The Slaughter of the Bison and Reversal of Fortunes on the Great Plains

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Abstract

In the late 19th century, the North American bison was slaughtered to near-extinction in just over a decade. We show that the bison's slaughter led to a reversal of fortunes for the Native Americans who relied on them. Once the tallest people in the world, the generations of bison-dependent people born after the slaughter were amongst the shortest. Today, formerly bison-dependent societies have between 20-40% less income per capita than the average Native American nation. We argue that federal restrictions limiting the mobility and employment opportunities of Native Americans hampered their ability to adjust in the long-run.

Keywords: North American Bison, Buffalo, Extinction, Economic History, Development, Displacement, Native Americans, Indigenous, Income Shock, Intergenerational Mobility

JEL classification: I15, J15, J24, N31, N32

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> *"But when the buffalo went away the hearts of my people fell to the ground, and they could not lift them up again."* (Crow Plenty-Coups quoted in Lindermann (1930, p. 169))

The changes of the late 19th century brought with them the near-extinction of the North American bison and, consequently, the elimination of a way of life for the Native Americans of the Great Plains, the Northwest, and the Rocky Mountains. Although Native Americans' reliance on the bison was not static or uniform across tribes, the bison had been a primary source of livelihood for over 10,000 years prior to its near-extinction (Frison, 1991; Gilmore, Tate, Tenant, Clark, McBride, and Wood, 1999; O'Shea and Meadows, 2009; Zedeño, Ballenger, and Murray, 2014). For many tribes, the bison was used in almost every facet of life, not only as a source of food, but also skin for clothing and blankets, and bones for lodging and tools. This array of uses for the bison was facilitated by generations of specialized human capital, which was accumulated partly in response to the plentiful and reliable nature of the animal (Daschuk, Hackett, and MacNeil, 2006). Historical and anthropometric evidence suggests that these bison-dependent societies were once the richest in North America, with living standards comparable to or better than their average European contemporaries (Carlos and Lewis, 2010; Prince and Steckel, 2003; Steckel, 2010; Steckel and Prince, 2001). When the bison were eliminated, however, the resource that underpinned these societies vanished in an historical blink of the eye. We show that the loss of the North American bison had substantial and persistent negative effects on the Native Americans who depended on them.[1] These effects are visible immediately after the bison's decline, 50 years after it disappeared, and over a century later.

In some regions, the bison was principally eliminated through a mass slaughter that occurred within a period of just over ten years. The slaughter was, at least in part, spurred by a drastic improvement in European tanning technology that allowed bison hides to be transformed into commercially viable leather, thereby increasing the demand for bison hides internationally (Taylor, 2011). However, in other regions of North America, the decline of the bison was a gradual process, beginning with the introduction of the horse and the arrival of European settlers. Our empirical strategy exploits regional variation in the speed at which the bison

[1] We use the term Native American to broadly refer to the original inhabitants of North America but acknowledge that this term is imprecise and is not without controversy (Corntassel and Witmer, 2008). We use it here because of its generality and common acceptance.

disappeared as well as tribal variation in bison-dependence to determine the impact of the loss of the bison on the Native American societies that depended on them.

We establish the contemporaneous impact of the elimination of the bison on Native American height using a number of historical sources. Our primary measures of bison-dependence are constructed from overlaying maps of the historic bison range and the timing of the bison's destruction (Hornaday, 1889) with maps of tribal ancestral territories (Gerlach, 1970; Sturtevant, 1981). This allows us to calculate the proportion of a nation's ancestral territory covered by the historic bison range during the slow and rapid periods of the bison's decline, which we merge with data on the height, gender, and age of over 15,000 Native American peoples collected between 1889 and 1919 by physical anthropologist Franz Boas (Jantz, 1995).[2] We begin by showing that bison-dependent peoples had a significant height advantage over their non-bison-dependent counterparts, paralleling the results of Steckel and Prince (2001) and Prince and Steckel (2003). The tribe-age structure of Boas' data allows us to employ a difference-in-differences identification strategy where we compare age-height trends between bison-dependent nations that were affected by different stages of the bison's depletion. We find that nations that lost the bison most quickly suffered a 5 to 9 cm decline in height relative to those that lost the bison slowly. These findings provide the first empirical support for the contention of Steckel and Prince (2001) and Prince and Steckel (2003) that the people of the Great Plains derived their height advantage, at least in part, due to their access to the bison.[3]

Although we generally expect individuals and regions to adjust to large economic shocks over time, the unique legal structures of Indian reservations and the institutional restrictions placed on Native Americans during the 19th century may have limited Native Americans' ability to adjust in the long-run. For example, out-migration from regions that no longer provided economic opportunities was not possible for many Native Americans who did not have the right to freedom of movement until 1924 (Marks, 1998), nearly two generations after the decline of the

[2]We supplement our primary measure of bison-dependence with an anthropological index derived from historical accounts of bison-dependence, the share of a tribe's traditional territory that is covered by short grasses, and a measure of cattle carrying capacity based on the 2012 U.S. Census of Agriculture.

[3]Our estimates of the decline in height among bison-dependent nations are almost certainly lower bounds on the height differential, as the age distribution of bison-dependent nations has less mass in the left tail. This finding is consistent with high levels of infant and youth mortality after the bison de-population. Thus, any estimates of the decline in height among bison-dependent nations after the bison depopulation will be biased towards zero. This is discussed further in Section II.

bison.[4] In addition to the mobility restrictions placed on Native Americans, they did not have equal protection under law, could not access credit, and only gained limited political autonomy in the late 1960s (Marks, 1998). A natural alternative to bison-hunting in the twentieth century may have been cattle ranching; however, Trosper (1978) suggests that limited access to capital markets as late as the 1960s prevented Native American ranchers from producing the same level of output as non-Native ranchers. Using data on tribal affiliation and occupational rank from the 1910 and 1930 American census, we show that people belonging to bison-dependent nations that lost the bison rapidly had significantly lower occupational rank relative to other Native Americans 20 and 50 years after the slaughter of the bison.

In accordance with other research that has found long-term persistence of economic shocks–perhaps mediated by other channels like social capital (e.g., Dippel (2014); Nunn (2008))–we investigate whether the negative economic effects of the loss of the bison can be seen in the present. We use data from the Census Fact Finder compiled by Dippel (2014) to show that per capita income on reservations comprised of previously bison-dependent nations was approximately 30% lower in 2000, compared with reservations comprised of non-bison-dependent nations.[5] We show this result is even larger among Indigenous communities in Canada. Further, we find that reservations whose members belonged to nations that lost the bison gradually had approximately 20% less income on average, while those whose members belonged to nations that lost the bison rapidly had roughly 40% lower incomes on average. Using night time light density in 2013 to proxy for economic activity on a larger set of reservations than the sample for which income per capita is available reveals that communities whose ancestors experienced the gradual loss of the bison have 35% lower light density and those whose ancestors lost the bison quickly have approximately 70% lower light density. The contrast in persistence among those belonging to "rapid-loss" and "gradual-loss" bison-societies highlights the margins along which Native Americans were able to adjust to the loss of the bison, with those losing the bison over a longer time horizon being better equipped, in the long-run, to adjust to life without the bison.[6]

[4]Freedom of mobility has been shown as an important channel for economic adjustment during other large economic shocks such as the American Dust Bowl Hornbeck (2012).

[5]We view this as building on the literature on the colonial and historical origins of economic development. See for example Acemoglu, Johnson, and Robinson (2001, 2002), Nunn (2008, 2009); Nunn and Puga (2012); Nunn and Qian (2011), Dell (2010), and Dippel (2014).

[6]Our findings are robust to the inclusion of controls for pre-contact conditions, colonial experiences such

Our primary classification of communities as bison-dependent and non-bison-dependent depends entirely on a Native American society's traditional territory; however, some nations whose traditional territories were rich in bison were not completely reliant on the bison. We exploit variation in societies' historical experience with agriculture to show that bison-dependent communities with some level of economic diversification prior to the bison's slaughter have suffered far less than communities with few or no alternatives after the destruction of the bison. Agriculture was one of the few occupational sectors available to Native Americans that was promoted, permitted, and supported by the Bureau of Indian Affairs during the 19th and 20th centuries (Daschuk, 2013; Iverson, 1997). This suggests that societies that had acquired human capital in other sectors were better able to adjust to the economic shock under the restrictive conditions placed on Native Americans by federal Indian policy at the time. In addition, we provide evidence that bison-dependent people who left their traditional homelands, and would have had more opportunities to participate in the mainstream economy, experienced modest economic convergence on average.

Our results present a clear picture: the rapid extermination of the American bison on the Great Plains led to an immediate, dramatic decline in the heights of the Native Americans whose livelihoods depended on them. The decline in heights was followed by a lower average occupational rank in the middle of the twentieth century, and persistently worse per capita income and light density on reservations over a century later. Our results contribute to the understanding of the relative underdevelopment of some Native American communities today,[7] and they provide an explanation for the geographic clustering of poverty among Indigenous communities in North America.[8] One way to understand the effects of the decline of the bison is as one of the most dramatic devaluations of human capital in North American history. In

as war and forced co-existence, and contemporary economic factors, and they hold for alternative measures of bison-dependence.

[7]This is a growing literature that has emphasized the role of institutions in shaping economic development (Akee, 2009; Akee, Jorgensen, and Sunde, 2015; Akee, Spilde, and Taylor, 2015; Anderson and Parker, 2008, 2009; Aragón, 2015; Cornell and Kalt, 2000; Dippel, 2014), and on the role of modern natural resource development on modern outcomes (Anderson and Parker, 2008, 2009; Aragón, 2015; Aragón and Rud, 2013; Dell, 2010; Leonard and Parker, 2016). Our work deviates from past studies by focusing on the loss of a natural resource that was central to the lives of many Native Americans and the potential intergenerational effects of that loss. To our knowledge, this is a novel channel to focus on with respect to Native American economic development.

[8]In the United States, the poorest Native American communities are the previously bison-dependent communities of the Great Plains, Northwest, and Rocky Mountain regions (Anderson and Parker, 2009; Hurst, 1997), while in Canada, the poorest Native American communities are found in Alberta, Saskatchewan and Manitoba and were also historically reliant on the bison (AANDC, 2015).

this sense, our research is related to the literature on the intergenerational effects of income shocks and shows that when individuals are restricted in their ability to respond to such shocks, adverse effects can persist across multiple generations (Oreopoulos, Page, and Stevens, 2008; Solon, 1999; Stevens, 1997).

Our findings are also connected to the work of economic historians who have examined the overuse and depletion of renewable resources in a colonial context (e.g., Allen and Keay (2004) and Carlos and Lewis (1993, 1999)). Taylor (2011), Hanner (1981), and Benson (2006) all examine the nature and causes of the bison's near extinction. We add to this literature by examining the effect of the loss of the bison on those communities that depended on it, instead of on the depletion of the resource itself.

Finally, our work also offers insight into how economies that rely on a single resource respond when that resource is depleted over a short period of time. The case we study coincides with federal policy that restricted mobility and, thus, the ability of Native Americans to invest in education or occupation-related skill acquisition. These conditions may be thought to parallel those that exist in relatively isolated nations today where individuals face barriers to international mobility or economies are based on a single resource. In this sense, our work also contributes to the literature on the natural resource curse (Jacobsen and Parker, 2016; Michaels, 2011).

The paper proceeds as follows. In the next section, we review the historical dependence of Native Americans on the bison, how the relationship has evolved over time, the decline and eventual slaughter of the bison, and the policies enacted by the United States government that limited the ability of Native Americans to use transferable human capital associated with bison hunting. In Section II, we discuss the data generation and matching processes we used to construct the datasets used in our empirical analysis. Section III outlines our methodological framework for both the short and long-term impacts of the decline of the bison. We then present the results in Section IV, followed by an analysis of the mechanisms through which the effect of the bison's decline has persisted in the long-run. Section V concludes with a discussion of the main findings and suggestions for future work.

I Background on Bison-Dependence and the Bison's Near-Extinction

Anthropological evidence suggests that Indigenous peoples in the Subarctic, Plains, Great Basin, and Rocky Mountain regions of North America hunted the bison for at least 10,000 years (Frison, 1991; Gilmore et al., 1999; O'Shea and Meadows, 2009; Zedeño et al., 2014). While estimates differ substantially, the number of bison that existed historically in North America has been estimated to be as high as 30 million to as few at 10 million (Taylor, 2011). Historically, the Plains bison roamed the territory between the Rocky Mountains in the west to the Appalachian Mountains in the east, and extending from as far south as the Mexican states of Chihuahua and Coahuila to as far north as the Canadian Northwest Territories (Hornaday, 1889).

Originally, the bison were hunted on foot, often assisted by domesticated dogs, initially with spears and later using the bow and arrow (Isenberg, 2000; Kornfeld et al., 2010). Pedestrian bison hunting was large-scale and highly specialized with strategies that evolved over time. Perhaps the most iconic method of the pedestrian hunt was the "buffalo jump", where hunters would set fire to grasses to force herds of bison over a cliff. These sorts of dramatic hunts were often conducted in conjunction with several nations, and entire communities participated to fully employ the extent of hunt. As an example of an alternative method, hunters would separate a portion of the herd, leading them into a pen of branches and blankets by lighting fires or using dogs. Following the hunt, the large animals were generally skinned and disassembled on-site in order to make the carcasses manageable. Women were primarily responsible for this task and would make use of nearly every part of the animal. They tanned and softened hides for clothing, blankets, and lodging, using the brains as grease. Bones were used to make tools, while the marrow was consumed for its nutritional content, and stomachs were converted into bags or vessels. Bison meat was often preserved by drying, or it was mixed with processed berries and bison fat to produce a mixture called pemmican. Enclosed in a bag made from the bison's stomach, pemmican could be stored for years and, as a result, during times of game shortages or crop failures, bison-dependent nations could sustain their peoples.

Archaeological records indicate that many bison-dependent peoples did not seek diversification in their economic activity, even though other resources were present, suggesting that the bison provided a reliable source of food and wealth (Daschuk et al., 2006; Zedeño et al., 2014). Due in part to the plentiful nature of the bison and the ability to store bison food products for years, the people of the Great Plains were arguably the wealthiest in North America and at least as well off as their average European counterparts (Carlos and Lewis, 2010; Prince and Steckel, 2003; Steckel and Prince, 2001). Early anthropologists often characterized bison hunting societies as egalitarian and lacking organizational complexity; however, the killing and processing of the bison was an endeavor of industrial proportions (Kehoe, 1967). Recent work by anthropologists suggests that bison-dependent societies evolved to have well-defined systems of ownership over hunting grounds, permanent sites of residence, complex kinship networks, and economic power relationships designed to secure the best bison herds (Zedeño et al., 2014). They were also involved in cultivating the lands by burning long grasses to encourage the growth of short grasses that were preferred by the bison (Isenberg, 2000; Zedeño et al., 2014).

While methods of hunting and employing the bison changed over time, the most dramatic change was driven by the introduction of the horse to North America. With the colonization of South America, horses spread from Spanish controlled territory in the south as far north as Canada, likely through pre-existing trade routes (Hämäläinen, 2003). By the 1650s, colonists had become aware of mounted Indians after encountering the riders of the Apache tribe. The introduction of the horse dramatically decreased the costs associated with hunting bison, leading some societies to shift from agriculture towards bison hunting as their main source of economic activity (Gwynne, 2010); however, it also brought the first waves of European diseases, infecting the people of the plains through their contact with native horse traders who had been exposed to Europeans (Daschuk, 2013). The extent to which Plains peoples were depopulated by European diseases has been intensely debated (Cameron, Kelton, and Swedlund, 2015). Early estimates suggest that, between 1774 and 1839, depopulation among Plains Natives was in the realm of 50%-60% (Decker, 1991), but later estimates suggest that this figure may be closer to 20% (Carlos and Lewis, 2012). Some historians have suggested that depopulation among the peoples of the Great Plains did not occur until *after* the extermination of the bison, when bison-dependent societies were on the brink of starvation and vulnerable to disease from malnutrition (Cameron et al., 2015; Daschuk, 2013; Daschuk et al., 2006). The earliest contact bison-dependent societies had with the English and French was through the fur trade, although this trade was typically indirect. Bison robes and pemmican were traded, but neither commodity was as lucrative as the furs being sought for resale in Europe. Bison-dependent peoples had been tanning hides for centuries, but the process was labour intensive and unprocessed leather from bison hides was not commercially valuable from a European perspective (Taylor, 2011).

With the end of the American Revolution and the westward expansion of the United States, settlers moving westward along the Oregon trail in the early 1800s effectively split the existing bison herd of the Great Plains and plateau region into a northern and southern herd (Taylor, 2011). As settlement continued, the bison were hunted at higher rates, which when combined with years of drought and competition for food sources from settler cattle, slowly began depleting the bison populations east of the Mississippi (Isenberg, 2000). The pace of the bison's extermination drastically increased with the construction of the Pacific Railroad between 1863 and 1869. Upon completion of the railway, settlers had access to the herds of the interior in an unprecedented manner (Hanner, 1981; Hornaday, 1889). Even so, the historical accounts suggest that settlers and native communities did not anticipate the bison's rapid extermination (Daschuk, 2013; Hanner, 1981). In fact, the construction of the railway through the Great Plains was made possible because of a series of treaties the United States negotiated during the late 1860s with the Apaches, Cheyenne, Kiowas, and the Comanche in the south, and North-Western Sioux and Northern Cheyenne—specifically the Teton Sioux, known as the Lakota—in the north.[9] Through these treaties, Natives exchanged large tracts of their ancestral territories for public goods, annuities, and protection of their exclusive right to hunt the bison herds. Moreover, the treaties included clauses that protected the bison from being hunted by settlers, which had resulted in a gradual decline of the herds in other areas of the country (Gwynne, 2010).

The fate of the bison changed unmistakably in 1871 when tanners in England and Germany developed a method for tanning buffalo hides so that they could be commercially viable (Taylor, 2011).[10] In response, hide hunters flooded to the plains. Figure A1 compiles estimates of bison hide exports from Taylor (2011) between 1865 and 1889. This figure shows the large spike in bison hide exports that occurred after the innovation in European tanning technology. Taylor (2011) estimates that in 1875, 1 million bison hides were shipped from the United States to

[9] These treaties include, but were not limited to, the Medicine Chest Treaties of 1867 in the South and the Fort Laramie Treaty of 1868 in the North.

[10] The sudden access to the bison from the newly constructed railways may have spurred European innovators to try and find a use for them, but without the commercial demand for the tougher bison leather, the incentive for commercial hunters to rush to the plains and slaughter the animal would not have existed. The European innovators likely did not see the treaties as a significant barrier to bison access.

France and England alone. The hide men initially focused on the more accessible southern herd,[11] and by the spring of 1874, the herds on the middle plains had been decimated. A country once "black and brown with bison was left white by bones bleaching in the sun" (Gwynne (2010), p.260-261). By 1879, the southern herd was completely eliminated (Hornaday, 1889). Gwynne (2010) provides a moving account of a group of Comanche men who left the reservation for a traditional bison hunt in the spring of 1878:

> *"They rode west from Fort Sill towards the high plains, full of dreams and nostalgia. They understood that the hide hunters had taken a terrible toll on the buffalo. But they had never doubted that there were herds left to hunt. What they found shocked them. There were no buffalo anywhere, no living ones anyway, only vast numbers of stinking, decaying corpses or bones bleached white by the sun. The idea of traveling a hundred miles and not seeing a buffalo was unimaginable. It had not been true at the time of their surrender.* (p. 294)

The slaughter of the northern herd did not occur until 1881, and, according to estimates of hide exports compiled by Taylor (2011), they were one tenth of those of the earlier southern slaughter. Taylor (2011), among others, attributes the delayed elimination to the "hostile Sioux" and other Native groups who were not part of the reservation system. However, to fully attribute the timing of the northern slaughter to hostile northern nations would be to over-simplify the historical context.

Reservations had already been established for the Northern Cheyenne, Northern Arapaho, and the Sioux by the Treaty of Fort Laramie in 1851 and later in 1868. Thus, they were equally a part of the reservation system as many of the southern communities in the same time period. Second, violence on the southern plains was also common and some authors suggest it may even have been provoked after the signing of the treaties by the slaughter of the bison (Smits, 1994). Once Native groups in the south realized the extent of the bison slaughter, they retaliated against hide hunters with violence, so the danger was not limited to the northern plains. The Sioux's reaction was in response to the violation of treaty terms when white men entered their territories. Even though the hide hunters did not slaughter the bison on the Lakota territory until the early 1880s, the Northern Herd was eliminated from the lands surrounding

[11] The railway at that point stopped at Dodge City, Kanas.

their traditional territories that had been under protection by the Treaty of Fort Laramie. This slaughter necessarily reduced the potential density of the bison within their lands. Hornaday (1889) suggests that the bison were exterminated in northern Montana and Saskatchewan by 1878, in Wyoming and Alberta by 1880, and that the last bison in the remaining territory was gone by 1883. The last bison hunt by the Sioux was in 1882 (Ostler, 2001). A well-established argument advanced by many scholars suggests that the United States government deliberately promoted the destruction of the northern herd to force the nations to give up their treaty rights (Hornaday, 1889; Smits, 1994). MacInnes (1930) argues that American soldiers drove bison herds south into the region of the hide hunters.

Several scholars have argued that the slaughter of the bison would not have happened in an environment with well-defined property rights (Benson, 2006; Hanner, 1981; Lueck, 2002; Taylor, 2011). As far as the Native nations were concerned, property rights existed, though they were clearly not enforced. One reason for this was political. General Phil Sheridan, then Commander of the Military Division of the Missouri stated in 1875:

> *"These men [hunters] have done in the last two years and will do more in the next year to settle the vexed Indian question, than the entire regular army has done in the last thirty years. They are destroying the Indians' commissary. Send them powder and lead if you will; for the sake of the lasting peace, let them kill, skin and sell until the buffalos are exterminated."* – quoted from Gwynne (2010), p.262

Army Generals actively encouraged their troops to kill the bison for food, sport, or "practice". Many military commanders believed that Native people would not be truly settled onto reservations until the bison were exterminated (Smits, 1994). Despite promises made to the northern nations in 1868, in 1874, the government dispatched the Custer Expedition into Sioux territory and discovered gold in the Black Hills. The Lakota were alarmed at this treaty-violation, as miners began to trespass on their territories. Initially, the government expelled miners that entered, but pressure built to secure the Black Hills from the Lakota, which in 1874 had not yet suffered the loss of the bison to the same extent as the southern nations.[12]

[12] At this point, the Northern Pacific Railway was not yet complete, reaching Fargo, Dakota Territory early in June 1872. A severe stock market crash and financial collapse after 1873 led by the Credit Mobilier scandal and the Union Pacific railroad fraud stopped further rail line from being built for 12 years. This halting of the railway may have delayed the destruction of the northern herd.

Within less than two decades, the economic and social core of the great bison nations was gone. By the early 1880s, there were no bison, little game, and inadequate and at times non-existent government food supplies. Records from trading posts, native leaders, Indian Affairs officials and media outlets reported widespread malnutrition and hunger among the native populations (Cameron et al., 2015). Communities resorted to eating horses, mules, soiled food, and old clothing to prevent starvation (Daschuk, 2013; Gwynne, 2010). The resource that underpinned centuries of human capital acquisition was eliminated with few alternative options. Some communities resorted to collecting the bison bones that littered the plains after the slaughter and selling them for fertilizer (Ostler, 2001).

Economic activity and mobility were severely constrained during this time period and arguably left few dimensions upon which Native Americans could adjust. Specifically in both Canada and the United States Native Americans could only leave their reservations with the permission of government officials on reservations, known as Indian Agents, until close to the 1930s (Marks, 1998). Cattle ranching, a plausible alternative use of skills for many bison peoples, was either activity prevented by Indian Agents or subject to serious credit constraints until the 1940s (Iverson, 1997; Trosper, 1978).[13,14] Agriculture was effectively the only economic activity supported or promoted by North American governments. However, agriculture was abhorred by many in the former bison-dependent nations and few individuals had experience in the area (Gwynne, 2010; Iverson, 1997; Ostler, 2001). That being said, several nations had varying degrees of agricultural reliance prior to the bison's decline, which we show may have provided them with an economic alternative to help mitigate the negative consequences resulting from the loss of the bison (Iverson, 1997).

In the next two sections, we outline the approach we take to empirically evaluate how the loss of the bison altered the historical trajectory for the societies that depended on them.

[13] Although some notable native leaders did manage to convince Indian Agents to come to food sharing and cattle ranching agreements, these were not a generally accessible forms of employment and only benefited a few members (Gwynne, 2010; Iverson, 1997).

[14] Using a sample of ranchers from the Northern Cheyenne Reservation in Montana, Trosper (1978) analyzes differences between Native and non-Native ranching and suggests that Native ranchers were as efficient, if not more efficient, than white ranchers, but due to limited access to capital, they produced less output than their non-Native counterparts.

II Data on Bison-Dependence, Historical and Modern Context and Well-being

We draw on a number of newly digitized and existing data sources in order to determine the short- and long-run impacts of the elimination of the bison on Native American outcomes. These data sources include GIS mappings of the geographic expanse of the bison over time and ancestral tribal territories, 19th and early 20th century Native American heights, as well as income, nighttime lights, and occupational rank for several time periods in the 20th century. We construct a number of additional variables related to regional variation in geography, colonial experiences, and cultural and demographic characteristics.

A Measures of Bison-Dependence and Timing of Bison-Loss

The elimination of the North American bison was recorded by William Temple Hornaday, who, at the time, was the chief taxidermist of the Smithsonian Institute. Towards the end of the 19th century, Hornaday was commissioned by the institution to construct as detailed an account as possible of the bison's range at various points in time, in order to preserve its history. As part of an extensive monograph, Hornaday published maps of the original bison range and of the timing and geographic nature of the bison's extinction. Figure 1 is a digital reproduction of Hornaday's map.[15] The lightest region is the bison range as of 1730, the middle region is the bison range as of 1870, and the final black regions are the remaining herds as of 1889 with their corresponding sizes. The 1889 ranges were in ranched captivity. The original map of Hornaday (1889) can be found in Figure A2 of the appendix.

To generate a measure of bison-dependency, we overlay the digitized version of Hornaday's map with maps of traditional ancestral territories of Native American groups. The outline of the ancestral territories in the continental US are also present in Figure A2. For the United States, we use ancestral territories from the Map of Early Indian Tribes in the National Atlas of the United States (Gerlach, 1970), combined with the ancestral territory maps from the Smithsonian Handbook of North American Indians (Sturtevant, 1981) following Dippel (2014).[16] This overlay gives us a measure of the proportion of ancestral territories that were covered by

[15]The maps were digitized with at least 24 points of support.

[16]The National Atlas map can be found in Figure A7.

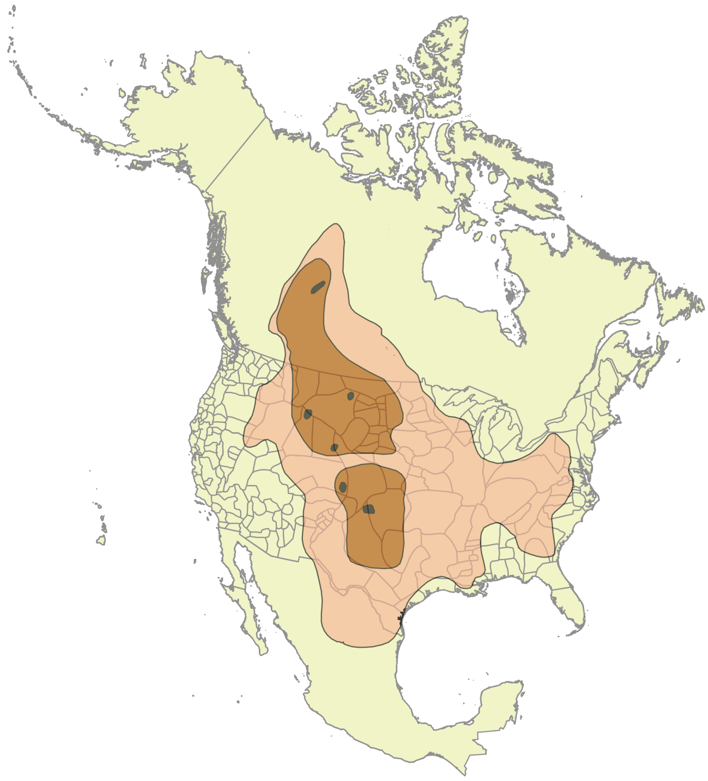

Figure 1: This is a digitized version of the map generated by Hornaday (1889), illustrating the original range of the North American bison and the timing of its decline. The lightest region is the range as of 1730, the middle region is the bison range as of 1870, and the final black regions are the remaining herds as of 1889 and their sizes. The 1889 ranges were in ranched captivity. Tribal territory boundaries are also displayed for the continental U.S.

the bison as of 1730, 1870, and 1889.[17,18] Our measures give a reasonable approximation as to whether societies experienced a high degree of bison-dependence and the speed at which communities experienced the extermination of the bison. The first variable we construct is a measure of initial bison-dependence. To do this, we measure the proportion of territory that was covered by the bison as of 1730. In our empirical analysis, all bison-related variables are continuous; however, to display descriptive statistics, we separate nations as bison-dependent or non-bison-dependent, where we classify nations as bison-dependent if 60% of their traditional territory overlapped with the historic bison range in 1730.

The next two variables we construct measure the timing of bison loss. The first timing-

[17]Note that in 1889, the only bison were found in captivity, so that the value of this variable is 0 for all tribes.

[18]While there may be some concern as to the precision of Hornaday's borders, we do not expect this will impact the empirical analysis, given that the maps of ancestral territories are themselves rough approximations of the traditional territories of many semi-nomadic or nomadic societies.

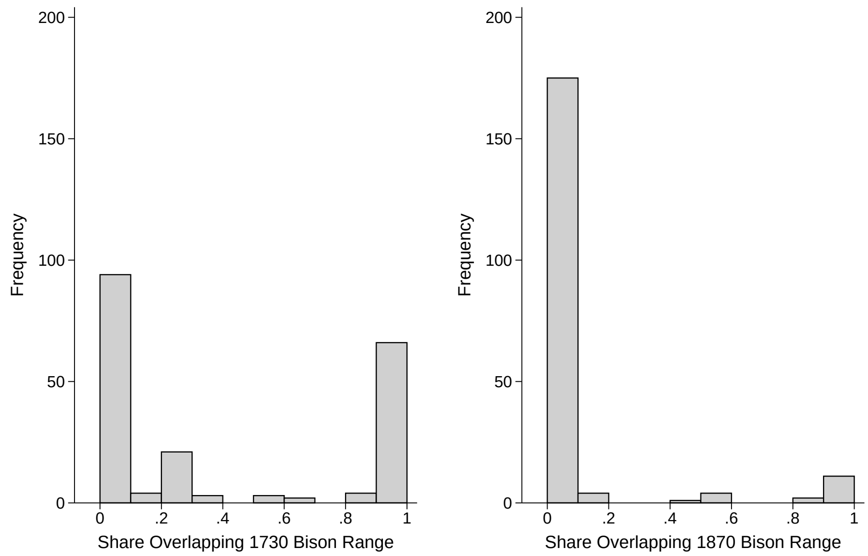

Figure 2: These histograms show the share of ancestral lands overlapping the original bison range (left) and the bison range as of 1870 (right).

related variable is the proportion of territory that was covered by bison as of 1730 minus the proportion that was covered as of 1870. The second is the proportion of territory that was covered by bison as of 1870 minus the proportion that was covered in 1889. A large value of the first measure means that the region lost the bison gradually, as discussed in Section I, over a 140 year period. A large value of the second measure implies that the territory lost the bison rapidly, as a result of over-hunting in response to European demand for bison hides. Figure 2 displays histograms of the share of ancestral lands overlapping the original and 1870 ranges. From these plots, we can see that many nations' ancestral lands overlapped with the original bison range; however, by 1870 the number of nations whose ancestral lands were covered by 90% or more of the bison range had dropped from over 60 to approximately 10.

The drawback of the above measures is that they are entirely based on geography. In some instances, however, the degree of bison-dependence among Native Americans–even in areas that were densely populated by bison–varied notably. For example, the Mandan peoples lived in the bison-dense territory of what is now North Dakota, yet they relied predominantly on agriculture and traded for bison meat and other supplies (Fenn, 2014). Our geographic measures would identify the Mandan as bison-dependent and among those that lost the bison rapidly. Thus we supplement our original measures of bison-dependence with anthropological accounts of bison-dependence taken from Waldman (2009). Using the accounts in Waldman (2009), we construct a scale from 0 to 1 in 0.1 increments that range from no contact with the bison to their calories being almost completely based on bison products. A full explanation for the coding of this variable and additional sources can be found in Tables A11, A12, A13, A14, and A15. For those nations that were not included in Waldman (2009), or whose tribal names in the data sources described below are too broad for reasonable classification of the anthropological measure, we use our original measures of bison-dependence. In all data sets, this represents a relatively small fraction of communities, and the correlation between the anthropological measure and the geographical measure is roughly 0.8.

To verify the robustness of our results, we generate two other proxies for bison-dependence. The bison range identified in the map of Hornaday (1889) does not take into account other factors that may have affected the density of bison, like the gradient of mountains, the presence of wetlands or lakes, and the diversity of vegetation. So while the bison may have roamed the area outlined in Hornaday (1889) in varying densities, the geographic measures constructed above assume a uniform density. To alleviate concerns regarding measurement error in this context, we construct a measure of carrying capacity that relies on the presence of modern-day cattle farming in tribes' traditional territories. Both cows and bison belong to the Bovinae subfamily, and although there are certainly differences in habitat use, forage use, and behavior between cattle and bison, much of the land once suitable for bison was replaced by domestic cattle after the bison's near extinction (Kohl, Krausman, Kunkel, and Williams, 2013). We use county level data from the 2012 United States Census of Agriculture to generate a measure of the number of cattle per kilometre squared in each tribe's traditional territory.

Next, we employ the World Wildlife Fund's World Grassland Types (Dixon, Faber-Langendoen, Josse, Morrison, and Louckn, 2014) dataset as an alternative mapping of the bison's expanse. This strategy should be effective as the bison is well adapted to grassland biomes. The WWF's GIS data provides a complete, global mapping of grassland types with a grassland being defined "as a non-wetland type with at least 10% vegetation cover, dominated or co-dominated by graminoid and forb growth forms, and where the trees form a single layer canopy with either less than 10% cover and 5m height (temperate) or less than 40% cover and 8m height (tropical)," (Dixon, Faber-Langendoen, Josse, Morrison, and Louckn, 2014). The data includes a total of 49 grassland divisions. Native traditional territories overlap with four grassland formations: cool semi-desert scrub and grassland, Mediterranean scrub, grassland and forb meadow, temperate grassland, meadow, and shrubland, and warm semi-desert scrub and grassland. We employ these measures in various combinations as robustness checks with a particular emphasis on temperate grassland, meadow and shrubland.

B Biological Measures of Standard of Living: 1888-1903

Given the lack of comprehensive income and occupational data for Native Americans pre-1900, we instead turn to the anthropometric literature for evidence, making use of childhood and adult height as biological indicators of well-being (Steckel, 1995, 2008). Through the undertaking of physical anthropologist Franz Boas, we have access to anthropometric data on approximately 15,000 Native Americans and Siberians. With funding from the Committee for the British Association for the Advancement of Science, the Bureau of American Ethology, the World's Columbian Exposition, the Jesup North Pacific Expedition, and the Huntington California Expedition, Boas directed a team of anthropologists to collect the data between 1888 and 1903. Boas was intent on sampling nearly all areas of North America where Native Americans could be found and focused on measures of height, sex, age, tribal membership and "racial purity" (Jantz, 1995). While there have been questions regarding the representative nature of Boas' sample (Komlos and Carlson, 2014), and of height data more generally (Guinnane, Bodenhorn, and Mroz, 2014), recent work comparing the Cherokee in Boas' sample to the Cherokee census suggests that Boas sample is representative on average, though it may over-represent the upper and lower classes (Miller, 2016). What is important for our empirical strategy is that, conditional on our set of covariates, over- or under-representation does not vary between age groups or between bison-dependent and non-dependent nations. We match the tribal associations in Boas' sample to our ancestral territory data.

Women are significantly under-represented in Boas' data and, consistent with prior literature, we focus on men (Prince and Steckel, 2003; Steckel and Prince, 2001). The male sample consists of 8,821 individuals after restricting the sample to those under the age of 60. We have matched 5,204 observations based on the exact tribal names given in Boas' data and with the tribal names provided in the American Atlas ancestral territories map. The remaining matches are based off both tribal and band names given in the Boas data. Some of the tribal names given are too broad for an exact match[19] and, in these cases, we construct bison-dependency as a geographically weighted average of all sub-tribal groups. The results are robust to limiting our analysis to our exact matches, but we present the results for the full sample in this paper.

Table 1 presents summary statistics from Boas' data for bison-dependent and non-bison-dependent nations. For the purpose of this exercise and those that follow, we classify a nation as bison-dependent if 60 percent of its ancestral territory overlapped with the historic bison range. In our empirical specifications, we use the proportion of share lost at various time periods as our primary variable of interest. Formerly bison-dependent nations were approximately 4 cm taller than non-bison-dependent nations and slightly less likely to have some non-Native American ancestry. They are also slightly older on average. Figure A3 shows that the differences in mean height in Table 1 are due to a uniform left shift in the height distribution, suggesting that the difference is not driven by differences in the tails of the distribution. On average, bison-dependent nations had operational railways established at a later date. Since railways proxy for timing of contact and pace of settlement of non-Indigenous peoples, we control for the date of operation in a number of specifications. As described in the historical section, settlement on reservations occurred for bison-dependent peoples largely before the loss of the bison and the introduction of the railway. However, the date of local railway operation will proxy for relative timing of these factors as well.

To further investigate the differences in mean age, we plot the age distribution of bison-dependent and non-bison-dependent nations in Figure A4. The results are striking. The age density is skewed towards older ages, with the largest differences occurring for those under the age of 20. There are notably fewer young people in the bison-dependent nations during the period in which they were sampled–after the bison were driven to near extinction. There are a number of plausible explanations for this pattern; however, one argument is that it is consistent with increased mortality rates at at younger ages, possibly due to the decimation of the bison. If the shortest (weakest) children are the ones who suffer higher rates of mortality, any empirical analysis of the heights of bison-dependent and non-dependent societies will likely *underestimate* the effects of the loss of the bison on height. We return to this data in the analysis that follows.

[19]For example, an observation may be labeled Apache, rather than Tonto Apache or White Mountain Apache.

Table 1: Summary Statistics from Boas Data

	Not Bison-Dependent	Bison-Dependent	Diff
Standing height in cm	156.44	162.01	-5.51
	(20.40)	(17.07)	
Year sampled	1892.56	1891.72	0.81
	(2.11)	(1.18)	
Birth year	1867.23	1865.44	1.70
	(15.14)	(14.28)	
Age	25.33	26.29	-0.87
	(15.14)	(14.10)	
Years since rail	-0.41	5.83	-5.96
	(29.46)	(23.26)	
Born after railway	0.41	0.38	0.03
	(0.49)	(0.49)	
Years born after rail	8.81	6.77	2.12
	(14.15)	(12.13)	
"Full Blood"	0.80	0.78	0.02
	(0.40)	(0.41)	
Canada	0.23	0.15	0.09
	(0.42)	(0.35)	
Observations	5104	3717	8,821

Notes: The data above is from Franz Boas' data expedition between 1888 and 1899. Means are reported with the standard deviations in parentheses. Difference-in-means tests are reported in the last column. Tribes are classified as "bison-dependent" if 60 percent or more of their ancestral territory overlaps with the historic bison range. "Full blood" is the proportion of people indicated to have no white ancestry. "Years since rail" is the number of rails between an individual's year of birth and the date the first railway went thorough their nation's traditional territory. "Born after rail" is the proportion of the sample that was born after rail went through their traditional territory. "Years born after rail" are the average years of age of someone born after the railway was introduced.

C Income, Nighttime Light Density, and Occupational Rank: 1910 to 2010

Biological measures are our only source of outcome data in the late 19th century, however beginning in the early 20th century explicit data on material well-being is available.

To show the immediate and longer term impact of the loss of the bison include data on occupational rank from the American Census and American Community Survey (ACS) to study effects of the loss of the bison on intermediate and long-run outcomes. This data is available publicly through the Integrated Public Use Microdata Series (IPUMS) (Ruggles, Genadek, Goeken, Grover, and Sobek, 2015). The occupational rank measure is constructed using the IPUMS occupational income score. This income score ranks occupations using the median incomes for each occupation from data published in the Census Bureau's 1956 special report on occupational characteristics. Apart from minor variations in post-1950 years, which required recoding post-1950 occupational classifications into the 1950 system, the measure of occupational rank is largely invariant across censuses. Unfortunately data is only available on occupational rank and tribal affiliation in 1910, 1930, 1990, 2000, and later in the ACS. We require detailed information on the tribal membership of Native Americans in order to determine ancestral dependence on the bison.

Measuring the long-run effects of the loss of the bison in a way that is strictly comparable to 1910 and 1930 is made difficult, as tribal membership in 1990 and 2000 is reported at a higher level of aggregation than in 1910 and 1930. This has implications for our ability to estimate the effects of the loss of the bison. For example, in 1990, the reported tribal membership may be "Apache"; however, the Apache can hardly be thought of as one unified cultural group, let alone homogeneous in bison-dependence or in the timing of bison loss. Nevertheless, to gain a sense of whether the effects of the loss of the bison have changed over time for the peoples that depended on them, as would be expected from a simple income shock, we aggregate tribal groups by year and compare the effects of bison-dependence and loss over this time period.

In Table A2, we show that the occupational status of bison-dependent nations is slightly higher than non-bison-dependent nations without accounting for state-level differences. Bison nations are somewhat older, which may be indicative of excess child mortality. For this exercise we focus on male occupational rank. The sample size is much smaller in 1910 and 1930 than in later years, accounting for only 1,101 observations of the total 66,786. To deal with the lack of detailed tribal information and measurement error in ancestral bison-dependence in the later censuses, we focus only on individuals who live on specified "Native homelands" or reservations, and assume that the individuals on reservations are the descendants of the nations for whom the reservations were designated.[20]

Given the limitations of tribal information in IPUMS data, we turn to modern, reservation-level data. The most complete information for reservation-level per capita income data is available through the 2000 American Census Fact Finder. While data back to 1970 is available, the number of included communities rapidly declines. For this reason, we focus on the 2000 data and show that our results are robust to the inclusion of these other data sets. In order to make our work comparable to recent work on Native American economic development, we use the tribal/reservation sample of Dippel (2014). This allows us to consistently include factors that have been shown to have large effects on economic development on reservations such as

[20]Given restrictive tribal membership laws and rates of intermarriage this is a reasonable assumption.

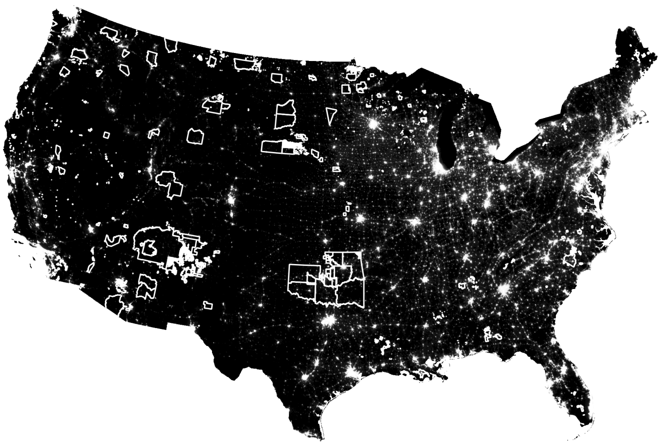

Figure 3: The distribution of nighttime lights in 2000 overlaid with Native American homelands or reservation boundaries in 2013.

forced and historic co-existence with other Native cultural groups, and the presence of casinos. We merge these tribal groupings with our measures of tribal-level bison-dependence.

As an additional measure of long-run outcomes, we use nighttime lights data from the National Centres for Environmental Information.[21] The nighttime lights data are gathered from satellites that measure light density at night at 30 arc second grids, which is equivalent to an area of approximately 1 square kilometre at the equator (Pinkovskiy and Sala-I-Martin, 2016). They are available globally for every year between 1992 and 2013, and serve as a reasonable proxy for economic activity in the absence of standard national statistics under the assumption that lighting is a normal good (Donaldson and Storeygard, 2016).[22] In Figure A8 we show that our measure of light density and GDP per capita move in tandem, which supports this assumption.

Each pixel is assigned a value between 0 and 63. For the purpose of our analysis, we use the log of mean light density of all pixels within a reservation's borders. Figure 3 displays the geographic distribution of light density overlaid with the 2013 boundaries of Native American homelands or reservations in the United States.[23] The advantage of using the nighttime lights

[21]The data can be downloaded online from `https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html`

[22]The nighttime lights data have been used extensively in recent economic literature and have been shown to be good proxies for economic activity at various levels of aggregation: countries (Pinkovskiy and Sala-I-Martin, 2016), ethnic homelands (Alesina, Michalopoulos, and Papaioannou, 2016; Michalopoulos and Papaioannou, 2013), sub- and supranational regions (Henderson, Storeygard, and Weil, 2012), and even at the pixel level (Bleakley and Lin, 2012).

[23]The boundaries displayed in Figure 3 include federal reservations, off-reservation trust land areas, state-recognized American Indian reservations, Oklahoma tribal statistical areas, tribal designated statistical areas, and state designated tribal statistical areas. Only the reservation boundaries (federal and state) are used in the

data for our reservation-level analysis is that we can compute the mean light density for all state and federal reservations in the United States, whereas GDP per capita data exists only for a sample of the reservations that meet certain reporting criteria. This expands our sample from 197 reservation-tribe observations to 313. All of our specifications that use the nighttime lights data control for the population of the territory using the Gridded Population of the World database from NASA's Socioeconomic Data and Applications Centre. The gridded population data is available at 5 year intervals from 2000-2015.[24]

D Pre-contact, Colonial Period, and Modern Control Variables

Formerly bison-dependent societies are not strictly comparable to non-bison-dependent societies, as the outcomes of the descendants of these societies and the governance structures on reservations may differ for other reasons. As such, in specifications that compare bison-dependent nations to non-bison-dependent nations, we control for pre-contact differences in geography and culture, their experiences with settlers, and other modern variables. For example, it is important to control for whether tribes experienced disproportionate levels of depopulation during first contact, war, treaty signing, forced co-existence on reservations, and relocation. We also want to control for economic activity of the reservations and surrounding areas, and access to other financial resources such as casinos.[25] We acquire economic information from Dippel (2014), as well as information on ruggedness, forced co-existence, displacement from traditional territory, and historic co-existence. We expand upon the pre-contact cultural measures used by Dippel (2014) from the Ethnographic Atlas Database of Murdock (1967) on the cultures of North America and include measures of calories from agriculture, calories from hunting, wealth distinctions, and the complexity of the location of each community. We add the average absolute mobility of counties within a 50 kilometre buffer surrounding each reservation using the absolute mobility index calculated in Chetty et al. (2014).[26]

We also control for treaty-making and violent encounters in war using information from

light analysis, as statistical areas can include non-Native cities.

[24]This data is available for download online from http://sedac.ciesin.columbia.edu/data/collection/gpw-v4

[25]Dippel (2014) acquires casino data from Taylor and Kalt (2005).

[26]Chetty et al. (2014) calculate two measures of intergenerational mobility. We use absolute upward mobility, which represents the expected income rank of children whose parents are at the 25th percentile of the national income distribution.

Spirling (2011). We match signatories of treaties using the location of treaty signing in relation to the traditional territories of nations in our data. Those nations involved in one of the 23 major "Indian Wars" from Spirling (2011) are matched by name in each data set. To account for the possible effects of differential depopulation from early exposure to European disease, we use gridded population data from the HYDE 3.1 database (Goldewijk, Beusen, and Janssen, 2010). We use the population size in 1600 for each ancestral territory as a control in the model.[27] One could imagine population to proxy for wealth, as in Acemoglu, Johnson, and Robinson (2001); however, we remain agnostic on its precise meaning, given that nomadic or semi-nomadic societies could hold large territories relative to their population as a sign of their wealth.

As controls for the timing of settlement, ease of access for settlers, exposure to disease, and pace and extent of economic development, we introduce a series of railway controls from Atack (2016). We overlay these railway mappings with historical tribal homelands and generate the date of railway operation in the tribal territory. There is a concern that since the railways are likely highly correlated with a loss of traditional resources, like the bison, we will absorb some variation in outcomes through this channel. However, since there are a number of contributing factors to the bison's decline–as discussed in the historical background–we do not expect the railway controls to absorb all of the effect of the rapid loss of the bison.[28]

One concern with comparing bison-dependent to non-bison-dependent nations is that there may be differences in the quality of reservation land allotted to each tribe that may have impacted their long-run development through their ability to cultivate the land. To address this concern, we construct indicators of soil quality for crop production on each reservation using data from the Harmonized World Soil Database v 1.2 (HWSD) from the Food and Agriculture Organization of the United Nations (Fischer, van Velthuizen, Shah, and Nachtergaele, 2008). The HWSD is a 30 arc-second raster database, containing soil quality along a number of di-

[27] The HYDE database uses a number of historical sources to compile comparable estimates of global population density at a 5 minute resolution, including Denevan (1992), Maddison (2001), Lahmeyer (2004), Livi-Bacci (2007), and McEvedy and Jones (1978). While it is likely that the HYDE database is measured with considerable noise, and especially so for Indigenous populations in the 17th and 18th centuries, it is arguably the most reliable source for population data that is both consistent over time and across regions.

[28] As alternative measures of timing and speed of European settlement and potential contact with disease, we calculate the state that overlaps with the majority of a tribe's ancestral territory and control for the date in which it was admitted to the union. We also compute the maximum population growth of each of these states prior to 1910. We do not present the results using these controls since they are similar to those that condition on our railway controls and we believe they account for the same variation in outcome variables.

Table 2: Summary Statistics: Dippel's (2014) Census Tract Sample by Tribe-Reservation in 2000 and Additional Colonial Variables

	Not Bison-Dependent	Bison-Dependent	Diff
Per Capita Income	10837.46	8629.64	2207.82
	(5120.06)	(4005.72)	
Nighttime Light Intensity	10.23	4.31	5.92
	(11.85)	(9.27)	
Percent Bison Coverage 1870	0.00	0.23	-0.23
	(0.00)	(0.38)	
# Cattle per sq km	7.39	12.56	-5.17
	(7.91)	(9.38)	
Nearby # Cattle per sq km	8.06	44.43	-36.36
	(8.93)	(213.45)	
Indian War	0.49	0.63	-0.14
	(0.50)	(0.49)	
Distance Displaced	11.74	11.97	-0.23
	(1.02)	(0.95)	
Historic Centralization	0.20	0.14	0.06
	(0.40)	(0.35)	
EA Calories Agriculture	1.59	2.61	-1.02
	(2.01)	(3.06)	
EA Sedentary	3.00	3.21	-0.21
	(1.65)	(2.13)	
Jurisdictional Hierarchy	2.75	2.31	0.45
	(0.43)	(0.46)	
Wealth Distinctions	1.32	1.03	0.29
	(0.76)	(0.17)	
Population in 1600	1947.04	1966.37	-19.32
	(3445.03)	(3244.10)	
Log Ruggedness	-1.28	-1.64	0.36
	(1.36)	(0.87)	
Forced Co-existence	0.66	0.65	0.01
	(0.47)	(0.48)	
Nearby Income Per Capita	18448.98	17438.36	1010.62
	(2939.09)	(2874.21)	
Observations	125	72	197

Notes: Means are reported with the standard deviations in parenthesis. Distance displaced is the distance in km from the centroid of a nation's traditional territory and the centroid of the current reservation. "Bison-Dependent" is 60 percent of a tribe's ancestral territory overlapping the historic bison range.

mensions and each pixel is coded on a scale from 1-7 regarding the suitability of the land for agriculture along the given dimension. This measure is categorical, with 1 representing "no or slight constraints", up to 7 representing "water bodies". We calculate the fraction of non-water pixels in each tribe's reservation that are classified as having "no or slight constraints" for 7 dominant soil quality measures: the nutrient availability of the soil, the nutrient retention capacity, rooting conditions, oxygen availability to roots, excess salts, toxicity, and workability of the soil. Table A16 provides a more detailed description of what each of the soil quality indices captures. We include these as controls in certain specifications.

Table 2 presents the summary statistics for the reservation/tribal sample taken from Dippel (2014) that we merge with data sources on historical bison-dependence, measures of the timing and the speed of settlement into traditional territories, and cultural controls. On average, bison-dependent nations earn about $2,200 less per capita in 2000, and their light density is 5.92 points lower than non-bison-dependent reservations. We also see that of the bison-dependent nations, only 23% of their traditional territories were covered by bison in 1870. Figure A5 shows the share of ancestral lands overlapping the original bison range and the bison range as of 1870 for this restricted sample. As of 1870, roughly 18 nations' ancestral territories were still covered by the bison range. The data in Table 2 show that bison-dependent nations were equally as likely as non-bison-dependent nations to engage in warfare, be displaced from their ancestral territories, be historically centralized, experience forced coexistence, be sedentary, be located in areas with similar levels of absolute mobility, have the same population density in 1600, and have similar levels of settler population growth; however, there are also notable differences. For example, bison-dependent nations are located in states that were admitted to the union later, they consume fewer calories from agriculture, have less wealth and political distinctions, are located on less rugged terrain, and are located next to slightly poorer counties.

III Methodology

Our empirical strategy uses two primary specifications depending on whether we are analyzing the immediate or long-term effects of the bison's decline. The structure of Boas' height data allows us to use a difference-in-differences estimation strategy based on a person's year of birth and the bison-dependence of their tribe, in order to identify the effect of loss of the bison on childhood and adult height. Let i denote the individual, N the Native nation, and H_{iN} the height of the individual in centimeters. Then our estimating equation for the immediate effects of the decline of the bison can be written as:

$$H_{iN} = \beta_0 + \beta_1 B_N + \beta_2 I_i(BornNoBison) + \beta_3 I_i(BornNoBison) \times B_N + A_i + \varepsilon_{iN}, \qquad (1)$$

where bison-dependence is given by B_N, one of our continuous measures of bison-dependence or loss, and $I_i(BornNoBison)$ is an indicator for the individual being born after the bison were eliminated. The coefficient of interest is β_3 which is the coefficient on the interaction of bison-dependence and the indicator for being born after the bison were eliminated. Each specification includes a full set of age fixed effects to control for trends in height, denoted by A_i. Standard errors are clustered at the tribal-age level. Our identification assumption is that the trends in the heights of bison-dependent nations would have been the same as the trends in the heights of non-bison-dependent nations, were it not for the loss of the bison. This is a plausible assumption, but we also run a more restrictive specification where we compare nations that lost the bison quickly (over a 10-20 year period) to those that lost the bison relatively slowly (over a hundred-year period). The average height in nations that lost the bison relatively slowly should not have changed sharply after the rapid loss of the bison even though they were subject to similar policies and had similar cultural backgrounds. In our most stringent specifications, we restrict the sample to those between the ages of 5 and 35.

We test for differences in pre-trends in height before 1870 and find that are no obvious differences in pre-1870 trends between the bison-dependent and non-bison-dependent nations. The F-statistic of a test of difference in trends has a value of 1.58 and p-value of 0.2129, suggesting, that statistically speaking, pre-existing differences in trends is not an overarching concern.

In our specifications that compare trends in the heights of those that lost the bison rapidly to those that lost the bison slowly, we use the date of 1886 as the cut-off for being born after the extinction of the bison. We use this year since the Sioux's last bison hunt was in 1882 and pemmican can last for nearly 3 years (Ostler, 2001). Varying this date slightly has no qualitative effect on the results. In our most stringent specifications, an F-statistic of a test of pre-bison-loss differences in height trends between those that lost the bison rapidly and those that lost the bison slowly is 0.03 with a p-value of 0.8673.

In order to determine how the loss of the bison affected income, occupational rank, and light density over the long run, we estimate both reservation-level and individual-level specifications. First, we use the 2000 American census data compiled by Dippel (2014), where we focus on either income per capita or mean light density as the outcome variable. All of these specifications are run at the reservation-tribe level. Note that this use of "reservation-tribe" as the unit of observation follows Dippel (2014), since tribal nations that may vary in historic bison-dependence may also share a reservation.

Second, we use individual-level data from the 1910, 1930, 1990 and 2000 American censuses that contain the most detailed tribal information. These specifications are run at the individual-level, with occupational rank as the outcome variable and we run separate regressions for each wave of data. In these specifications we collapse the tribal groups in 1910 and 1930 into the more coarsely measured tribal affiliations from the 1990 and 2000 American censuses, in order to use a comparable sample over time. Denote i as an individual or reservation-tribe, depending on the specification, and N as a nation, then the estimating equation is given as:

$$O_{iN} = \alpha_0 + \alpha_1 B_N + X_i \alpha_2 + Z_N \alpha_3 + \varepsilon_{iN}, \tag{2}$$

where O_{iN} is our outcome, either occupational rank, income, or log mean light density. We control for individual-level characteristics, X_i, such as age and current location of residence in the regressions using occupational rank, and reservation-level characteristics, such as the ruggedness of reservation terrain, surrounding counties' economic characteristics, in the regressions using income per capita. Cultural controls, such as whether the society was traditionally nomadic, the proportion of their calories derived from agriculture, whether the society exhibited observable wealth distinctions, or whether the society had an aristocracy, are included in Z_N and vary at the level of the tribe. Finally, Z_n also includes colonial controls–whether the average society experienced forced co-existence (Dippel, 2014), the speed and timing of settlement in a society's ancestral territories, and whether the nation was displaced from their traditional territory which are discussed in Section II–as they vary at the level of the tribe.

We examine the impact of the bison's decline in three ways in order to discern the possible impact of the bison in this context and the coefficient of interest is α_1. For these specifications, the measure of bison-dependence, B_N, is the share of tribal territory covered by the original bison range. The second comparison differentiates between tribes whose traditional territories experienced the rapid or gradual loss of the bison. For these specifications we include two measures of bison-dependence, either the share of tribal territory covered by the original bison range, in addition to the share of the tribal territory covered by the 1870 bison range, or the reduction in a nation's tribal territory bison-coverage as of 1870 and the reduction as of 1889. In our most stringent specification, we restrict the sample to those whose traditional territories overlap with the original range by more than 60% and compare how bison-dependent nations that lost the bison quickly fare compared to those that lost the bison gradually.[29] The causal interpretation of our results relies on the speed of loss being conditionally uncorrelated with other unobservable differences between these societies. It is important to note that in these geographical measures of bison-dependence, the timing of bison depletion is likely correlated

[29]Using the terms "rapidly" or "quickly" and "slowly" or "gradually" may be a slight misuse since given a time horizon of previous bison reliance of 10,000 years, both of the time horizons of bison-loss are short.

with bison density and thus with economic diversification of the Native nations.[30] This is much less of a problem for our alternative measures of bison-dependence discussion in II.

IV Results

Our results are divided into three subsections: the effects of the bison's decline on 19th century height data, the effects of the bison's decline on more modern measures using income and light density, and an analysis of the possible mechanisms through which historically bison-dependent peoples may still be adversely affected by the loss of the bison today.

A Immediate Effects

Table 3 presents the results of estimating equation 1. Columns (1)-(6) control for a linear trend in birth year to account for potential trends in heights over this time period. The first column shows that those nations that lost the bison gradually, as measured by a large value of "share lost as of 1870", were about 2 cm taller than all other Native nations, on average, but lost this height advantage after 1870.[31] In column (2), we restrict our specification to only include nations that had at least 60 percent of their original ancestral territory overlapping the 1730 bison range. This allows us to look within bison-dependent nations and compare those communities that were affected by the gradual decline to those who were affected by the rapid slaughter. On average, nations that lost the bison quickly were slightly taller than other bison-dependent peoples, but after 1886 *more than their entire height advantage* was eliminated, with declines in height of up to 5 cm.[32] These findings are consistent across specifications with additional controls, those that focus on individuals aged 5 to 35 years, and those focusing only on Native Americans in the United States.[33] The most dramatic estimates suggest that among those born

[30] For example, we would be considering bison in the woodlands and bison in the high plains as equivalent. However, bison herds in the woodlands were less dense and, given the relative scarcity of the woodlands bison, other game such as deer, or hare were often hunted.

[31] Recall that each of our bison-dependency measures are continuous variables $\in [0, 1]$, so that a one unit change in "share lost as of 1870", for example, can be thought of as moving from the scenario where there is no reduction in bison-coverage in a tribal territory by 1870 to that where the reduction in bison-coverage in a tribal territory is 100%.

[32] The exact coding of the Sioux and Ojibway sub-tribal groups turns out to be important for the precise magnitude of the reversal of fortunes when focusing solely on the former bison-dependent societies. We have taken the approach that uses an average of bison-dependency among the Sioux and Ojibway when the exact tribal grouping is ambiguous here, however, any reasonable coding of these groups yields the result that the loss of the bison at very least eliminated the height advantage of formerly bison-dependent peoples.

[33] Different age restrictions can be used with similar results.

Table 3: The Impact of the Loss of the Bison on Male Native American Height

	(1)	(2)	(3)	(4)	(5)	(6)
I(Born After 1870) X Shr lost as of 1870	-1.990			-1.496		
	(0.963)			(1.094)		
I(Born After 1886) X Shr lost as of 1889		-5.488	-9.764		-7.918	-6.470
		(2.333)	(3.604)		(2.329)	(3.747)
I(Born After 1870)	1.486			1.002		
	(0.780)			(0.862)		
Share lost as of 1870	2.025			1.387		
	(1.083)			(1.133)		
I(Born After 1886)		4.485	6.178		2.849	3.997
		(1.699)	(2.465)		(1.726)	(2.184)
Share lost as of 1889		1.717	1.662		1.262	0.870
		(0.774)	(0.763)		(1.102)	(1.091)
Year of Birth	-1.419	-1.708	-2.065	-1.388	-1.686	-2.041
	(0.338)	(0.031)	(0.049)	(0.333)	(0.047)	(0.062)
Year Sampled	1.168	1.311	1.479	1.213	1.565	1.741
	(0.353)	(0.222)	(0.292)	(0.369)	(0.202)	(0.254)
Full blood	-1.157	-1.208	-1.266	-0.878	-1.403	-1.368
	(0.363)	(0.463)	(0.454)	(0.403)	(0.559)	(0.561)
Canada	-0.867	0.885	0.794			
	(0.903)	(0.417)	(0.430)			
Years since rail				-0.0130	0.0200	0.0309
				(0.022)	(0.013)	(0.022)
Born after railway				1.314	-0.357	-0.725
				(0.696)	(0.719)	(0.818)
Years born after rail				-0.0376	-0.0529	-0.0622
				(0.028)	(0.027)	(0.034)
Observations	8821	3717	2626	7112	3175	2238
Adjusted R^2	0.875	0.859	0.865	0.871	0.854	0.864

Notes: Clustered standard errors at the tribe level in parentheses. There are 133 clusters at most and 48 clusters at least. The columns (2), (3), (5) and (6) are for only bison-dependent nations (i.e. only includes only those tribes whose traditional territories overlap with the historic bison range by at least 60%). Columns (3) and (6) restrict the age of the sample to be between 5 and 35 and the last three columns are for American tribes only.

into bison-dependent nations that lost the bison as part of the rapid slaughter, heights declined by 9 cm relative to those that lost the bison gradually.[34]

Komlos and Carlson (2014) note a decline in the height of Plains Indian scouts in the U.S. Army after the Civil War; however, they do not connect this to the loss of the bison, nor do they explicitly examine trends in heights by the age or bison-dependence of the individual. Our results present an explanation for their findings. It is important to note that it is unlikely that settlement on reservations are able to offer a reasonable alternative explanation for our findings for two reasons. First, there was a lack of a sharp change in reservation policy after this time

[34]Table A3 shows results when using our alternative measure of bison-dependence constructed from anthropological accounts. A similar pattern is observed and the results are of similar magnitude when we interact our anthropological measure with an indicator that tribal territories still had 80 percent of their territory covered by bison at the time of the slaughter. While the results are similar but more muted if we interact the anthropological measure with an indicator that 60 percent of territory was covered by bison immediately before the slaughter.

period. Second, Steckel (2010) shows that the number of years on a reservation if anything is positively correlated with height. That being said, there may be a concern that our results are driven by differential penetration of the railway and thus European settlement over this time period. Hence, in columns (3) to (6), we control for the number of years since the railway first entered an individual's tribal territory and whether an individual was born after the first railway entered their traditional territory. Although we see that for every year after someone was born after the introduction of the railway to their territory they are approximately 0.5 cm shorter, this does not significantly diminish the effect of the loss of the bison.

Given the suggestive results on the age distribution regarding higher levels of youth mortality, we examine whether there is further evidence of a population decline after the rapid extinction of the bison. Unfortunately, to the best of our knowledge complete population accounting of Native American nations was sparse at best before 1910. We compile the available statistics from the Historical Statistics of the United States on the population counts of American Indians by tribe (Carter, Gartner, Haines, Olmstead, Sutch, Wright, and Snipp, 2006).[35] There is a large gap in data availability between 1780 and 1907, with population counts from 1845 available only for a small selection of tribes, thus we focus on 65 tribes for which we have consistent data in 1780 and 1907. Nations that were bison-dependent had a population that was much larger than non-bison-dependent tribes in 1780, and we find that by 1907 their population size statistically converges to that of the non-bison-dependent tribes. Further, bison-dependent nations lost nearly 70 percent of their population over this period. The sample of tribes contained in the Historical Statistics does not allow us to compare the rapid loss of the bison to the gradual loss. While we view these statistics as substantially less clean than our results on height, they offer additional evidence in support of the finding that the loss of the bison had large effects on the people that depended on them. These results can be found in Table A4.

B Intermediate Effects

Next, given the limited scope for economic adjustment available to Native American communities, we examine whether the effects of the loss of the bison persist 20 years and 50 years after the slaughter. Standard indicators of well-being, like income per capita, are uncommon in the

[35]We use the tables Ag392-433, Ag265-330, Ag17-129, and Ag130-264.

early twentieth century, so we use information on occupational rank from the American Census in 1910 and 1930 to examine whether the loss of the bison is correlated with outcomes in the medium-run. Table 4 presents the results of our findings. In all specifications we include a set of nine regional fixed effects.[36]

Column (1) and column (2) present the results for the full sample in 1910 and 1930, respectively. In columns (3) and (4) we limit the sample to individuals who belong to tribes whose ancestral territory overlapped with the historic bison range by at least 60 percent. Focusing on within bison-dependent tribes allows us to hold constant unobservable factors that may differ between bison-dependent and non-bison-dependent tribes, without explicitly controlling for them in the model.[37] We find that the share of territory lost as of 1889 is highly correlated with occupational rank. The effect becomes larger when we restrict the sample to only those tribes who had at one point had some reliance on the bison, suggesting that 20 and 50 years after the bison's slaughter, Native Americans who had faced the most substantial economic shock had yet to recover.

C Modern Income and Nighttime Light Density On Reservations

Finally, we examine whether the bison's decline has led to long-run differences in well-being between bison-dependent and non-bison-dependent nations. Table 5 presents the average differences in per capita income on reservations based on bison-dependence and the speed of bison loss. In column (1), we look at the average difference in income per capita of moving from having the original share of the bison range not overlapping the tribes' ancestral territory, to overlapping it by 100%. This income difference is roughly \$2,500 compared to an average income per capita of only \$11,000. In columns (2), (3), and (4), we look at the correlation between losing 100% of the share pre-1870 or losing it post-1870 relative to never having been bison-dependent. Across these specifications, losing the bison as part of the slaughter is associated with a larger negative effect on income: nearly \$4,000 (or 38%) less is earned by those that lost the bison during the slaughter relative to a non-bison-dependent nation. The final column focuses within

[36]These results hold with a full set of state and place of birth fixed effects. The most substantial difference in the estimates with these more demanding fixed effects is in column (1) which is estimated with substantially more noise.

[37]The detailed controls we have for our reservation-level (long-run) results would be nearly co-linear with a tribal fixed effect in this data because of the limited number of tribes in the sample.

Table 4: Correlation between Standardized Occupational Rank and Tribe Historic Bison-Dependence in 1910 and 1930

	1910	1930	1910	1930
	Full Sample		Only Bison-dependent	
Share lost as of 1870	0.0431	0.126		
	(0.191)	(0.118)		
Share lost as of 1889	-0.582	-0.474	-0.604	-0.720
	(0.211)	(0.155)	(0.201)	(0.164)
Age	0.111	0.0726	0.100	0.100
	(0.026)	(0.031)	(0.046)	(0.052)
Age-Squared	-0.001	-0.001	-0.001	-0.001
	(0.000)	(0.000)	(0.001)	(0.001)
Constant	-2.234	-1.195	-1.825	-1.962
	(0.418)	(0.628)	(0.920)	(1.121)
Observations	463	620	225	296
Adjusted R^2	0.067	0.086	0.038	0.125

Notes: Clustered standard errors at the tribe level in parentheses. All columns include regional fixed effects (Census regions as defined by IPUMS: the New England Division, Middle Atlantic Division, East North Central Division, West North Central, South Atlantic Division Division, East South Central Division, West South Central Division, Mountain Division, and the Pacific Division). Occupational rank has been standardized to a mean of zero and a standard deviation of one. "Bison-dependent' is defined as at least 60 percent of a tribes' ancestral territory being covered by the original historic bison range.

bison-dependent nations and shows that those that lost the bison rapidly have roughly 30% less income in 2000 compared to those who lost the bison slowly. Strikingly similar results are shown for Canada in Table A6 where we condition on a number of controls that are similar to those used with the American data.[38]

In the descriptive statistics of Section D, we show that formerly bison-dependent nations are systematically different than non-bison-dependent nations, thus Table 6 reports the results of the exercise above for columns (4) and (5), but conditional on a set of cultural, geographic, colonial, and modern economic factors. Systematically, we find that formerly bison-dependent nations make less on average, even after conditioning on the income per capita of nearby counties. Those that lost the bison as part of the mass slaughter in 1870 (columns (4)-(6)) make less than those that had time to adjust to the bison's gradual elimination from their territory. The results become less precisely estimated in our most restrictive specifications, but the point estimate remains large and negative. We report the results of this exercise using the original bison share (as in column (1) of Table 5) in the appendix in column (1) of Table A5. We

[38]For the Canadian regressions we focus on the relationship between the share of traditional territory covered by the bison's original range and long-run outcomes. We do not find large differences between bison-dependent nations who lost the bison gradually compared to those that lost the bison quickly. Presumably this is because there is not sufficient variation between those that lost the bison slowly and those that lost the bison gradually, as evident in Figure 1. Table A18 reports the sources used to construct the Canadian data set.

Table 5: Correlation between the Share of Bison Covering Traditional Territory and Income Per Capita by Reservation in 2000

	(1)	(2)	(3)	(4)	(5)
Original Share	-2588.3				
	(823.913)				
Share lost as of 1870		-1632.6		-2015.0	
		(894.083)		(892.423)	
Share lost as of 1889			-3918.5	-4380.3	-2556.2
			(590.392)	(671.006)	(616.157)
Constant	11074.9	10553.0	10355.2	11038.3	9213.4
	(618.927)	(599.328)	(441.578)	(624.817)	(500.193)
Observations	197	197	197	197	72
Adjusted R^2	0.053	0.014	0.037	0.060	0.045

Notes: Clustered standard errors at the tribe level in parentheses. The last column only includes tribes for whom at least 60% of their original territory was covered by bison.

also display estimates of the effects of rapid bison loss using the anthropological accounts of bison-reliance, the presence of temperate grasslands, and modern cattle density of counties in a nation's traditional territory.

In Table 7, we perform a number of robustness exercises. First, we include regional fixed effects in all columns. Next, we consider the fact that the bison-dependent nations may have encountered a later and more rapid period of settlement than other Native Americans. This may influence modern development, either through later exposure to disease or through less time for economic assimilation. In the historical section, we argued that bison-dependent nations were likely first exposed to European diseases indirectly through trade, as early as many of the coastal nations, but we view the current exercise as relevant for alleviating any concern that this is not true. To account for the speed and timing of settlement, we condition on the presence and timing of the railway entering a nation's ancestral territory. The results of this exercise can be seen in the first column of Table 7. In column (2) we show that our results are robust to controlling for the date the last treaty was signed with each Native American nation. We use this information, which comes from Spirling (2011), as an additional proxy for settlement and federal policy towards Native Americans.[39] It is important to note that over two thirds of the lands ceded by both bison-dependent and non-bison-dependent peoples were done so prior to 1870, as shown in Table A1, which was before the bison were eliminated.[40] This suggests that

[39]Spirling (2011)shows that the time period in which treaties were signed is a strong predictor of treaty quality.

[40] These data were taken from digitized maps of the total lands ceded to the United States by Native Americans between 1784 and 1972 from Hilliard (1972). The original version of this map can be found in Figure A6.

Table 6: Correlation between the Speed of Bison Loss and Income Per Capita by Reservation in 2000

	(1)	(2)	(3)	(4)	(5)	(6)
Share lost as of 1870	-1449.3	-1863.2	-1721.3			
	(815.493)	(775.640)	(829.519)			
Share lost as of 1889	-4813.4	-3845.4	-3134.9	-2684.8	-1627.4	-1354.2
	(820.761)	(905.124)	(920.421)	(912.440)	(1120.595)	(928.096)
Historic Centralization	1969.6	3628.6	3516.5	664.9	2240.5	2124.0
	(1006.533)	(1013.379)	(956.761)	(640.271)	(1164.175)	(1053.450)
EA Calories Agriculture	-102.0	-167.8	-110.8	-308.4	133.8	194.1
	(296.148)	(198.276)	(184.399)	(345.249)	(424.263)	(421.256)
EA Sedentary	-166.6	-204.5	-298.7	613.5	-524.3	-717.7
	(310.750)	(308.386)	(290.931)	(488.434)	(690.147)	(687.466)
Jurisdictional Hierarchy	-107.0	-662.4	-504.0	-893.5	-1033.3	-1123.5
	(969.866)	(727.207)	(747.352)	(574.677)	(844.388)	(1067.697)
Wealth Distinctions	-313.5	585.1	455.6	2386.6	3952.5	4145.2
	(954.534)	(618.650)	(619.317)	(846.462)	(1312.723)	(1376.627)
Log Ruggedness	396.5	229.9	142.7	-376.6	-751.3	-597.9
	(395.714)	(304.299)	(306.944)	(588.526)	(600.748)	(501.940)
Population in 1600	0.0164	0.00976	0.0475	-0.0517	0.217	0.238
	(0.087)	(0.090)	(0.083)	(0.121)	(0.184)	(0.192)
Forced Co-existence		-5030.6	-4616.8		-7093.4	-6268.5
		(852.942)	(868.501)		(3639.297)	(3221.233)
Indian War		-969.8	-264.2		586.0	904.3
		(741.623)	(821.244)		(1424.492)	(1475.355)
Distance Displaced		710.2	546.4		867.1	854.5
		(328.398)	(294.814)		(996.512)	(882.388)
Nearby Income Per Cap.			0.340			0.380
			(0.129)			(0.238)
Observations	197	197	197	72	72	72
Adjusted R^2	0.058	0.279	0.308	-0.032	0.226	0.267

Notes: Clustered standard errors at the tribe level in parentheses. The last three columns only include tribes for whom at least 60% of their original territory was covered by bison.

the slaughter did not force the signing of treaties, a narrative that has been advanced by some scholars.

In column (3) of Table 7, we attempt to control for the early exposure to European trading using a proxy for the degree of involvement in the fur trade: the proportion of traditional territory that was covered by the historical range of the beaver.[41] Beaver pelts were lucrative commodities that were frequently traded between natives and Europeans and could have likely resulted in earlier initial contact. The beaver was also depleted, but it was not a traditional food source or primary resource for the communities that traded it (Carlos and Lewis, 1993; Innis, 1999).[42] Once again, conditioning on this measure has little impact on our results. Interestingly, the portion of territory covered by the beaver range is positively correlated with income today.

[41]We digitize a map of the traditional beaver range from the Canadian Geographic: `https://www.canadiangeographic.ca/article/rethinking-beaver`.

[42]Reliance on the beaver as a source of livelihood may be more of a concern for Indigenous groups in Canada, as declining fur prices towards the end of the nineteenth century affected the demand for treaties, as well as conditions for Indigenous peoples in the north of the country (Miller, 2009).

Table 7: Correlation between the Share of Bison Covering Traditional Territory and Income Per Capita by Reservation in 2000: Robustness Checks

	(1)	(2)	(3)	(4)	(5)
Share lost as of 1870	-2468.5	-2490.0	-3371.7	-2163.2	-2395.0
	(981.148)	(970.742)	(1059.954)	(1140.959)	(1100.153)
Share lost as of 1889	-4118.7	-4805.6	-5473.4	-3143.7	-2949.6
	(1689.165)	(1702.899)	(1783.954)	(1721.465)	(1736.317)
Cultural & Colonial Controls	X	X	X	X	X
Railway Indicators	X	X	X	X	X
Treaty Indicators		X	X	X	X
Beaver Share			X	X	X
Extended Modern Controls				X	X
Soil Quality Indicators					X
Observations	197	197	197	197	197
Adjusted R^2	0.314	0.309	0.312	0.409	0.419

Notes: Clustered standard errors at the tribe level in parentheses. All columns includes cultural region fixed effects which include: California, the Great Basin, the Northeast, the Northwest, the Plains, the Plateau, the Southeast and the Southwest. Railway indicators include dummy variables for never having a rail line in your territory, the first developed in 1840-1850, 1851-1860, 1861-1870, 1871-1880, 1881-1890, and after 1890. The treaty controls include dummy variables for signing post-1880, between 1861-1870, 1871-1880, 1881-1890, and after 1890. The omitted treaty category is 1870-1880, and omitted railway category is 1830-1840. The extended modern controls include log reservation kilometers squared, nearby gap per capita, nearby absolute mobility, log distance to nearest city, log population, presence of a casino, log of land ruggedness on each reservation, and the adult population share. Soil quality controls include share of reservation land without constraints from excess salts, nutrient availability, nutrient retention, rooting conditions, oxygen availability, toxicity, and workability. The cultural and colonial controls are the same as in 6. For all estimated coefficients, please see Table A7.

In column (4), we add our contemporary controls and the size of the reservation in 2000. This attempts to account for the fact that Native American lands were differentially allotted to settlers, with most losing a substantial share of their land base. Once again, our results are unchanged. In column (5), we control for differences in soil quality across reservations using the indicators we construct from the HWSD. We control for the degree to which excess salts, nutrient availability, nutrient retention capacity, rooting conditions, oxygen availability, soil toxicity, and soil workability may affect crop productivity on reservations. A higher value of any of these variables indicates better average soil quality along this dimension. While soil quality is likely endogenous to factors like irrigation, again, our findings still hold that bison-dependent nations who lost the bison rapidly have lower incomes than other nations. For all estimated coefficients, please see Table A7.

We complement the regressions of GDP per capita on bison-dependence by estimating the same specifications using the log of mean light density in each reservation as the dependent variable. First, we estimate these regressions for the sample of reservations from Dippel (2014);

these results can be found in the appendix. Figure A9 displays the coefficient estimates on "Share Lost as of 1870" and "Share Lost as of 1889" with log mean light density as the dependent variable. The left panel is analogous to column (4) from Table 5, where we do not include any controls (other than the population density of the territory) and the right panel is analogous to column (3) of Table 6, where we include the full set of controls and fixed effects. We estimate each regression separately for the years 1998-2013.[43] Without controlling for any factors other than population density, we find a negative relationship between both the gradual and rapid loss of the bison and modern light density. This effect is smaller when we add the full set of controls, but is nevertheless statistically significant for both coefficients in 12 out of the 16 years, and statistically different from zero for the rapid loss of the bison in every year.

Table 8 examines the effect of the bison's loss on log mean light density in the year 2013–the most recent year for which light data is available–for the expanded set of reservations.[44] It is analogous to Table 6. We exclude reservations that contain multiple tribes that cannot be clearly mapped to our controls, in particular, the Ethnographic Atlas. In each regression, we control for the reservation's population to account for the fact that reservations with a larger population might mechanically have a higher light density. We also include a dummy variable for whether the reservation was formed at the federal or state level. Column (1) shows this baseline regression with the cultural controls from the Ethnographic Atlas, the ruggedness of reservation terrain, and the pre-contact population estimate. Here, we compare both tribes that experienced the gradual elimination of the bison and those that experienced the rapid elimination of the bison to non-bison-dependent tribes. Those that lost 100% of their bison territory in the gradual decline have on average 76% lower light density today, while those that lost 100% of their bison territory in the rapid decline have approximately 137% lower light density today compared to non-bison-dependent tribes.

Columns (2) and (3) add controls for whether the tribe on the reservation was involved in an Indian War, the distance it was displaced from it's traditional territory, and the light

[43]This exercise also acts as a useful check on the potential error across satellites that measure the nighttime lights data (Chen and Nordhaus, 2011).

[44]Table A17 lists the additional sources we used in order to include the expanded set of covariates in our regressions. We do not include the measure of forced coexistence from (Dippel, 2014) in the full set of reservations; however, in Figure A9 in the appendix we show using the set of communities that match to the data from (Dippel, 2014) that our results do not change when we add the full set of controls from this dataset, including forced coexistence.

Table 8: Correlation between Share of Bison Territory Lost and Log Mean Light Density in 2013

	(1)	(2)	(3)	(4)	(5)	(6)
Share lost by 1870	-0.757	-0.610	-0.349			
	(0.208)	(0.235)	(0.216)			
Share lost by 1889	-1.371	-1.250	-0.727	-0.721	-0.774	-0.533
	(0.249)	(0.250)	(0.209)	(0.309)	(0.307)	(0.267)
Population in 2015	0.000101	0.000984	0.000748	-0.00292	-0.00245	-0.000603
	(0.005)	(0.005)	(0.004)	(0.008)	(0.008)	(0.008)
Federal Reserve	-0.508	-0.423	-0.207	-0.939	-0.966	-0.752
	(0.311)	(0.314)	(0.265)	(0.232)	(0.220)	(0.287)
Historic Centralization	-0.128	-0.122	-0.238	0.468	0.337	0.0845
	(0.160)	(0.183)	(0.128)	(0.279)	(0.306)	(0.292)
EA Calories Agriculture	0.0645	0.0435	-0.0224	0.243	0.195	0.151
	(0.054)	(0.051)	(0.051)	(0.110)	(0.134)	(0.143)
EA Sedentary	0.00917	-0.00434	0.0549	-0.145	-0.153	-0.198
	(0.049)	(0.054)	(0.039)	(0.113)	(0.119)	(0.117)
Jurisdictional Hierarchy	-0.142	-0.159	-0.181	-0.613	-0.604	-0.679
	(0.152)	(0.146)	(0.138)	(0.178)	(0.176)	(0.197)
Wealth Distinctions	-0.0466	-0.115	-0.0558	-0.344	-0.327	-0.212
	(0.108)	(0.108)	(0.083)	(0.195)	(0.182)	(0.158)
Log Ruggedness	-0.274	-0.311	-0.300	-0.199	-0.217	-0.0983
	(0.059)	(0.059)	(0.063)	(0.099)	(0.091)	(0.108)
Population in 1600	0.00834	0.0137	0.00509	0.0205	0.0268	0.0430
	(0.008)	(0.008)	(0.008)	(0.028)	(0.026)	(0.022)
Indian War		-0.302	0.0472		-0.203	-0.0413
		(0.161)	(0.118)		(0.228)	(0.228)
Distance Displaced		-0.00186	-0.00207		-0.00239	-0.00328
		(0.002)	(0.001)		(0.002)	(0.001)
Nearby Light Density			0.661			0.700
			(0.061)			(0.170)
Constant	3.979	4.427	2.886	4.778	5.328	4.020
	(0.604)	(0.661)	(0.607)	(0.831)	(0.869)	(1.046)
Observations	337	337	337	108	108	108
Adjusted R^2	0.156	0.167	0.370	0.232	0.230	0.385

Notes: Clustered standard errors at the tribe level in parentheses. The last three columns only include tribes for whom at least 60% of their original territory was covered by bison. Population related variables are measured in 1000s.

density of nearby regions. In each column, as we add more controls the coefficients on the share lost by 1870 and the share lost by 1889 reduce in magnitude slightly. In our most restrictive specification, our results suggest that reservations whose bison-dependent tribes experienced a gradual loss of the bison have approximately 35% lower light density today, while those that experienced a rapid loss of the bison have approximately 73% lower light density today. In columns (4) through (6) we restrict our sample to only tribes whose territory overlapped by at least 60% with the original bison range and we test whether the effect of the rapid decline of the bison is statistically significant. In our most restrictive specification, our findings suggest that within bison-dependent tribes, those who experienced the rapid slaughter have approximately 53% lower light density today, compared to those that lost the bison gradually.

Finally, we take advantage of data on news stories also collected by Dippel (2014) from 1991 to 2000 to examine how frequently a reservation name has been in the news for social conflict or corruption within the community. We find that nations that were reliant on the bison at the time of the slaughter have a higher incidence of social conflict and corruption, even after conditioning on pre-contact, colonial, and other economic controls. This is suggestive that loss of the bison may have had long run social consequences, other than the loss of income. These results are reported in Table A9.

D Mechanisms: Margins of Adjustment

In this section, we consider the mechanisms that might explain the persistently lower economic well-being of bison-dependent nations into the present. Our main objective is to determine the margins along which individuals and societies were able to adjust to the loss of the bison and along which margins they were not. In some ways, this question relates to asking whether the long-run effects of the loss of the bison are the result of an income shock that persisted due to imperfect intergenerational mobility, or if the effects are attributable to institutional idiosyncrasies that developed between bison-dependent and non-bison-dependent Native American nations. We investigate several channels through which bison-dependent individuals and societies may have been prevented from adjusting economically after the decline of the bison.

The income measures at the reservation-level are informative regarding the long-run correlation between bison-dependence and income per capita; however, we wish to understand how a shock in the late 19th century is still correlated with well-being over 100 years later. Our first exercise is to compile a consistent indicator of well-being over this time period. Given that income data is not available until the late 20th century at the reservation-level, we return to the occupational rank data from the American Census in 1910, 1930, 1990, 2000, and the 5-year average ACS in 2010.[45] We focus on within bison-dependent nations to compare those that lost the bison as part of the rapid slaughter to those that lost the bison gradually. Our objective is to check whether the effect of the slaughter has diminished over time and to investigate whether the effect of the bison's loss differs between those who live outside traditional homelands and those who live on traditional homelands.

[45] Occupational rank has been standardized to have a mean of zero and a variance one.

Table 9: Correlation between Standardized Occupational Rank and Tribe Historic Bison-Dependence for Bison-Dependent Native Americans

	1910	1930	1990	2000	2010
Share lost as of 1889	-0.604	-0.720	-0.167	-0.263	-0.122
	(0.201)	(0.164)	(0.079)	(0.073)	(0.065)
Age	0.100	0.100	0.0948	0.0710	0.0804
	(0.046)	(0.052)	(0.009)	(0.005)	(0.006)
Age-Squared	-0.001	-0.0001	-0.001	-0.001	-0.0001
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Constant	-1.825	-1.962	-1.326	-0.975	-1.120
	(0.920)	(1.121)	(0.144)	(0.170)	(0.136)
Observations	225	296	11123	9850	9251
Adjusted R^2	0.038	0.125	0.046	0.039	0.033

Notes: Clustered standard errors at the tribe level in parentheses. All columns include regional fixed effects (Census regions as defined by IPUMS: the New England Division, Middle Atlantic Division, East North Central Division, West North Central, South Atlantic Division Division, East South Central Division, West South Central Division, Mountain Division, and the Pacific Division). All specifications restrict the sample to tribes whose traditional territory was at least 60 percent overlapping with the bison range.

Table 9 presents the results of our findings regarding whether the effect of the slaughter has diminished over time. The first column reports the results for 1910 and the second for 1930, which repeat columns (3) and (4) from Table 4 for comparison. The last three columns present results for 1990, 2000 and 2010, respectively. All specifications include region fixed effects.[46] Individuals who were members of nations that still depended on the bison at the time of the slaughter have systematically lower occupational rank scores, with these effects economically larger in 1910 and 1930. Table A10 tests whether these differences are statistically significant. In general, the point estimates suggest that the slaughter of the bison diminishes over time.[47] The modest convergence in occupational rank is consistent with the narrative that the decline of the bison was akin to an income shock that persisted intergenerationally, since a shock of this nature should dissipate over time. However, the fact that we observe a strong correlation between income and bison-dependence for the reservation-level sample suggests that there may also be an institutional component to the persistence of the shock.

To examine whether the effect of the bison's decline is different for those living on Native homelands and those living outside of homelands, we use information available in the 2000

[46] All results are unchanged if we include place of birth fixed effects, state fixed effects, or both.

[47] While ethnic out-migration from the tribe after 1930 may be a plausible channel for the observed decline in persistence for those that live outside native reservations, there is no evidence that ethnic mobility is greater among previously bison-dependent nations. From the Historical Statistics from the United States used earlier, we can see that while it is not statistically significant, if anything the population size of the bison nations grew slight more between 1930 and 2000 than the non-bison nations. These results are available upon request.

Table 10: Correlation between Log Total Income and Tribe Historic Bison-Dependence: Individuals On and Off Homelands in the 2000 Census

	Pooled 1	Off Homelands	On Homelands	Pooled 2
Share lost as of 1889	-0.424	-0.347	-0.505	-0.352
	(0.117)	(0.140)	(0.198)	(0.139)
Homeland X Share lost as of 1889				-0.146
				(0.240)
Homeland				X
Age & Age-Squared	X	X	X	X
Region of residence fixed effects	X	X	X	X
State of birth fixed effects	X	X	X	X
Observations	19101	7407	11694	19101
Adjusted R^2	0.077	0.060	0.082	0.080

Notes: Clustered standard errors at the tribe level in parentheses. All columns include region and place of birth fixed effects. Results are statistically equivalent if state fixed effects are used instead of region fixed effects. Log real wages with a base year of 99 are the dependent variable. These only include tribes whose share of territory was at least 60 percent covered by the historic bison range as of 1730. The last column includes interaction of homeland with the other covariates in specifications 1 and 2.

Census and 2010 ACS 5 year sample, which report an individual's tribal association and whether they were living within native homelands.[48] Since the average income per capita is much lower on homelands than off homelands, using the level of income per capita could mechanically generate smaller coefficients on bison-dependence for the sample living on Native homelands. Thus to assess the relative differences in income per capita we regress the logarithm of individual total income on our measure of bison-dependence. Table 10 presents the results of this exercise. We see that the correlation between income and our measure of bison-dependence is significant, large, and negative in the full sample in column (1). By dividing the sample between those that live on Native homelands and those that live outside Native homelands, we see that the negative correlation between income and bison-dependence is qualitatively larger for those living on reservations in column (3). Column (4) presents the estimates from a pooled regression to test whether the difference between the on-reservation and off-reservation samples is statistically significant; although this coefficient is not statistically significant, it is negative which suggests that a substantial component of modern persistence is due to institutional or cultural structures

[48] According to IPUMS documentation, Native homelands can include federal American Indian reservations and off-reservation trust land areas, the tribal subdivisions that can divide these entities, state reservations, Alaska Native Regional Corporations, Hawaiian homelands, Alaska Native village statistical areas, Oklahoma tribal statistical areas, tribal designated statistical areas, and state designated American Indian statistical areas. Ideally we would compare the population living on American Indian reservations to those not living on Indian reservations; however, unfortunately, we cannot differentiate between any of these Native homelands and therefore can only split our sample between those living on homelands or off homelands.

Table 11: Correlation between Share of Bison Covering Traditional Territory and Income Per Capita Adjusted for Experience with Agriculture

	(1)	(2)	(3)
Share lost as of 1870	-3884.2	-2294.6	-1098.5
	(1494.426)	(1210.170)	(1217.349)
Share lost as of 1870 X AG Cal	941.4	26.41	-341.3
	(344.777)	(341.150)	(394.416)
Share lost as of 1889	-2998.7	-4370.0	-4866.3
	(1390.663)	(1499.165)	(1580.858)
Share lost as of 1889 X AG Cal	1490.4	2836.9	4290.2
	(922.949)	(1129.248)	(1345.322)
Cultural Controls	X	X	X
Soil Quality Controls	X	X	X
Colonial Controls		X	X
Contemporary Controls			X
Observations	197	197	197
Adjusted R^2	0.113	0.292	0.420

Notes: Clustered standard errors at the tribe level in parentheses. “Cultural controls” include calories from agriculture, historic centralization, measures of nomadism, jurisdictional hierarchy, wealth distinctions, log ruggedness and population in 1600. “Colonial controls” include being involved in an Indian war, a measure of forced co-existence, and distance displaced from traditional territory. “Contemporary controls” include nearby income per capita, log distance to the nearest city, presence of a casino. “Soil Quality controls” include share of reservation land without constraints from excess salts, nutrient availability, nutrient retention, rooting conditions, oxygen availability, toxicity, and workability.

on the reservations of the formerly bison-dependent nations. It should be noted that these specifications also include place of birth fixed effects in order to capture the initial conditions faced by individuals currently living outside native homelands and those living within.

We attempt to understand whether nations that had some additional ability to adjust to the loss of the bison have better outcomes today. Specifically, we hypothesize that bison-dependent communities that had more traditional experience with agriculture would be more likely to have their human capital maintain value, especially since the agriculture sector was promoted by the Bureau of Indian Affairs. Table 11 shows the results of interacting bison-dependency with a measure of tribal reliance on agriculture. This measure is an index of calories coming from agriculture that we take from Murdock’s Ethnographic Database. For those nations that lost the bison rapidly, a larger share of calories from agriculture mitigates up to 90% of the negative effect of the bison’s loss. These results suggest that bison-dependent tribes that had some degree of economic diversification prior to the bison’s elimination were partially able to mitigate the negative effects of the bison’s decline.

V Conclusion

At the beginning of the 19th century, the North American bison roamed the Great Plains in the tens of millions, but by 1880, the bison were nearly extinct from a mass slaughter that occurred within as little as 10 years. To our knowledge, we are the first to quantify the long-run effects of the slaughter on the Native Americans who relied on the bison for over 10,000 years prior to its extinction. We compile historical, anthropological, ecological, geographic, and modern economic data to show that the elimination of the bison affected the well-being of the Indigenous peoples who relied on them, both immediately after the bison's decline, and up to 130 years later. We argue that the loss of the bison resulted in a dramatic reversal of fortunes: historically, bison-reliant societies were among the richest in the world and now they are among the poorest.

Using a difference-in-differences estimation strategy and taking advantage of the fact that the speed of the destruction of the bison varied across traditional tribal territories due to an exogenous change in European tanning technology, we demonstrate that the previous height advantage of formerly bison-dependent peoples was completely eliminated within a generation. These effects are likely a lower bound on the effects on height since the demographic distribution of bison-dependent peoples after the decline of the bison is consistent with non-trivial increases in youth mortality.

After establishing that bison-dependent societies were adversely affected by the decline of the bison contemporaneously, we turn to the long-run effects of the elimination of the bison. We document a robust negative relationship between historic bison-dependency and income on American Indian reservations today using data from the Census Fact Finder compiled by Dippel (2014). In 2000, unconditionally, formerly bison-dependent nations had approximately 30% less income per capita today. Nations that lost the bison slowly had approximately 20% less income on average, whereas those that lost the bison rapidly had approximately 40% less income. Using nighttime light density as a proxy for economic activity leads to the same conclusion. This negative impact of rapid bison loss is robust to conditioning on a rich set of cultural, colonial, and modern economic factors. We show that this same pattern holds for bison-dependent Indigenous groups in Canada, as well.

Finally, we attempt to gain an understanding of why there has been such a persistence in the low standard of living of bison-dependent nations. We test whether the relatively lower incomes of bison-dependent nations today are isolated to reservations or if they hold for all members of nations that belong to historically bison-dependent tribes. The available data for this exercise is coarse, given the tribal affiliation data available in modern Census and American Community Survey data. Nevertheless, we demonstrate that incomes of members of historically bison-dependent tribes that lost the bison rapidly are lower today, even for those members who do not live on their traditional homelands. We integrate data from the 1910 and 1930 Census and demonstrate that nations that lost the bison rapidly compared to those that lost the bison slowly had significantly lower occupational rank; however, by the 1990s those nations that rapidly started to converge to the occupational rank of those that lost the bison slowly. This finding suggests that the rapid loss of the bison acted as an immediate shock to well-being and that this shock was transmitted intergenerationally. Similarly, we show that societies that had some level of economic diversification prior to the bison's extermination were substantially less adversely affected by its loss.

The long run effects of the loss of the bison may have been magnified by the policies and economic context that prevented bison-dependent nations from transferring their human capital to other sources, causing a social disruption that had implications for the governance structures in these communities. We are unable to fully account for how government policy amplifies or mitigates the loss of the bison after the initial extinction, but we suggest that the reservation system and government restrictions on the freedoms of Native Americans had consequences for how the loss of the bison resource played out. Finally, we recognize that we are only able to examine the effect of the bison's decline on a small number of measurable outcomes. The spiritual, cultural, and long-run health consequences of the loss of the bison are not addressed here and are meaningful in the broader narrative for Native American communities.

In September 2014, a cross-boarder treaty was signed by several formerly bison-reliant Native American nations to restore the bison to traditional Indian territory with the added goals of co-managing and preserving the animal (ICMN, 2014). Although the economic environments and institutional structures have changed significantly since the bison was first exterminated, the restoration of this symbolic icon has great political and cultural significance for formerly bison-dependent nations. It remains to be seen whether the re-introduction of the bison will reverse the negative economic effects that resulted from the bison's extermination, but we view this initiative as a significant step towards improving the standard of living of those who were once decimated by the bison's extinction.

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