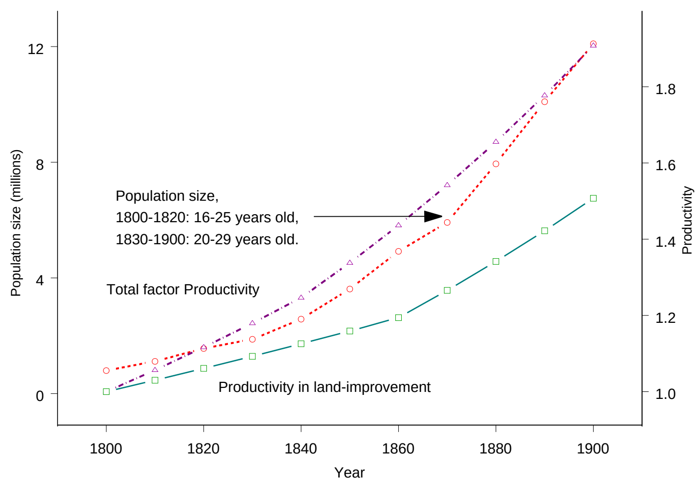

Figure 8: Population size and productivity growth, U.S., 1800–1900 .

		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 2: Land-clearing statistics, U.S., 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 3: Fencing statistics, U.S., 1860 and 1900.

ϕ	Capital share in consumption good sector	0.28
μ	Labor share in consumption good sector	0.68
δ	Depreciation factor	0.90^{10}
β	Subjective discount factor	0.95^{10}
σ	Utility parameter	1.66
l^e	Land services in the east	0.02
θ	Land efficiency parameter	0.59
γ	Cost of migration	0.20
$\{z_t\}$	**Path for total factor productivity**	
	Initial condition	1.0
	Annual growth rate for 1800-1840	0.55%
	Annual growth rate for 1840-1900	0.71%
$\{z_t^c\}$	**Path for productivity in land clearing**	
	Initial condition	0.006
	Annual growth rate for 1800-1860	0.3%
	Annual growth rate for 1860-1900	0.6%
Population		U.S. data.

Table 4: Calibration of the baseline model.

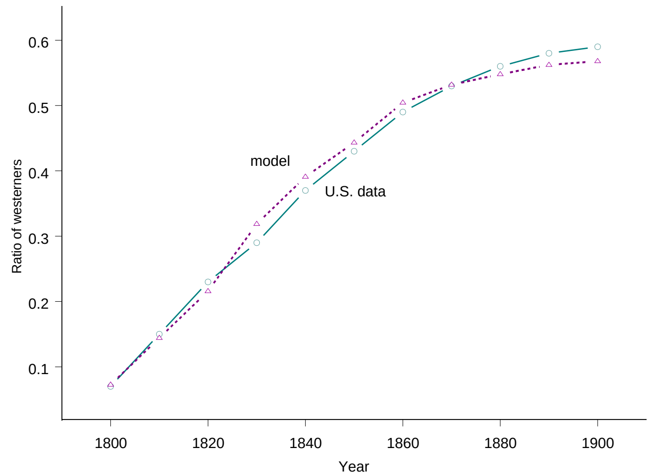

Figure 9: Ratio of westerners, U.S. data and model, 1800–1900.

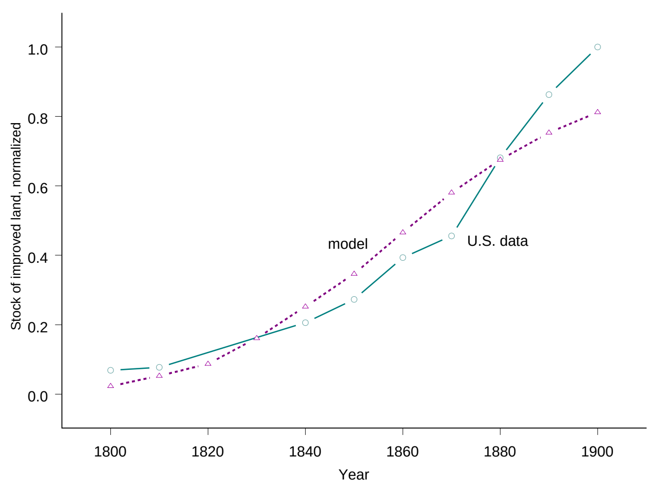

Figure 10: Stock of improved-land, U.S. data and model, 1800–1900.

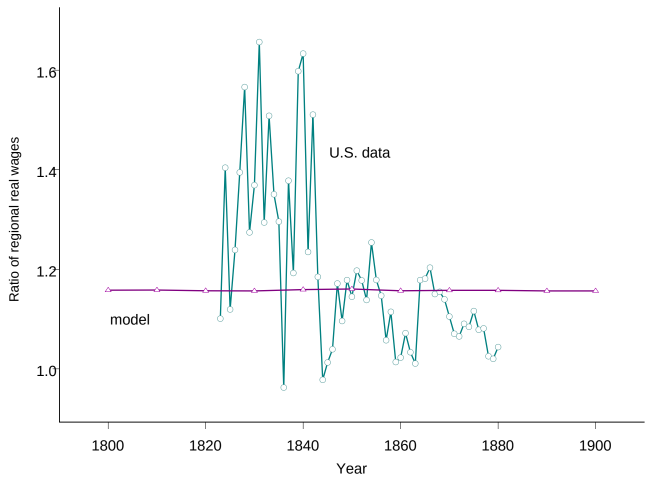

Figure 11: Ratio of western to eastern real wages, U.S. data and baseline model, 1800–1900.

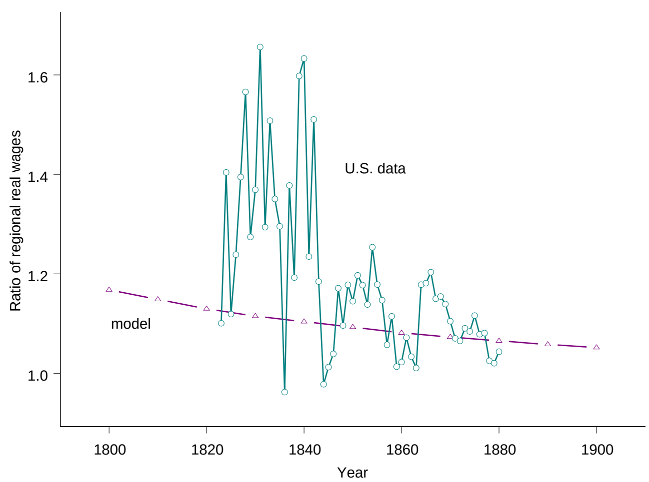

Figure 12: Ratio of western to eastern real wages, U.S. data and model with decreasing cost of migration, 1800–1900.

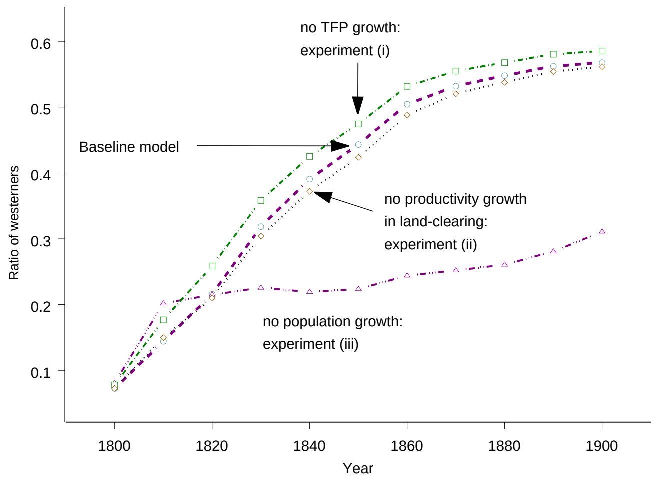

Figure 13: Counterfactual experiments.

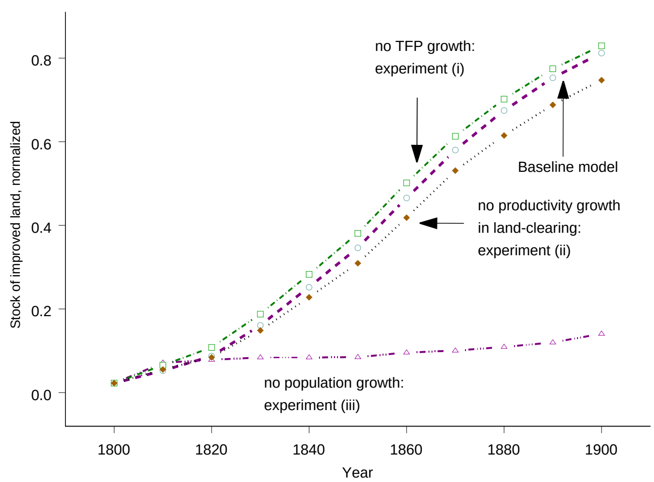

Figure 14: Counterfactual experiments.

		Ratio of Westerners	Stock of improved-land
	Baseline model	1.005	0.960
	Counterfactuals:		
(i)	No growth in total factor productivity	1.094	1.037
(ii)	No growth in land-improvement productivity	0.985	0.885
(iii)	No growth in population size	0.706	0.320

Table 5: Average relative difference between model and U.S. data, various experiments.

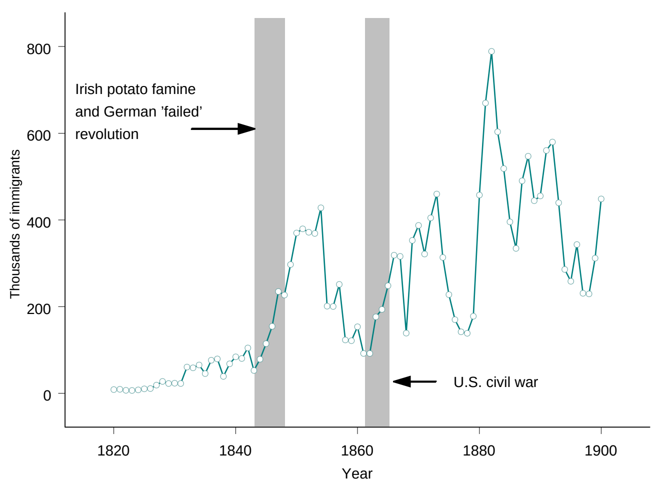

Figure 15: International immigration to the United States, 1820-1900.

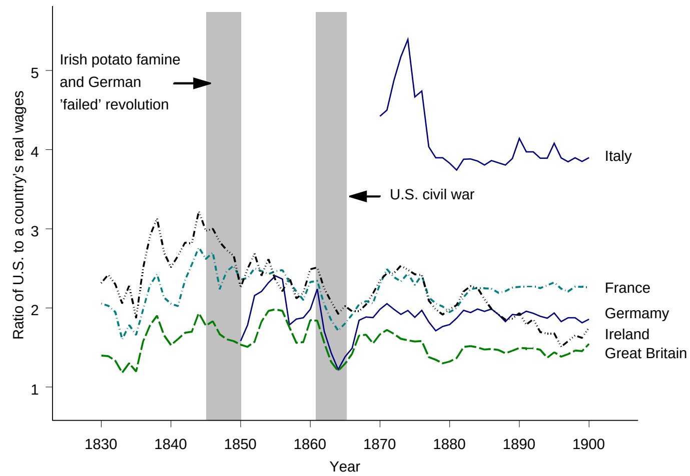

Figure 16: Ratio of U.S. to European real wages, 1830-1900.

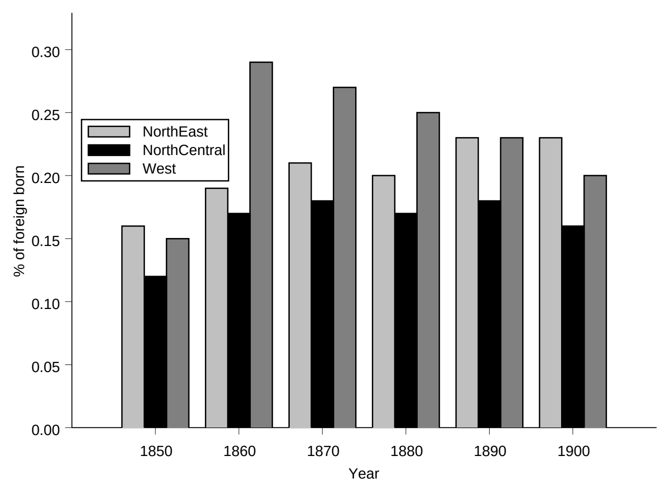

Figure 17: Proportion of foreign born per regions, U.S. 1850-1900.

	1820	1860		1820	1860
New England			**Middle Atlantic**		
Maine	0.57	6.00	New York	1.13	26.10
New Hampshire	0.05	6.40	New Jersey	0.59	19.00
Vermont	0.40	10.40	Pennsylvania	1.05	15.10
Massachusetts	0.66	22.20			
Rhode Island	0.30	21.90			
Connecticut	0.21	17.90			
East North Central			**West North Central**		
Ohio	0.61	14.20	Minnesota	-	34.70
Indiana	0.57	8.80	Iowa	-	15.70
Illinois	1.11	19.00	Missouri	0.89	15.10
Michigan	7.63	20.30	Dakota	-	68.90
Wisconsin	-	35.80	Nebraska	-	22.10
			Kansas	-	11.90

Table 6: Proportion of foreign born per regions (%), U.S. 1820 and 1860.

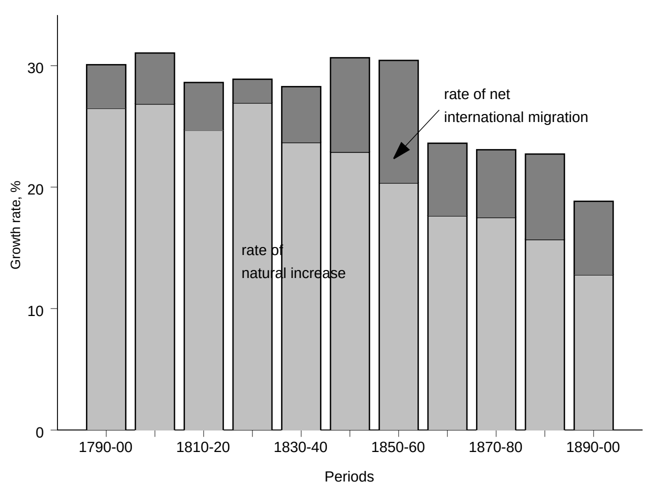

Figure 18: Growth rate of total population, U.S., 1800-1900.

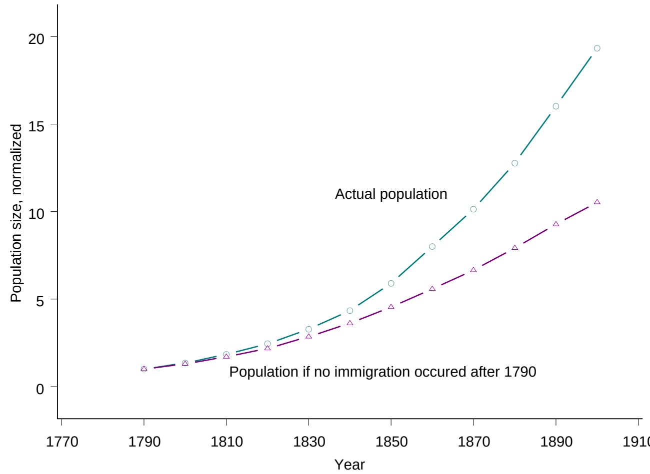

Figure 19: Population of the United States: actual and the no-immigration case, 1790-1900.

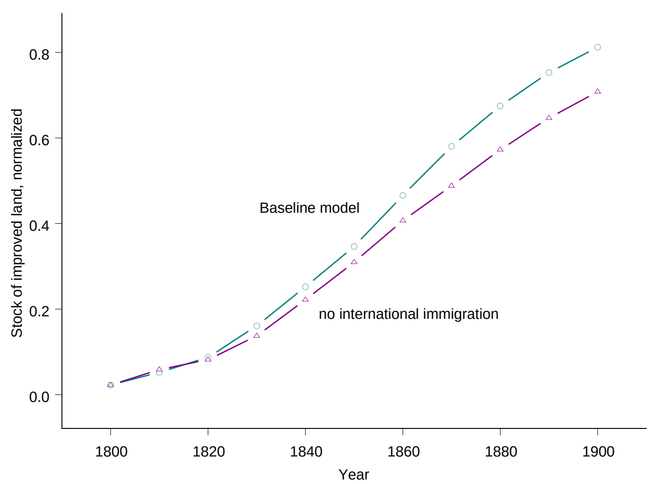

Figure 20: Stock of improved-land, baseline model and the no-immigration case, 1800–1900.

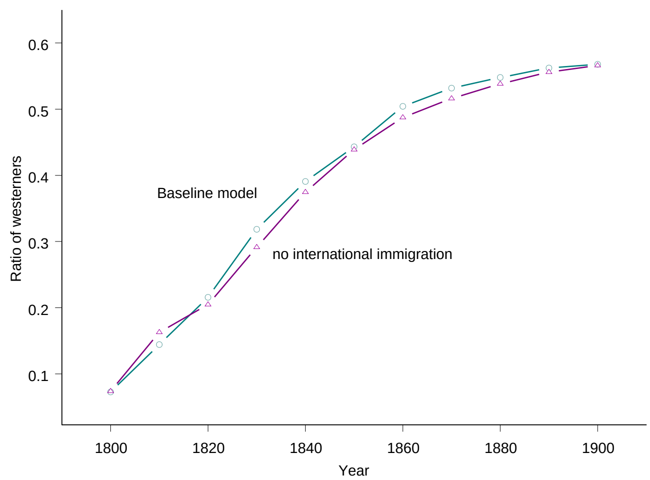

Figure 21: Ratio of westerners, baseline model and the no-immigration case, 1800–1900.