Was Domar Right?
Serfdom and the Land-Labour Ratio in Bohemia

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Abstract

Are institutions shaped by factor endowments? Labour-coercion institutions such as serfdom, which profoundly restricted economic growth, were ascribed by Domar to high land-labour ratios. But historical evidence appeared to refute this hypothesis. We analyse the causal effect of the land-labour ratio on serfdom, using data for Bohemian serf villages in 1757. The net effect of higher land-labour ratios was indeed to increase labor coercion. The impact intensified when landlords extracted labour in human-animal teams, and diminished as land-labour ratios rose. We conclude that institutions are indeed partly shaped by economic fundamentals.

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1. Introduction

Are institutions shaped by factor endowments? Labour coercion institutions such as serfdom and slavery prevailed in many societies for centuries. But what caused such institutions to be stronger in some places and weaker in others? Serfdom existed in most European economies from c. 800 onwards, declining in some regions as early as 1300 but surviving in others into the 1860s. In many economies under serfdom, a large percentage of rural people were serfs who were compelled to do coerced labour for landlords and prevented from migrating to escape it. As late as 1750, the rural economy produced 50 to 80 percent of GDP, so where serfdom prevailed it affected the majority of economic activity. Labour coercion under serfdom reduced labour productivity, human capital investment, innovation, and living standards, so much so that its varying intensity is widely regarded as a major determinant of European economic performance between 1350 and 1864 (Broadberry and Gupta 2006; Klein 2014; Ogilvie 2014a, 2014b; Baten, Szołtysek, and Campestrini 2017; Markevich and Zhuravskaya 2018). What made this labour coercion system strong in some places and weak in others?

One well-known explanation is Domar's (1970) conjecture that coerced labour systems were stronger where the land-labour ratio was higher, provided that the political authorities in the economy acted in the interests of landowners. In economies where labour was scarce relative to land and hence there was little difference between the average and marginal product of labour, landowners would gain from restrictions on peasant mobility, since tying serfs to the land would prevent competition between landowners from driving wages up to the value of the marginal product of labour. In economies where the land-labour ratio was high, therefore, Domar expected serfdom or slavery to arise if the political authorities favoured landowners. If the land-labour ratio was very low, the value of the marginal product of labour would be close to subsistence, and landowners would have little

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or nothing to gain by introducing serfdom instead of a labour market in which peasants were free to move. Domar did not expect serfdom to occur in economies with low land-labour ratios, therefore, even if the political authorities acted in landowners' interests. A limitation of this analysis, as Domar recognised, was that the relationship between the land-labour ratio and serfdom depended on the behaviour of the political authorities, which he did not attempt to explain but took as exogenous. Despite this limitation, Domar thought that a positive correlation between the land-labour ratio and serfdom would be observed.

In practice, however, this correlation has not been observed. Historical studies of the relationship between serfdom and the land-labour ratio in different countries have failed to find any clear relationship. Whether serfdom weakened or intensified in particular countries appears to depend on country-specific variables, with a different explanation proposed for each society. However, although the absence of any definite relationship between serfdom and the land-labour ratio in cross-country comparisons shows that Domar was wrong to think that a positive correlation would typically be observed, it does not mean that his conjecture that the land-labour ratio influenced serfdom was wrong. Domar recognised that the relationship between serfdom and the land-labour ratio depended on political and institutional variables. Differences in these variables between countries obscure any effect of the land-labour ratio on serfdom, making it almost impossible to test the Domar conjecture using cross-country data.

A better way to test the Domar conjecture, therefore, is to hold political and institutional variables constant by analysing the relationship between serfdom and the land-labour ratio in a specific serf society. The specific serf economy we analyze is Bohemia, which is now part of the Czech Republic. The institutional characteristics of the serf economy make it possible to take variables as exogenous that would be endogenous in a modern

market economy, and this makes it possible to treat the land-labour ratio at the local level as exogenous in our econometric analysis.

Even in an economy where the political authorities act in the interests of landlords, the relationship between the local land-labour ratio and serfdom is theoretically ambiguous, as we show. Landlords typically used both coerced and hired labour, and an increase in the local land-labour ratio could affect the relative marginal profitability of both types of labour. Among other things, an increase in the local land-labour ratio is likely to increase the returns serfs receive from working on their own holdings, and thus to increase both the wage serfs require to supply hired labour and their incentives to evade coerced labour obligations, so that landlords have to incur greater monitoring costs. Thus the costs of both types of labour are likely to increase, making the effect on the relative marginal profitability theoretically ambiguous.

How the land-labour ratio influenced serfdom is therefore an empirical question. We find that in Bohemian villages where the land-labour ratio was higher, labour coercion was indeed higher, and thus that, when political institutions are held constant, Domar's conjecture is correct. The net effect was not huge, but nor was it trivial, and it was much larger when coerced labour is measured not just in terms of human time but in terms of total human and animal work energy extracted by landlords from serf households.

Our findings demonstrate that the land-labour ratio affected the intensity of serfdom as a labour-coercion institution. Even if political and institutional factors play a dominant role in explaining differences across countries, and without denying that many other variables affected landlord extraction from serfs, the land-labour ratio influenced serfdom as an institutional system. This in turn implies that institutions are influenced, at least to some degree, by economic fundamentals.

2. Serfdom and the Land-Labour Ratio

Why are labour-coercion institutions systematically stronger in some contexts and weaker in others? Domar (1970) argued that the key factor was the land-labour ratio. Where labour is scarce relative to land, the cost of labour in a non-coerced labour market will be high. The owners of land as employers therefore have strong incentives to extract large amounts of coerced labour to ensure that their land will be worked at low cost, and will seek to establish and maintain institutions enabling systematic labour coercion. Domar supported his conjecture using the examples of slavery in under-populated parts of the Americas and serfdom in lightly-settled parts of Europe, notably in the east. Serfdom intensified in seventeenth-century Russia, he hypothesized, because the Muscovite colonial conquests increased the area of land relative to the existing population, motivating landlords to extract coerced labour from scarce peasant workers. According to Domar, conditional on the political and institutional framework giving employers coercive power, slavery and serfdom were their responses to relative factor prices.

Domar's conjecture has been rejected by most economic historians. Postan (1937, 1966) argued that low land-labour ratios caused by population growth in twelfth- and thirteenth-century England intensified labour coercion by reducing outside options for serfs, while high land-labour ratios created by population losses during the Black Death (1348-9) conversely made labour coercion decline by offering serfs outside options in vacant rural farms and urban workshops. North and Thomas (1973) used this reasoning to explain the decline of coerced serf labour in western Europe more generally after the Black Death, while Małowist (1973) argued that high land-labour ratios caused by low population densities in thirteenth- and fourteenth-century eastern Europe induced landlords to make concessions to peasants and relax labour coercion.

Brenner (1976) went even further, completely dismissing all claims that the land-labour ratio affected serfdom. Neither increases nor decreases in labour scarcity could explain extraction of coerced labour from serfs, he argued, since the continent-wide increase in land-labour ratios after the Black Death saw serfdom declining in some societies but intensifying in others. Brenner argued that it was class struggle, not the land-labour ratio, that decided whether serfdom survived or disappeared.

Subsequent historical scholarship has also largely dismissed Domar's idea. The fact that coerced labour under serfdom responded in widely varying ways to the huge changes in the land-labour ratio after the Black Death suggested that country-specific variables were decisive – although there remained huge disagreement about which variables mattered, with a different story being told for each European society (Aston and Philpin 1988; Hatcher and Bailey 2001). In any case, the fact that similar changes in land-labour ratios affected serfdom in diametrically opposite ways in different societies seemed to imply that Domar's conjecture could be rejected.

Domar's conjecture, however, was that a higher land-labour ratio would increase labour coercion if the political and institutional framework tied peasants to the land (Domar 1970, 21). Thus his conjecture cannot be rejected by evidence that similar changes in land-labour ratios influenced serfdom differently in different societies, since this might be due to different societies having different institutions. Even in a society where the political and institutional framework allowed labour coercion, the land-labour ratio might affect labour coercion differently in different contexts, as the theoretical analysis of Acemoglu and Wolitzky (2011) shows. In their model, an increase in an economy's land-labour ratio has two distinct general equilibrium effects on labour coercion. One is to increase the price of the output produced by landlords, which induces more labour coercion as Domar conjectures.

The other is to increase the outside options available to serfs, which results in less labour coercion. Which of these effects dominates is an empirical question.

Acemoglu and Wolitzky thus offer a major advance over previous approaches to labour coercion by showing how a higher land-labour ratio can give rise to different outcomes even when the institutions favour landlords. But empirical testing of the Acemoglu-Wolitzky model is difficult. Cross-country analyses would have to obtain measures of the strength of the two different effects of the land-labour ratio on labour coercion, as well as of the institutional framework within which landlords operated. Data to carry out such cross-country analyses do not survive. For this reason we do not use the Acemoglu-Wolitzky framework as the basis of our empirical analysis.

Instead, we argue that the basic features of the serf economy in eighteenth-century Bohemia make it possible to analyse the relationship between coerced labour and the land-labour ratio at the level of the serf village. Doing so holds the institutional framework constant, while providing a large number of observations of labour coercion and land-labour ratios. The following section provides a detailed explanation of this argument.

3. Serfdom and the Economy in Bohemia

A serf economy is very different from a modern market economy. The land-labour ratio in a small local area of a market economy cannot be regarded as exogenous, because while land is typically an immobile factor of production, labour is not tied to specific locations and can move relatively freely, at least within an economy. But this was not the case in a serf economy. The whole point of the institutional framework of serfdom was to prevent factor markets from operating freely. Serfdom granted powers to landlords to intervene legitimately in markets for labour, land, capital, and output, precisely so as to facilitate extraction from serfs.

To test the Domar conjecture, we analyse labour coercion in eighteenth-century Bohemia (now part of the Czech Republic). In Bohemia, as in other European serf societies, the institutional entitlements of landlords prevented the endogenous adjustment of village-level land-labour ratios to changing circumstances. The powers of landlords in Bohemia were embedded in a wider institutional framework which also granted entitlements to serf communities, the state, and towns. This interlocking institutional system meant that land and labour markets in the Bohemian serf economy did not adjust to changes in scarcity, prices, or technology flexibly, in the sense of responding quickly to changes in economic circumstances. Instead, each landlord's estate, and each serf village within it, operated as a quasi-autarkic entity in which the quantity and price of factor inputs was determined by institutional features and market forces specific to that locality. Consequently, some variables inside serf villages were determined by market forces – e.g., the price and quantity of hired labour, which co-existed with coerced labour extracted by landlords. But many of the village-level variables that might be thought to be endogenous in a modern market economy – e.g., the size of farms and the number of households inside each serf village – can reasonably be regarded as exogenous, in the sense that they were unresponsive to economic signals in the short term and displayed striking continuities in the long term.

From the medieval period until the late eighteenth century, Bohemia resembled other European serf economies in being characterized both by landlord extraction of coerced labour and also by a range of other institutional constraints exercised by landlords, serf communities, the state, and towns. The institutional rules of serfdom combined with the institutional entitlements of each serf community meant that the labour supply in a village did not adjust quickly to changing economic circumstances. Although coerced labour and hired labour coexisted under serfdom, the size of farms and the number of households in each village were controlled vigilantly by both the landlord and the serf community with a view to

ensuring the maintenance of their respective entitlements. Village labour supply and farm sizes did sometimes change, but only occasionally, via a costly and cumbersome process of negotiation, lobbying, conflict, and institutional decision-making by the manorial administration and the serf commune. Institutional constraints on individual migration, combined with the institutionalized rigidity in the landholding system, meant that – as we shall see – the land-labour ratio varied considerably across villages in the same estate and also manifested long-term continuities within each village.

3.1. Landlords

In Bohemia, as in other European serf societies, rural people were obliged to deliver coerced labour along with other payments to their landlords in return for being allowed to occupy land (Graus 1957; Macek 1982). Bohemian landlords reserved a substantial share of land (20-25% in the early seventeenth century) as the manorial "demesne", which they directly exploited for their own profit (Ogilvie 2014a). The remaining land was occupied by serf tenants, who rendered money rents and coerced labour to landlords in return for occupying land. Landlords directly exploited their demesne land using a combination of coerced labour from serfs and paid labour from live-in servants and casual wage-labourers (Ogilvie 2001). Coerced labour extracted from serfs was unpaid but not completely free, since the landlord incurred monitoring costs, both to ensure that the serfs turned up to work at all and that they laboured acceptably once they were there. Consequently, landlords used coerced serf labour in unskilled and easily monitored tasks, alongside paid servants and labourers (often themselves local serfs) for tasks requiring greater care or skill (Klein 2014). Inside serf villages, therefore, both coerced labour and hired labour were employed by the landlord. Coerced labour obligations were inflexible and migration restrictions prevented

serfs from moving away from the village to escape them. But there was also a village-level market for hired labour in which prices did adjust flexibly.

The earliest documents recording landlord-serf relations in Bohemia show that labour coercion existed by 1350 at latest. Over the next half-century, Bohemian landlords increased the coerced labour they extracted from their serfs, and converted many sporadic labour dues into regular ones (Graus 1957). The 1435 victory of the Bohemian nobility in the Hussite Wars caused another upsurge in serf burdens, and between 1450 and 1500 the Bohemian crown and parliament passed laws entitling landlords to extract more coerced labour, restrict migration, and regulate serfs' economic and demographic choices (Graus 1957; Wright 1966; Macek 1982). By 1500, serfdom had declined in most of western Europe, but in Bohemia and most of eastern-central Europe, it survived and intensified in a development known as the "second serfdom" (Petráň 1964; Wright 1966; Klíma 1979; Maur 1983; Ogilvie 2001, 2005a, 2005b, 2005c; Klein 2014). After 1550, many Bohemian landlords expanded their demesne lands and set up textile manufactories, mines, ironworks, glassworks, breweries, distilleries, and fish farms, deriving an increasing share of their income from sales of manorial output, which gave them incentives to extract more coerced labour from their serfs to work these demesne enterprises (Ogilvie 2014a, 2014b; Klein 2014). Burdens on serfs intensified substantially during the Thirty Years War (1618-48), and by 1680 had become so onerous that there was a general serf uprising which landlords suppressed with state assistance. Despite periodic state legislation seeking to limit landlord extraction, Bohemian landlords succeeded in expanding labour coercion and other burdens on serfs in irregular episodes throughout the first three quarters of the eighteenth century. In 1781, Emperor Joseph II formally abolished serfdom, but Bohemian peasants continued to owe coerced labour to landlords until 1848. The expansion of labour coercion in Bohemia, as in other European serf economies, was not a continuous process but rather proceeded episodically as a result of

conflict and negotiation between landlords, serf communities, and the political authorities (Krofta 1919; Graus 1957; Petráň 1964; Wright 1966, 1975; Kočí 1972; Macek 1982; Mrvík 2016; Lhoták 2018).

Bohemian landlords were legally entitled to regulate their serfs' geographical mobility, and used this entitlement to prevent serfs from migrating to avoid coerced labour and other forms of extraction (Ogilvie 2001, 2005a, 2005b, 2005c; Klein 2014). Fewer than 0.5% of the Bohemian rural population were freemen, mainly privileged practitioners of skilled occupations (Klíma 1979, 53). Occupying a landholding on a particular landlord's estate involved accepting hereditary serf status to that landlord. Serf status meant that the entire family was subject to all the constraints of serfdom imposed by that landlord, including migration regulations. A serf who wanted to emigrate from his village was required to obtain the landlord's consent. This requirement applied even if he wanted to move to another settlement on the same estate, let alone to leave his landlord's estate altogether. A landlord could compel a serf to stay in a particular community or to move to another community owned by the landlord; a serf wishing to migrate had to get the consent of the landlord, which was contingent on the serf's departure not endangering the supply of coerced labour services from his community (Wright 1966; Ogilvie 2005a; Klein 2014). Even temporary labour migration required a serf to obtain manorial permission, pay a fee, provide a personal or monetary guarantee, find a replacement worker, or satisfy some combination of these conditions. Inside the estate, serf communities reported illegal emigration by their members to the landlord's office (or themselves punished it) because such emigration increased burdens for the remaining serfs. Between estates, the state obliged landlords to return and punish other landlords' serfs who had illegally emigrated. Serfs who migrated without permission were penalized – by money fines, imprisonment, coerced servanthood, or retribution against family members – as were fellow serfs who assisted them (Ogilvie 2005a).

Illegal migration was sufficiently costly and risky that serfs were willing to pay substantial

fees to obtain migration permits from their landlords. A serf who emigrated illicitly

confronted a non-trivial expectation of direct penalties inflicted by the landlord and his own

community, as well as the loss of property, inheritance rights, family ties, and social capital

(Klíma 1975; Maur 1983; Ogilvie 2005a, 2005b; Klein 2014). Empirical studies of such serf

migration as did take place in Bohemia show that it was restricted to individuals whose

migration was tolerated by landlords and communities: non-householders, land-poor serfs,

those who secured a replacement, and others whose departure would not reduce the capacity

of their village to deliver manorial obligations such as coerced labour (Petřáň 1964; Maur

1983; Štefanová 1999; Grulich 2005, 2013). These restrictions on serf migration meant the

labour force in each serf community did not adjust flexibly to economic signals, but rather

was determined by the institutional powers of the landlord and the serf community, which

were directed at maintaining the reliable delivery of coerced labour and other levies.

A Bohemian landlord held his land and serfs in a unit called an "estate" (*panství*,

Herrschaft). Bohemia contained 1,355 separate landlord estates in the great Theresian tax

register of 1757. An estate could contain just a single serf village or as many as 350. In 1757,

Bohemia had 11,873 serf villages on 1,355 landlord estates, so that the average estate

contained between 8 and 9 serf villages. As in other serf societies, in Bohemia each landlord

enjoyed far-reaching economic, regulatory and jurisdictional autonomy inside his estate

(Ogilvie 2005a; Dennison and Ogilvie 2007; Dennison 2011). Each estate was administered

differently, according to the preferences, resources, customs, and administrative traditions of

each generation of landlords, manorial officials, communal officials, and serfs (Weizsäcker

1913; Vacek 1916; Krofta 1919; Mika 1960; Hanzal 1964; Wright 1966, 1975; Barbarova

1969; Kočí 1972; Blodgett 1978; Winkelbauer 1993; Ogilvie 2005a, 2005c; Matlas 2011).

Some estates were subject to great nobles, others to medium-level lords, others to minor

knights and gentry, while still others were subject to the crown, the church, or a town. Some estates had elaborate bureaucratic structures, some had modest manorial offices, and others were administered personally by the lord himself. Some landlords were permanently absent in Prague or Vienna and merely spent the revenues delivered by their manorial administrators, while others resided on their estates. Estates also varied in the customary rights, privileges, and jurisdictions of the serf communities discussed below, although even within an estate each community had a different set of privileges and customs (Ogilvie 2005a, 2005b, 2005c; Matlas 2011). The jurisdictional and administrative autonomy of landlords combined with the migration restrictions of serfdom to sustain such differences across estates. This meant that each Bohemian estate differed from others in ways that cannot be observed. There were as many "second serfdoms" in Bohemia as there were landlords' estates.

A multilayered enforcement system enabled Bohemian landlords to extract coerced labour, regulate landholding, and prevent serfs from escaping coercion by migrating without permission to a different estate or to a different village inside the same estate. Each landlord operated a manorial office and manorial court with powers to regulate serf behavior, including delivery of coerced labour, compliance with migration restrictions, and obedience to manorial regulations concerning land transmission. Penalties included money fines, imprisonment, confiscation, forcible relocation, and corporal punishment. To ensure local compliance, landlords imposed a community responsibility system which imposed burdens such as coerced labour on the serf village as a whole and penalized the entire community for deviant behavior by individual serfs. Landlords also granted formal privileges and informal favours to community headmen and elders to give them incentives to collaborate with manorial extraction, including by organizing coerced labour services. Without doubt, serfs sometimes illicitly circumvented labour coercion, migration controls, and other manorial

restrictions. But micro-analysis of Bohemian estates and communities suggests that the enforcement system was effective enough to make such evasion by serfs extremely risky and costly, so that violations constituted isolated deviations rather than systematic non-performance (Svoboda 1969; Kočí 1972; Maur 1976; Winkelbauer 1992; Himl 2003; Ogilvie 2005a; Matlas 2011; Klein 2014; Seligová 2015).

3.2. Serf Villages

Serfs comprised over 99% of the Bohemian rural population (Klíma 1979, 53). Every Bohemian serf household was legally defined as holding the status of peasant (*sedlák, Bauer*), smallholder (*zahradník, Gärtner*), crofter (*chalupník, Chalupner*), or landless cottager (*chalupník, Häusler*). These legal categories reflected the size of a serf family's landholding and determined the coerced labour and other obligations it owed the landlord. The households that were defined as peasants owed the highest quantity of labour services and were required to supply animal as well as human labour. Those of smallholders, crofters and cottagers owed human labour services only, calibrated to the size of their landholding (Ogilvie 2005b).

Serfs lived in village communities, which operated as units not just of residential settlement, but also of communal self-government and manorial extraction. Each village (or group of hamlets) had its own communal administration, consisting of a headman and council of elders, whom the landlord made responsible for allocating coerced labour among serf households and organizing its delivery (Himl 2003; Ogilvie 2005a). Bohemia resembled other European serf societies in having some rural settlements in which lordship was fragmented, with different parts of the settlement being subject to different landlords and thus operating as distinct institutional entities. In 1757, about one-quarter of Bohemian rural settlements were characterized by fragmented lordship and thus consisted of multiple distinct

components, each of which was subject to a separate manorial office and was administered by its own headman and elders (see Table 2 below).

Serf villages had institutional characteristics which prevented land and labour markets from responding flexibly to changing circumstances. Most Bohemian villages had been established in the medieval period, although some were newly carved out of forest or waste land as late as the seventeenth century. At the establishment (or resettlement) of a village, it was issued with a foundation charter by its landlord in negotiation with the settlement entrepreneur (*Locator*) and the original group of peasants settling the village. This charter laid down the size and the number of landholdings of each legally defined stratum in the village: peasants, smallholders, crofters, and cottagers. Each landholding in a community was occupied by a single serf household, so the number of village holdings determined the total labour supply in the village. From the beginning, therefore, Bohemian villages varied widely in their land-labour ratios, reflecting local geographical and agronomic conditions, the number and characteristics of initial colonists, and other circumstances of the initial settlement process. The initial wide variation across serf villages in their land-labour ratios was rendered more persistent by the fact that basic village characteristics were specified in this foundation charter, creating institutional obstacles to subsequent changes. For reasons to be discussed shortly, subsequent manorial rent-rolls (*urbaře*) were based upon the original village charter: changes were costly, sporadic, and usually quite minor.

Village communities in Bohemia, as in many other serf societies, had a further institutional feature that prevented land and labour markets from responding flexibly. Serf holdings were legally impartible, and it was forbidden to divide, combine, add to, or subtract from any holding through inheritance, sale or purchase (Procházka 1963). The only land not affected by these impartibility restrictions were fragments of waste and fallow which were too few and small to exercise economically meaningful effects on total land supply. Both

landlords and serf communities opposed subdivision of holdings on the grounds that it would weaken the fiscal capacity of the holding and destabilize the system of manorial and communal extraction. Empirical studies confirm that these institutional restrictions were carefully enforced by both landlords and serf communities in normal times; subdivisions and mergers occurred only occasionally, as deliberate institutional decisions to deal with unforeseen emergencies such as wartime destruction (Procházka 1963; Ogilvie 2005a; Klein 2014; Klein and Ogilvie 2016).

In theory, it might seem to be in a landlord's interest to expand the labour supply in a village through subdividing holdings or permitting settlement of land-poor and landless groups. In practice, however, this occurred to a surprisingly limited extent. Sporadically over the centuries, a landlord might grant permission for a small number of new smallholdings or cottages to be set up on land carved out of forest or common land. This rarely involved any addition to the number of full peasant holdings, which typically comprised most of the land in the village and provided the bulk of the coerced labour, especially since only peasant holdings owed coerced labour from draft animals as well as humans. The number and size of full peasant holdings remained virtually unchanged in many villages across the centuries (Cerman 1996). The abolition of serfdom on Bohemian Crown estates in 1775 gave rise to an immediate upsurge in the number of rural households, a strong indication that the institutional framework of serfdom had hindered previous expansion (Wright 1966). The reasons underlying the infrequency and irregularity of changes to the number of landholdings and households in Bohemian serf villages have not been fully elucidated, but available studies suggest that several interlinked institutional features were responsible. Village charters and subsequent rent-rolls formally stated the privileges and obligations of both landlords and serfs, preventing both manor and commune from taking unilateral action. Changes had the potential to threaten the interests of both landlords and serf communities, for instance by

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reducing the fiscal viability of existing holdings, burdening common woods or pastures used by both landlord and serfs, increasing competition in rural non-agricultural activities, or disequilibrating other manorial and communal arrangements. In the face of such threats, either party could block change by appealing to prevailing customs and privileges. As a consequence, any such change required burdensome serf-landlord negotiations and high transaction costs. For these reasons, changes in the number, size, and manorial obligations of holdings in a community were discontinuous, reflecting episodes of conflict and institutional negotiation between specific landlords and that community. As a result, the land-labour ratio in a serf community did not respond flexibly to changing circumstances in the short term, instead displaying striking long-term continuities.

Taking a broader perspective, each Bohemian serf community operated according to a conglomerate of institutional rules and privileges laid down in its foundation charter, subsequent rent-rolls, edicts resolving conflicts, and both unwritten and written village customs. These institutional norms regulated the number and size of holdings, land transmission practices, manorial burdens, access to common resources, and communal self-administration. They thus strongly influenced how factor markets operated within that community. Each Bohemian serf community was thus distinct from every other serf community, and operated as a quasi-autarkic entity, in which economic, social and demographic choices were constrained by the institutional rules, privileges, burdens and customs of that specific community.

3.3. The State

State institutions also affected the operation of serfdom in Bohemia, as in other serf societies. Bohemia was an autonomous kingdom inside the Austrian Habsburg empire, governed via a state administration that was separate from that of other polities within the

Empire. Although the state had fiscal, military and regulatory interests distinct from those of the landlords, in pursuing these interests, it depended on cooperation from three bodies dominated by the landlords – the Bohemian Parliament, the seventeen Bohemian regional administrations (*kraje*, *Kreise*), and the manorial office of each landlord's estate. Royal power virtually stopped at the gates of the manor. Until the last two decades before the abolition of Bohemian serfdom in 1781, the Habsburg rulers had almost no power inside landlords' estates, merely requiring each estate to deliver an aggregate quantity of taxes and military recruits, which its landlord had sweeping discretion in allocating among his serfs; the landlord also paid separate taxes to the state. Although the state did not have identical interests to the landlords, it did have strong incentives to enforce the system of serfdom that underpinned the landlords' economic, coercive, and regulatory capacities (Grünberg 1893; Wright 1966; Maur 2006; Sander-Faes 2017, 2018).

For the Bohemian state, serfs were the major source of tax payments and army conscripts. This gave it two countervailing incentives vis-à-vis serfdom. On the one hand, fiscal interests motivated the state to compete with overlords for serf money and labour, and thus to moderate landlord extraction of coerced labour and other burdens on serfs. On the other hand, the costs of maintaining state officials on the ground created strong incentives for the state to devolve tax-collection and conscription to local personnel, which meant collaborating with the manorial administration and the whole regime of serfdom. This meant that when there was a serf revolt against landlord extraction, which occurred repeatedly from 1680 to 1775, the state provided military assistance to the landlords to put down the uprising while offering the serfs ineffectual mitigation of labour coercion and other burdens (Maur 1998; Petráň 1972).

The state played a central role in solving the free-rider problem among landlords (Ogilvie 2014a). Labour scarcity created incentives for landlords to compete with one another

for serf labour. In serf societies, including Bohemia, landlords responded to labour scarcity by using mobility restrictions to prevent serfs from voting with their feet to migrate to better conditions and by cooperating with other lords to send fugitives back. Like any cartellistic arrangement, this was threatened by free-rider problems: lords collectively benefited from other lords' compliance but individually profited by violating the arrangement. In Bohemia, as in other serf societies, rulers offered themselves as a sort of referee, creating a formal legislative framework that enabled lords to commit themselves collectively not to compete for serfs.

3.4. Towns

Like most serf societies, Bohemia had an economy that was primarily agricultural, with a much smaller industrial and commercial sector than western European economies at the same date (Klein and Ogilvie 2016). Urbanization rates were low, with 3-4% of the Bohemian population living in towns over 5,000 inhabitants in 1750-1800, compared to 17-19% on average in Western Europe (Malanima 2011; Klein and Ogilvie 2017). The tiny Bohemian urban sector consisted of three main types of urban settlement: royal towns, seigneurial full towns, and seigneurial agro-towns. Tables A1 and A2 in the Appendix report detailed information about urban settlements in eighteenth-century Bohemia.

Royal towns were self-governing entities independent of the estate of any lord and subject directly to the ruler. Their inhabitants were not subject to serfdom and sometimes the town itself was the landlord over serfs in surrounding villages. The capacity of royal towns to offer outside options to serfs declined after 1547, when their number, size, and political power was reduced (Míka 1978). Furthermore, royal towns lay outside the feudal estates on which serfs lived, so a serf had to get his landlord's permission or incur risks and penalties to use their markets (Maur 1983; Ogilvie 2005a). In the mid-eighteenth century, Bohemia had

43 royal towns, with an average size of just 291 households (about 1,300 inhabitants). The only large town in Bohemia was Prague, which had c. 60,000 inhabitants around 1750 and was thus an order of magnitude larger than any other royal town; as the royal capital city, it also had a special legal and institutional status. The next largest Bohemian town was Cheb/Eger with 7,000-8,000 inhabitants, while no other town had even 5,000 inhabitants (Míka 1978; De Vries 1984).

Seigneurial towns, by contrast, were located on lords' estates and were subject to landlords' administration and jurisdiction (Dědková 1978; Maur 2002; Hoffmann 2009; Česáková 2013; Dvořák 2013). Consequently their inhabitants were subject to many of the constraints of serfdom including migration controls and some coerced labour obligations. The seigneurial towns were smaller on average than the royal towns, but outnumbered them greatly, accounting for a large majority (79%) of the urban population of Bohemia in 1757.

Seigneurial towns were distinguished into two types with differing designations: full town (*město*) and agro-town (*městys*). A comprehensive analysis of the institutional and economic differences between full and agro-towns is still lacking. However, analysis of the 1757 Theresian tax cadaster reveals some clear differences. The full towns were on average two to three times as large as the agro-towns, with 158 compared to 60 households, i.e., about 710 compared to 270 inhabitants. The full towns also differed from the agro-towns in having a much lower share of inhabitants with enough land to live wholly from farming (18% compared to 33%). However, there were only half as many full towns as agro-towns (168 compared to 328 in 1757). Serf access to towns was thus very limited. Of the total serf population in 1757, 43% lived on estates with no town, 26% lived on estates with only an agro-town, while less than one-third (31%) lived on estates with a full town.

Towns offered options outside agriculture to both serfs and landlords. They provided opportunities to serfs as markets for labour (serfs could commute to work in nearby towns as

long as they continued to dwell and deliver coerced labour in their villages), farm output (especially foodstuffs), other primary products (e.g. timber), and cottage manufactures (e.g. yarn, linen). Towns also offered opportunities to landlords as markets for output from demesne farms, breweries, distilleries, fishponds, mines, glassworks, and textile manufactories. However, the degree to which Bohemian towns could provide outside opportunities to either serfs or landlords was limited by their small size and quasi-agricultural economies. Moreover, urban opportunities for serfs were limited by urban institutional privileges enabling townsmen to restrict rural competition in their own interests (Ogilvie 2001). Most towns in mid-eighteenth-century Bohemia were thus of minor economic importance to the serf economy. Far from acting as centres of economic dynamism, they were merely settlements which had succeeded in obtaining urban privileges that were used to benefit town burghers, often by imposing costs on other parts of the economy (Maur 2002; Miller 2007; Hoffmann 2009; Dvořák 2013).

The institutional characteristics of the Bohemian serf economy discussed in this section mean that we can reasonably test the Domar conjecture by analyzing cross-village variation in coerced labour and the land-labour ratio. The institutional rules of serfdom prevented labour supply from responding flexibly to economic signals in the short term. On the local level, the quantity and price of factor inputs were determined by institutional features and market forces specific to each serf village, which therefore operated as a quasi-autarkic entity.

4. Theoretical Framework

The previous section showed that villages in Bohemia typically had land-labour ratios that were exogenously given. The number of serf households in a village was fixed, and it was very difficult for serfs to move away from their village, although they could commute to

nearby towns and villages to work, provided that they delivered their coerced labour obligations. Landlords produced various goods using both coerced and hired labour. How would landlord use of coerced labour be expected to differ in villages with differing land-labour ratios?

In the Appendix we develop a simple theoretical model to address this question. It assumes that landlords produce output using both coerced and hired labour. The cost of using coerced labour is the cost of monitoring it to ensure that serfs turn up to perform their obligations and then carry them out acceptably without shirking. The cost of hired labour is the wage that the landlord has to pay. As the largest single employer, the landlord may have monopsony power in the village labour market, so the wage paid may depend on the amount of labour hired. Both the cost of coerced labour and the wage of hired labour may depend on the village land-labour ratio. A higher land-labour ratio in a village means that the marginal productivity of serf labour on serf landholdings is likely to be higher. The consequent greater return to their labour on their own holdings is likely to increase serfs' incentives to avoid coerced labour, thus raising monitoring costs for the landlord, and also to increase the wage serfs require to supply a given amount of hired labour to the landlord.

A profit-maximising landlord chooses the amounts of coerced and hired labour he employs so that the marginal cost of each type of labour equals its marginal revenue product. The marginal revenue product of each type of labour may also depend on the village land-labour ratio. A higher land-labour ratio means that serfs have higher returns from working on their landholdings, which is likely to alter their demand for goods, and thus alter the marginal revenue products of both coerced and hired labour used by the landlord.

The effect of a marginal increase in the village land-labour ratio on the landlord's use of coerced labour depends on how this change affects the marginal profitability of using the amounts of coerced and hired labour that maximised profit before the increase in the land-

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labour ratio. Before the land-labour ratio increases, these amounts are such that the marginal revenue product of each type of labour equals its marginal cost, so that its marginal profitability is zero. An increase in the village land-labour ratio is likely to affect both the marginal revenue product of the initially profit-maximising amount of coerced labour and also its marginal cost, for the reasons noted above. There is no reason in general for these to changes to be equal, so the marginal profitability of the initial amount of coerced labour is likely to be non-zero after the change in the land-labour ratio. The same is true of the marginal profitability of the initial amount of hired labour. We show in the Appendix that, when there is a marginal increase in the village land-labour ratio, the landlord's use of coerced labour will increase, remain constant, or decrease according to whether the change in the marginal profitability of the initially profit-maximising amount of hired labour is less than, equal to, or greater than the change in the marginal profitability of the initially profit-maximising amount of coerced labour multiplied by a positive term. Hence if the change in the marginal profitability of hired labour is negative and the change in the marginal profitability of coerced labour is positive, the landlord's use of coerced labour will increase. Conversely, if the signs of these changes in the marginal profitability of the two types of labour are reversed, the use of coerced labour will decrease. If the changes in the marginal profitability of the two types of labour have the same sign, then whether coerced labour increases or decreases depends on the precise values of these changes in marginal profitability, as well as that of the positive term which multiplies the change in the marginal profitability of coerced labour.

For these reasons, the effect of a change in the land-labour ratio in a village on coerced labour in a village is an empirical question. We address this question by analysing the relationship between land-labour ratios and coerced labour in Bohemian villages in the mid-eighteenth century.

5. Data Description

The main source of the data we use to analyze Bohemian serfdom is a comprehensive tax register known as the Theresian Cadaster (*Tereziánský katastr*) which records all villages and towns in the country in 1757. We supplement this with information recorded in a comprehensive tax register called the Berní Rula, drawn up in 1654 (see Pekař 1913; Berní Rula 1, 1950).

The Theresian Cadaster was meticulously drawn up over a period of years, during which data were collected, checked, and corrected in four stages (Pekař 1913; Hradecký 1956; Chalupa et al. 1964-70; Lhoták 2018). In the first stage, the state authorities required each landlord to provide a report on each householder in each village on his estate; reports were certified by communal officials from serf villages and manorial administrators from neighbouring estates. In the second stage, the landlord reports delivered in the first stage were checked by a state commission that visited each village. Finally, in the third and fourth stages, the emended reports were reviewed by a central commission and corrected on the basis of further local information; comparisons of the second and third stage shows that substantial corrections were introduced, especially in the measures of the land area in each estate (Lhoták 2018). The results of these four stages of reporting, recording, checking, and correcting were published in 1757 as the so-called "final version" (*konečný elaborát*) of the Theresian Cadaster, from which we draw our data. Landlords had incentives to make sure that the information on coerced labour obligations they reported to the cadaster commission was correct: they had no incentive to exaggerate its quantity as that would lead the crown to over-estimate their fiscal capacity; they were hindered from under-reporting by its being checked and certified by outside agents who had incentives that were countervailing (in the case of serf communes) or independent (in the case of outside manorial officials).

The Theresian Cadaster recorded serfs' coerced labour obligations at the level of the village, our unit of analysis. The cadaster recorded a total of 11,873 villages. Landlords were instructed to report coerced labour obligations (*robota*) for all villages, but for unrecorded reasons 321 villages (2.7 percent) were listed without this information. These missing values cannot be interpreted as zeros since, as Table 1 shows, the cadaster explicitly recorded many villages as having zero coerced labour obligations. Villages with missing values for coerced labour obligations therefore had to be dropped from our analysis. Information on other important variables (land area, number of households, geographical location) was inadequately recorded for another 216 villages, which had therefore also to be excluded from analysis. This left us with a data set of 11,336 serf villages, comprising more than 95 percent of all villages in Bohemia in 1757.

In previous work (Klein and Ogilvie 2016), we collected data from the Berní Rula for 7,257 villages. Using this sample, it proved possible (despite changes in village names) to match 5,199 villages in 1654 with their counterparts in the 1757 Theresian Cadaster. For 46 percent of the full sample of 11,336 villages in 1757, we therefore had data on some of their characteristics in 1654.

Tables 1 and 2 show descriptive characteristics of the full data set of 11,336 villages, the matched subsample of 5,199 villages, and the unmatched subsample of 6,137 villages for which 1654 data were not available. There are some differences between the matched and the unmatched subsamples in 1757. In the full sample of 11,336 villages, a large majority (84 percent) were ones in which the inhabitants owed coerced labour obligations to the landlord. The proportion of villages with such obligations differed between the matched subsample of 5,199 villages (89 percent) and the unmatched subsample of 6,137 villages (80 percent). The inhabitants of the villages that were not obliged to perform coerced labour were still subject to many other constraints of serfdom, however, including migration controls, regulation of

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Table 1:
Characteristics of Villages, Bohemia 1757

Characteristic of Village	Full Sample		Matched Sample		Unmatched Sample	
	No.	%	No.	%	No.	%
Coerced labor obligations are recorded	11,336	100.0	5,199	100.0	6,137	100.0
Has coerced labor obligations that are:						
Zero	1,835	16.2	582	11.2	1,253	20.4
Non-zero	9,501	83.8	4,617	88.8	4,884	79.6
Located in a settlement subject to:						
Unitary lordship	8,555	75.5	4,350	83.7	4,205	68.5
Fragmented lordship	2,781	24.5	849	16.3	1,932	31.5

Note: Matched sample = the 5,199 villages in the 1757 Tereziánský katastr for which data from the 1654 Berní Rula were available; unmatched sample = the 6,137 villages in 1757 for which data in 1654 were not available.

Source: Tereziánský katastr 1757.

land transfers, "forced wage labour" (at capped wages), years of compulsory servanthood for offspring of dead serfs, and numerous other economic and demographic restrictions (Ogilvie 2001, 2005a, 2005b; Klein 2014).

Our focus is not on the total value of serf obligations to lords, but rather the existence and magnitude of the extraction of coerced labour specifically. Other burdens on peasants (in cash, kind, coerced purchases, and other forms of market distortion) existed in all pre-modern agrarian systems, but the distinctive characteristic of serfdom was that it involved the possibility of extracting obligations in the form of coerced labour. There are reasons to believe that coerced labour has distinctive and profoundly negative effects on economic growth and development, which is why understanding its causes is so important. Our focus in this paper is therefore on the determinants of coerced labour obligations.

Our first step was to record whether a village had any labour coercion and to measure the quantity of coerced labour extracted. The 1757 cadaster recorded, for each village, the number of serf households required to provide coerced labour, the number of days they had to

do it, and the number and type of draft animals they had to provide alongside human workers. Coerced labour obligations were sometimes recorded for the entire village, sometimes separately for each social stratum, sometimes for distinct geographical sections of the village, sometimes by the year instead of by the week, sometimes for several villages together (fortunately in just 2.5 percent of cases), and many other variants corresponding to local practice.[1] Some serfs owed just human labour but many were required to supply work teams combining human labour with a specified amount and type of animal labour. We reduced these complexities to two measures of coerced labour. The first focused solely on human time, and comprised the total number of days of labour by human beings which the village was obliged to provide to its landlord each week. The second focused on the total work energy extracted from serf households: animal energy was converted to a numeraire (as explained in the Appendix) and combined with human labour to yield the total number of "serf-equivalent" days the village had to provide each week. As Table 2 shows, in 1757 the average Bohemian village in the full sample owed its landlord 27 days of human-only labour in each week, but 321 "serf-equivalent" days of human plus animal labour. Again there were differences between the matched and unmatched subsamples: the former had larger mean values for both human and human-animal labour than the latter.

The 1757 cadaster also enabled us to calculate the land-labour ratio in each village. For the denominator, we used the number of householders in the village. The most comprehensive information on Bohemian historical demography, derived from a national religious census in 1651 (*Soupis poddaných podle viry*), yields a mean household size of approximately 4.5 persons; such statistics are not available for the eighteenth century, but there is no evidence that mean household size varied systematically across regions, villages,

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[1] Where the cadaster reported the total number of serfs and the number of days of forced labour for two or more villages together, we distributed the number of serfs and the number of days worked proportionately across the villages.

Table 2:
Summary Statistics for Full Sample, the Matched Sample, and the Unmatched Sample, Bohemia 1757

Variable	Full Sample (n=11,336)				Matched Sample (n=5,199)				Unmatched Sample (n=6,137)			
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
Coerced labor (human-only)	27.44	20.38	0.00	792.00	31.13	24.50	0.00	792.00	24.31	29.42	0.00	404.71
Coerced labor (human-animal)	321.38	213.00	0.00	6,149.96	367.43	264.24	0.00	5,629.50	282.38	366.61	0.00	6,149.96
Land-labor ratio (basic)	29.50	24.88	0.00	989.00	28.96	25.01	0.00	618.25	29.96	28.40	0.00	989.00
Land-labor ratio (maximal)	35.38	30.26	0.00	1003.00	33.94	30.10	0.00	584.75	36.60	32.42	0.00	1,003.00
Village size	13.47	10.00	1.00	407.00	14.46	11.00	1.00	168.00	12.63	14.83	1.00	407.00
Urban potential - full, inside	13.81	0.00	0.00	535.00	13.00	0.00	0.00	535.00	14.51	47.16	0.00	535.00
Urban potential - agro, inside	8.87	0.00	0.00	255.62	9.09	0.00	0.00	140.89	8.69	20.21	0.00	255.62
Urban potential - full, outside	325.32	315.17	132.56	875.43	326.23	314.57	196.81	851.08	324.55	63.69	132.56	875.43
Urban potential - agro, outside	254.79	257.64	89.90	644.41	260.82	261.41	143.23	476.61	249.69	46.85	89.90	644.41
Urban potential - royal	169.74	153.55	57.15	854.13	169.02	151.98	84.45	755.03	170.35	89.41	57.15	854.13
Urban potential - Prague	62.14	41.46	14.96	923.13	63.16	42.29	22.74	923.13	61.28	39.76	14.96	923.13
Longitude	14.45	14.45	12.22	17.69	14.44	14.47	12.41	16.58	14.45	0.95	12.22	17.69
Latitude	49.88	49.91	48.61	51.04	49.92	49.87	48.88	51.01	49.85	0.59	48.61	51.04
Fragmented lordship dummy	0.25	0.43	0.00	1.00	0.16	0.37	0.00	1.00	0.31	0.46	0.00	1.00

Notes: Coerced labor obligations are measured as "serf-equivalent" days per week. Land-labor ratios are measured as strych per household
(1 *strych* =0.29 hectares); 15 *strych* was minimum required for household of 4.5 persons to survive wholly from agriculture. "Basic" land-labor ratio includes
arable land only; "maximal" land-labor ratio includes arable, pastoral, meadow, and forest. Urban potential is measured separately for full towns inside
the same estate as a village, agro-towns inside that estate, full towns outside that estate, agro-towns outside that estate, and royal/free towns which are not
inside any estate. For further detail on variable definitions, see text.
Source: Tereziánský katastr 1757.

or social strata in early modern Bohemia (Horská 1994; Horský and Maur 1994; Cerman 1994; Seligová 1996; Cerman and Štefanová 2002; Grulich 2002; Matušíková 2002; Pazderová 2002; Velková 2002; Zeitlhofer 2002). This justifies treating the number of households in a Bohemian village in 1757 as the best proxy measure of its total labour supply.[2]

To calculate the numerator of the land-labour ratio, we used the quantity of land in the village. The 1757 cadaster records the area of arable (crop-bearing) land, pasture, meadow, and forest, all measured in *strych* (a unit equivalent to 0.29 hectares). This yielded the two alternative measures of the land-labour ratio shown in Table 2. For the full sample, the mean value of the basic (arable-only) land-labour ratio was 29.5 *strych* per household, while that of the maximal one (including arable, pastoral, meadow, and forest) was 35.4. The mean values of the basic land-labour ratio for the matched and unmatched subsamples were very similar, but the mean maximal land-labour ratio was somewhat larger in the unmatched than in the matched subsample. We were only able to obtain data for the amount of arable land in each village in 1654. For this reason, we focus on the basic (arable-only) measure of the land-labour ratio in 1757. However, we also investigated the maximal land-labour ratio in 1757 on the grounds that it reflected all the land from which serfs in that village had to support themselves as well as to pay off the state and the landlord, and thus may better measure the influence on local factor prices. Both measures of the land-labour ratio yield virtually identical results, as we show in the Appendix.

Towns are regarded as having weakened serfdom in western Europe by providing serfs with outside options (Postan 1937, 1966; Blum 1971; Acemoglu & Wolitzky 2011). To explore whether there is any evidence of towns doing this in Bohemia, we compiled

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[2] This measure of the total labour supply in the village can be converted to the same units as the measure of coerced human labour in the village (days of coerced serf labour delivered to the landlord per week), by multiplying it by 4.5 (the mean number of persons per household) and then by 5 (the approximate number of working days per week).

information on the urban sector in 1757. Bohemian towns varied along two dimensions: migration restrictions, which made towns on the home estate more accessible to serfs than towns outside the estate; and institutional type (discussed in Section 3), in which royal towns, full towns, and agro-towns differed in size and occupational structure. We calculated urban potential by assigning each town except Prague to one of five categories: agro-town inside or outside the same estate as a given village, full town inside or outside the same estate as a village, and royal town. Prague was placed in a separate sixth category since, as discussed in Section 3, it had a special status as the royal capital city and was an order of magnitude larger than any other urban centre. Then for each village in 1757, the inverse of the distance from the village to each town in Bohemia was multiplied by the population of the relevant town, with the sum of these products yielding the urban potential offered by that town to that village (in the case of Prague, of course, no summation was involved). This gave rise to six variables, measuring the urban potential to serfs in each village of each category of town and also of Prague. As Table 2 shows, all urban potential variables took similar values in both the full sample and the two subsamples.

The 1757 cadaster records whether a village was part of a settlement under fragmented lordship, in which different parts of the settlement were subject to different landlords, with possible effects on the incentives and capacity of lords to extract, and serfs to deliver, coerced labour. We used a dummy variable to indicate such villages in our regression analysis. Finally, we identified settlement names on historical maps and used GIS to calculate location, enabling us to assign a latitude and longitude to each village.

6. Estimation Strategy

To investigate the Domar conjecture for the Bohemian serf economy, we estimate a reduced-form relationship between labour coercion and the land-labour ratio at the village

level. Our theoretical discussion suggests that the effect of an increase in a village's land-labour ratio on its coerced labour obligations depends on the relative sizes of the changes it induces in the marginal profitability of coerced and hired labour. If an increase in the land-labour ratio increases the marginal profitability of coerced labour relative to that of hired labour, labour coercion will increase, as Domar conjectured.

Our dependent variable is village-level labour coercion, a substantial part of whose distribution is concentrated at zero. These zero values are true zeros, not values that reflect the censoring of some hypothetical negative coerced labour values. In such circumstances, consistent estimates can in principle be obtained from a linear regression model. However, the assumption that the mean of coerced labour is a linear function of the regressors is unlikely to be satisfied, and the marginal effects of the regressors on coerced labour are unlikely to be constant for different regressor values. We therefore use a two-part regression model to estimate the effect of the land-labour ratio on labour coercion. The first part is a probit regression which models the probability that a village has positive coerced labour, while the second part is a linear regression model of coerced labour conditional on such labour being positive. The same set of regressors is used in both parts.[3] In addition to allowing for the substantial proportion of villages which have no coerced labour obligations, the two-part model enables us to estimate the effect of the land-labour ratio on both the presence of any labour coercion and the amount of such coercion when it exists.[4]

Each village in our sample was part of the estate of a particular Bohemian lord. There were different types of landlord, and each estate had a distinct history and administrative regime. Thus unobserved estate-level effects are likely to influence labour coercion. We do not want to assume that these are uncorrelated with the observed regressors. At first sight, the

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[3] We estimate this two-part model using the Stata command *twopm* of Belotti et al. (2015).
[4] We obtain similar results if we estimate a Tobit rather than a two-part regression model, as we show in the Appendix.

natural way of dealing with this would be to include estate fixed effects as regressors. With a linear regression, this can be achieved by using the within transformation, but the within transformation cannot be applied to the two-part regression model that we wish to use. The solution we adopt is that of Mundlak (1978): we specify the unobserved estate effect as being a linear function of the estate-level means of all the observable regressors, which we assume to be present in both parts of the model. This specification means that the estimates of the coefficients of those regressors in the two-part model which are not estate-level means do allow for correlation between these regressors and unobservable estate effects.

Since the regions of Bohemia in which villages were located did not vary within estates, the unobserved estate effects include any regional effects. If there are unobserved region-level influences on labour coercion, such as regional administrative practices, any correlation between them and the regressors is taken account of by the estate-level means of the regressors.

The regression model we estimate assumes that the probability of a village having coerced labour obligations and the amount of non-zero labour coercion are independent, conditional on the regressors. The historical literature provides good reasons for this assumption. Studies of coerced labour in medieval and early modern Bohemian villages show that whether a village had coerced labour obligations at all was determined at an early date, typically at the foundation of the village, whereas the level of coerced labour obligations in those villages that had them was determined in a separate and later process. The types of rent, including coerced labour obligations, paid by serfs in each village were laid down in the manorial rent-roll (*urbař*) issued when the village was founded. As discussed in Section 3, most Bohemian villages were founded in the medieval period; although some were established at later dates as forest or waste was cleared, virtually all had been founded by 1700. The villages that had zero coerced labour obligations in 1757 thus enjoyed this status

by virtue of privileges issued generations and in most cases centuries before 1757. Once the status of zero coerced labour obligations was granted, it was difficult to change it since a village could oppose the introduction of non-customary obligations much more effectively than it could resist incremental increases in the level of customary obligations. Changing from zero to non-zero coerced labour obligations was a process that was extremely long and costly, often involving litigation, appeals, and revolts; changing from lower to higher coerced labour was less difficult for the landlord and took place in a separate process (Strauß 1929; Míka 1960; Wright 1975; Klíma 1975; Macek 1982).

Can a regression of village labour coercion on the village land-labour ratio identify the causal effect of the latter on the former? Some of the objections that might be made to giving such a regression a causal interpretation have already been addressed. Reverse causation running from coerced labour to the land-labour ratio is very unlikely given the features of the Bohemian serf economy discussed in Section 3: serfdom limited geographical mobility precisely to prevent serfs from migrating in response to labour coercion. However, even though the estate fixed effects included in our regressions are likely to capture omitted variables such as features of the policy of particular landlords or their officials, we cannot rule out the possibility that other variables are omitted from our regression model. For example, as noted in Section 3, landlords tended to use serf labour in unskilled and easily monitored tasks. If landlords in different villages produced output using a different mix of skilled and unskilled tasks, and this mix was correlated with the village land-labour ratio, the land-labour ratio would be an endogenous regressor, since the skill composition of the landlord's total labour force is an omitted variable because of lack of data. Instrumental variable (henceforth IV) estimation of the two-part regression model is therefore required to give the effect of the land-labour ratio on labour coercion a causal interpretation.

As noted in Section 5, we were able to obtain data on the characteristics of 5,199 Bohemian villages for both 1654 and 1757. The historical evidence discussed in Section 3 provides strong reasons to think that, although village land-labour ratios in Bohemia did change over time, changes were infrequent and episodic, requiring extensive negotiation between landlords and serfs. The Berni Rula records the amount of arable land in each village in 1654. It also contains information about both occupied and unoccupied holdings in villages. 1654 was shortly after the end of the Thirty Years War, and wartime destruction meant that in some villages there was a high proportion of unoccupied holdings. We take the total of occupied and unoccupied holdings to be the best measure of the number of households that would be expected to live in a village in the absence of the disruption created by warfare. This assumption is supported by historical evidence from the decades after the Thirty Years War, when landlords and communities offered inducements such as building-wood and rent reductions to new farmers until the deserted landholdings in the village had been filled, at which point such inducements ceased. In Ludvíkov p. S./Lusdorf in 1684, for instance, Gottfriedt Vllrich was granted one more year's rent reduction, but told that "henceforth, when the community there is completely filled again, then he shall be obliged to pay the full dues".[5]

We define arable land in a village divided by the total of occupied and unoccupied holdings in a village as the normal land-labour ratio in 1654, which we regard as a measure of the land-labour ratio that would prevail in the absence of wartime disruption and population loss. The normal land-labour ratio in 1654 is our IV for the land-labour ratio in 1757. Since the normal land-labour ratio has to be defined in terms of arable land because of data availability (see Section 5), we focus on the arable-only land-labour ratio in 1757, but the

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[5] Statní Oblastní Archiv Litoměřice, Pobočka Děčín, Fond Rodinný archiv Clam-Gallasů, Historická Sbírka, Kart. 82, Dekretbuch Friedland, fol. 3, 17 Jul. 1684.

maximal land-labour ratio (i.e., including pasture and forest alongside arable fields) gives very similar results.

The normal land-labour ratio in 1654 on its own accounts for 38.5 per cent of the variation in the land-labour ratio in 1757 in the sample of 5,199 villages, but the land-labour ratio in 1654 together with estate fixed effects account for 76.8 per cent of this variation. The importance of estate fixed effects in accounting for the changes in village land-labour ratios between 1654 and 1757 is consistent with the view that these changes were largely the result of decisions made by landlords or their officials in negotiation with serfs.

Our use of the normal land-labour ratio in 1654 as an IV for the land-labour ratio in 1757 means that we are using the variation in the 1757 land-labour ratio generated by the land-labour ratio a century earlier to identify the effect of the 1757 land-labour ratio on labour coercion in 1757. Variables which influenced labour coercion in 1757 at some point in the preceding 103 years that are omitted from the regression model and correlated with the land-labour ratio in 1757 will not affect the validity of our IV. However, if there are omitted variables correlated with the 1757 land-labour ratio that influenced labour coercion in 1757 before 1654, then our IV will not be valid. Our identifying assumption is therefore that the omitted variables that might make the land-labour ratio in 1757 an endogenous regressor only had an effect on labour coercion in 1757 after 1654.

In order to be a valid IV, the normal land-labour ratio in 1654 must also have no direct effect on labour coercion in 1757. Because of the destructive effects of the Thirty Years War, in some villages the actual land-labour ratio in 1654 (defined as arable land divided by the number of occupied holdings) was very different from the normal one. In such cases, Bohemian landlords often granted reductions in coerced labour obligations to induce peasants to rebuild abandoned farms and restore the actual land-labour ratio to its normal value. If labour coercion was below its usual value in 1757 because landlords were still trying

to induce serfs to take on unoccupied holdings, then it is possible that the normal land-labour ratio in 1654 did have a direct effect on coerced labour in 1757, since these obligations would be influenced by the extent to which the actual land-labour ratio in 1757 differed from the normal land-labour ratio in 1654. If this were the case, the normal land-labour ratio in 1654 would be an invalid IV. However, it is unlikely that coerced labour obligations were still being reduced to offset the effects of the Thirty Years War more than a century after it had ended. Most such reductions were strictly temporary, covering either a standard period of three years, or the time required to bring the farm back under cultivation, or the period until all farms in the village had been resettled. Thus, for instance, village-level exemptions were rescinded when, as in Horní Řasnice/Bernsdorf in 1676, "a number of deserted holdings in the community have now been filled".[6] Nevertheless, in order to rule out any possible direct effect of the normal land-labour ratio in 1654 on labour coercion in 1757 via this channel, we measure wartime destruction by the proportion of total holdings in a village in 1654 that were unoccupied, and include this variable as a regressor.

To allow for a possible non-linear relationship between labour coercion and the land-labour ratio, we include the square of the land-labour ratio in 1757 as well as its level as regressors. We therefore use both the level and the square of the normal land-labour ratio in 1654 as IVs.

In our basic regression specification, we also include the latitude and longitude of each village as regressors in order to control for possible spatial effects on labour coercion, as well as a dummy variable to indicate whether a village in our sample was part of a larger settlement that was under fragmented lordship. We also estimate an extended specification in which we add further regressors to those in the basic model. These are the level and square of

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[6] Statní Oblastní Archiv Litoměřice, Pobočka Děčín, Fond Rodinný archiv Clam-Gallasů, Historická Sbírka, Kart. 81, Dekretbuch Frýdlant 1676-7, fol. 42, 17 Jul. 1676.

village size, measured by the number of holdings in 1757, and the urban potential variables.

As we discuss in the next section, we estimate two different specifications because of the

possibility that village size and urban potential are not exogenous regressors.

Our immediate concern, however, is with the strength of the IVs we use for the level and

square of the land-labour ratio in 1757. Table 3 shows the first-stage relationship between the

endogenous regressors and the instruments in the basic and extended specifications.

When there is more than one endogenous variable, the standard F statistic cannot be

used to gauge the strength of the IVs, as pointed out by Angrist and Pischke (2009, 216-8).

Consider an example of two endogenous regressors and two IVs in which one of the IVs is

strongly, and the other is weakly, correlated with both endogenous variables. In this example,

it is possible for the standard F statistics from the two first-stage regressions to suggest that

Table 3: The First-Stage Relationship between the Endogenous Regressors and Instrumental Variables

	Basic Specification		Extended Specification	
	Endogenous Variables		Endogenous Variables	
	Land-labour ratio 1757	Land-labour ratio 1757 sqr	Land-labour ratio 1757	Land-labour ratio 1757 sqr
Normal land-labour ratio 1654	0.762	-59.930	0.762	-60.860
	(0.177)	(99.01)	(0.178)	(99.02)
Normal land-labour ratio 1654 squared	-0.001	1.462	-0.001	1.461
	(0.002)	(1.241)	(0.002)	(1.237)
Share of unoccupied holdings in 1654, latitude, longitude, and fragmented lordship dummy	Yes	Yes	Yes	Yes
Village size and urban potential variables	No	No	Yes	Yes
Standard F statistic	151.98	18.53	145.84	17.65
Sanderson-Windmeijer conditional F statistic	844.85	25.84	836.98	21.88

Note: Number of observations for all regressions is 5,199. Figures in parentheses are standard errors clustered at the estate level. Each regression also includes the estate means of the regressors indicated in the table.

both endogenous regressors are identified by the two IVs, even though there is actually only one strong IV, and thus only one of the endogenous regressors is identified. To avoid such problems when there is more than one endogenous regressor, the Sanderson-Windmeijer (2016) conditional F statistic should be used to assess whether each endogenous regressor is strongly or weakly identified. The values of the Sanderson-Windmeijer conditional F statistic in Table 3 show that the land-labour ratio in 1757 is very strongly identified by the normal land-labour ratio in 1654 and its square in both the basic and the extended specifications. In both specifications, the square of the land-labour ratio in 1757 is also reasonably well identified by the two IVs according to this F statistic. Thus weak IV problems do not arise in using the normal land-labour ratio in 1654 and its square as IVs for the land-labour ratio in 1757 and its square.

The two-part regression model we use is non-linear, so we use a control function approach to obtain the IV estimates (Wooldridge 2015). We add the residuals from the first-stage regressions shown in Table 3 to the two-part model. Provided that the IVs are valid and relevant, these residuals control for the possible endogeneity, and the resulting estimates of the effects of the variables of interest can be given a causal interpretation. Because these residuals are estimates of the unobservable first-stage errors, bootstrapping is required in order to obtain the standard errors of the point estimates in the regressions that include the residual as a regressor. We can test the null hypothesis that the potentially endogenous regressors are exogenous by testing the significance of the residuals when they are added to the two-part regression model.[7]

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[7] Under the null hypothesis that the regressor is exogenous, conducting this test does not require bootstrapping the standard errors of the residuals (Wooldridge 2010, 131).

7. Results

7.1 Basic Specification

Table 4 reports the estimated marginal effects, evaluated at sample mean values, obtained from the basic specification of the two-part regression model. We use human-only and human-animal coerced labour as alternative dependent variables in these regressions, and cluster the standard errors at the estate level, so they are robust to heteroskedasticity in the entire sample and correlation of the regression errors within each estate.
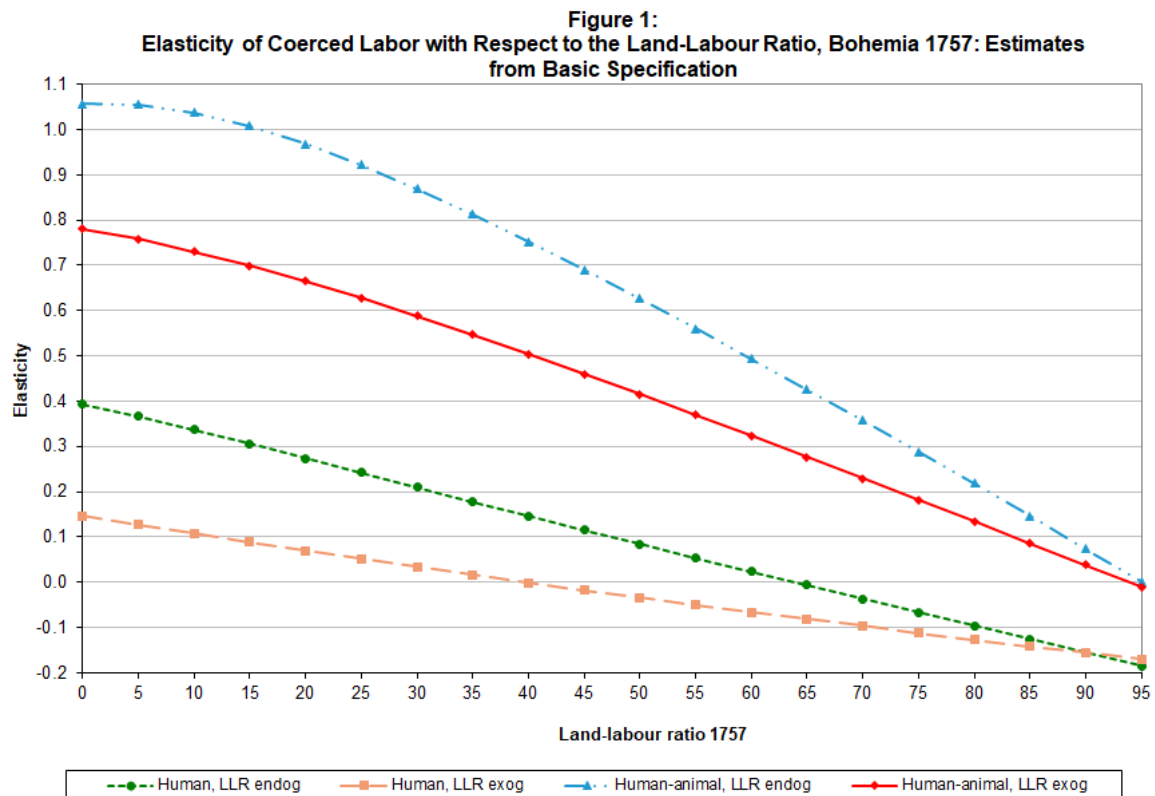
The estimated effect of the land-labour ratio in 1757 on both measures of coerced labour in 1757 differs according to whether the land-labour ratio is treated as an endogenous or an exogenous regressor. These differences are statistically significant, as shown by the p values of the test of the null hypothesis that the land-labour ratio in 1757 and its square can be regarded as exogenous. They are also economically significant, as shown in Figure 1. This figure depicts the elasticity of coerced labour with respect to the land-labour ratio implied by the various estimates in Table 4 at different values of this ratio, with all other variables at their sample mean values. In order to interpret Figure 1, it is helpful to describe the sample distribution of the land-labour ratio in 1757. The mean and median values of the land-labour ratio in the matched sample of 5,199 villages are 28.96 and 25.01 respectively. The values of 35, 40, 50, 60, 80 and 95 for the land-labour ratio correspond respectively to the following percentiles of its distribution: 71.7, 79.3, 89.3, 95.5, 98.0 and 99.0. Values of the land-labour ratio in 1757 above 60 thus account for just 4.5 per cent of the distribution of the sample of 5,199.

For most values of the land-labour ratio in 1757, the estimated elasticity of labour coercion with respect to the land-labour ratio when this ratio is regarded as endogenous is substantially larger than when it is treated as exogenous. Figure 1 shows that the effect of the land-labour ratio on labour coercion is larger by an economically significant amount when IV

Table 4. Regression Analysis of Coerced Labour in Bohemia 1757: Basic Specification

	Dependent Variable			
	Human coerced labour		Human-animal coerced labour	
	LLR 1757 endogenous	LLR 1757 exogenous	LLR 1757 endogenous	LLR 1757 exogenous
	(4.1)	(4.2)	(4.3)	(4.4)
Land-labour ratio 1757	0.425***	0.140**	15.774***	10.827***
	(0.128)	(0.070)	(1.587)	(1.191)
Land-labour ratio 1757 squared	-0.003***	-0.002***	-0.082***	-0.057***
	(0.001)	(0.0004)	(0.014)	(0.010)
Share of empty holdings 1654	4.875**	3.647*	45.719	23.401
	(1.989)	(2.029)	(29.677)	(29.278)
Latitude	10.690	11.028	184.197*	189.559*
	(8.698)	(9.075)	(107.397)	(109.351)
Longitude	3.877	4.644	-68.177	-55.120
	(7.020))	(7.177)	(69.456)	(73.281)
Fragmented lordship	-10.681***	-10.469***	-140.020***	-135.436***
	(1.023)	(1.085)	(14.152)	(14.076)
p value of test of exogeneity	0.025		0.002	

Notes. The number of observations for all regressions is 5,199. All regressions also include the estate means of the variables specified in the table, the coefficients of which are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (4.1) and (4.3) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure 1:
Elasticity of Coerced Labor with Respect to the Land-Labour Ratio, Bohemia 1757: Estimates from Basic Specification

estimation is used, for both human-only and human-animal coerced labour, at least for values of the land-labour ratio up to 35, i.e., for more than 70 per cent of the sample. This evidence suggests that the land-labour ratio should be regarded as an endogenous regressor in the basic specification of our regression model.

Omitted variables are the most plausible reason why the land-labour ratio in 1757 is an endogenous regressor in this basic specification. As Section 3 explained, reverse causation from labour coercion to the land-labour ratio can be ruled out because of the features of the serf economy. The extended specification of the regression model which we discuss in the next sub-section includes additional regressors. The differences between the estimated effects of the land-labour ratio in the extended specification according to whether this ratio is treated as endogenous or exogenous are smaller than in the basic model, though they are still present.

The negative and well-determined estimate of the marginal effect of the square of the land-labour ratio in 1757 on coerced labour in Table 4 implies that the estimated elasticity of both human-only and human-animal coerced labour with respect to the land-labour ratio decreased as the land-labour ratio increased. Figure 1 shows that the elasticity of human coerced labour fell from a value of just under 0.4 at very low levels of the land-labour ratio to a value of roughly zero when the land-labour ratio was just over 60, above the 95th percentile of its distribution. The p values of these estimates are below 0.05 until the land-labour ratio is nearly 40. Thus, for almost 80 per cent of the observed values of the land-labour ratio, increases in this ratio had a statistically as well as economically significant positive effect on human-only labour coercion. The estimates in equation (4.3) imply that the elasticity of human-animal coerced labour fell from just under 1.06 at very low values of the land-labour ratio to a value of essentially zero when the land-labour ratio is 95, at the 99th percentile of its distribution. The p values of these estimates are below 0.05 until the land-labour ratio is almost 80, so increases in this ratio had a statistically and economically significant positive

effect on human-animal coerced labour for nearly 98 percent of observed values of the land-labour ratio in mid-eighteenth-century Bohemia.

Thus there is clear evidence that increases in the land-labour ratio in Bohemian villages increased both human and human-animal labour coercion in the vast majority of cases. In terms of our theoretical analysis of a landlord's choice of coerced and hired labour, this evidence implies that, for most observed values of the village land-labour ratio, increases in this ratio increased the marginal profitability of coerced relative to hired labour. Our reduced-form regressions do not enable us to say exactly why the land-labour ratio changed the relative marginal profitability of the two types of labour in this way. An increase in the village land-labour ratio would mean that the value of the labour serfs used on their own holdings was higher, and thus they would both require increased wages to supply hired labour and have greater incentives to avoid and shirk coerced labour obligations. The rise in the marginal profitability of coerced relative to hired labour might therefore have been because an increase in the land-labour ratio increased the marginal cost of hired labour, by raising the wage the landlord had to pay, more than it increased the marginal cost of coerced labour, by increasing the costs of monitoring such labour. But the marginal profitability of coerced labour might also rise relative to that of hired labour because the increase in the village land-labour ratio increased the marginal revenue product of coerced relative to hired labour. Whatever the mechanism involved, Figure 1 shows that Domar's conjecture was correct in mid-eighteenth-century Bohemia: increases in the village land-labour ratio led to greater use of coerced labour.

Figure 1 also shows that the land-labour ratio had a much larger effect on coercive extraction of human-animal than human-only labour, with elasticities at least 2.5 times as high. The estimates from equation (4.3) imply that the elasticity of human-animal coerced labour with respect to the land-labour ratio was above 0.5 for nearly 95 per cent of the

matched sample, while the elasticity of human coerced labour implied by the estimates from equation (4.1) never reached 0.5. The reduced-form nature of our regression analysis means that we cannot say definitely why the land-labour ratio affected human-animal coerced labour more than human coerced labour, but our interpretation is as follows. An increase in the village land-labour ratio increased the value of serf labour on serfs' holdings, whether human or animal. Thus the cost of hiring both human and animal labour increased when the land-labour ratio rose. Since the value of serf human and animal labour on serf holdings increased with the land-labour ratio, the incentive to avoid delivering coerced human and animal labour also rose. However, the greater visibility of draft animals than humans meant that landlords could more easily monitor the delivery of coerced animal than coerced human labour, so the costs of this monitoring increased much less for coerced human-animal than human-only labour. Thus human-animal labour coercion responded more strongly to increases in the land-labour ratio than human-only.

What explains the second feature of our results, the declining impact of the land-labour ratio on coercion as the land-labour ratio rose? Our reduced-form regressions do not enable us to give a definitive explanation, but in terms of our theoretical framework this finding means that the marginal profitability of coerced labour, though usually greater than the marginal profitability of hired labour, was decreasing relative to that of hired labour as the land-labour ratio increased. This might have occurred because, as the land-labour ratio increased and the opportunity cost of serf working time rose due to serfs' higher productivity on their own holdings, the marginal cost of coerced labour rose relative to that of hired labour and the marginal revenue product of coerced labour fell relative to that of hired labour. Increases in the value of the time that serfs gave up to work for the landlord were likely to increase both the wage that landlords had to pay for hired labour and the monitoring costs landlords incurred because of serf evasion and shirking of coerced labour obligations. Serf

resentment of coerced labour obligations might result in the monitoring costs rising more than the wage. In addition, if a higher village land-labour ratio increased the shirking that serfs were likely to do when providing coerced labour, it was possible that the marginal revenue product of coerced labour fell relative to that of hired labour as the land-labour ratio increased. These reasons for a fall in the marginal profitability of coerced relative to hired labour as the village land-labour ratio increased would account for the declining, and ultimately zero or negative, elasticity of labour coercion with respect to the land-labour ratio as the latter rose.

In the Appendix, we show that the relationship between labour coercion and the land-labour ratio implied by the estimates from the two-part regression model also holds for each part separately. Both the probability of a village having coerced labour obligations at all and the size of such obligations conditional on their being positive increased with the land-labour ratio, but at a diminishing rate. The effect of the land-labour ratio on the amount of coerced labour conditional on this being positive was stronger than its effect on the probability of having coerced labour.

7.2 Extended Specification

The basic specification of our regression model omits any measures of urban potential or village size. Labour coercion in a village would be expected to be influenced by both the opportunities provided by nearby towns and the number of households in the village. However, the relationship between coerced labour and the land-labour ratio can be analysed in the basic specification provided that our IV, the normal land-labour ratio in 1654, is not correlated with urban potential or village size. Furthermore, since both urban potential and village size are potentially endogenous variables, they might be bad controls if they were included as regressors. It is therefore not obvious that better estimates would be obtained if

these variables were added to the basic specification. Nevertheless, it is a useful check on the results from the basic specification to estimate an extended specification in which urban potential and village size measures are included as regressors.

We therefore added to the basic regression specification the six urban potential variables discussed in Section 5 together with the number of households in a village in 1757, our measure of village size. We also included the square of the number of village households in order to allow for the possibility of a non-linear relationship between the amount of coerced labour and village size, since landlords are likely to have incurred costs in extracting coerced labour that did not have a constant relationship to village size. In a very small village, the return to the minimum quantity of manorial manpower required to extort any coerced labour was likely to be low because the number of serfs available to provide it was very small. In a very large village, conversely, the costs of detecting shirking could be inflated by the potential for serfs to conceal their behavior behind larger numbers of other serfs.

Table 5 shows the results of estimating the extended specification of the two-part regression model. As in Table 4, we report the marginal effects evaluated at sample mean values; we use both human-only and human-animal coerced labour as dependent variables, and we present estimates treating the land-labour ratio in 1757 and its square as endogenous and exogenous regressors.

A comparison of the estimated marginal effects of the land-labour ratio and its square in equations (5.1) and (5.3) with the corresponding estimates in equations (4.1) and (4.3) shows that there is little difference between these estimates in the extended and basic specifications when the land-labour ratio is regarded as an endogenous regressor. However, when the land-labour ratio is treated as exogenous, there is a clear difference between the estimates in (5.2) and (5.4) and the corresponding ones in (4.2) and (4.4). This difference is unsurprising. The basic specification omits a number of possible influences on coerced labour

Table 5. Regression Analysis of Coerced Labour in Bohemia 1757: Extended Specification

|	Dependent Variable			
	Human coerced labour		Human-animal coerced labour	
	LLR 1757 endogenous	LLR 1757 exogenous	LLR 1757 endogenous	LLR 1757 exogenous
	(5.1)	(5.2)	(5.3)	(5.4)
Land-labour ratio 1757	0.432***	0.293***	16.105***	12.786***
	(0.098)	(0.056)	(1.324)	(1.068)
Land-labour ratio 1757 squared	-0.003***	-0.002***	-0.074***	-0.056***
	(0.0008)	(0.0005)	(0.013)	(0.009)
Village size 1757	2.005***	1.990***	28.909***	28.411***
	(0.303)	(0.326)	(2.621)	(2.801)
Village size 1757 squared	-0.003	-0.003	-0.123**	-0.119*
	(0.008)	(0.008)	(0.060)	(0.064)
Full towns inside estate	0.023	0.024	0.190	0.198
	(0.015)	(0.014)	(0.157)	(0.172)
Agro-towns inside estate	-0.040	-0.042	-0.166	-0.222
	(0.043)	(0.047)	(0.421)	(0.443)
Full towns outside estate	0.025***	0.026***	0.427***	0.450***
	(0.009)	(0.008)	(0.137)	(0.129)
Agro-towns outside estate	-0.010	-0.011	0.724	0.690
	(0.038)	(0.043)	(0.527)	(0.603)
Royal towns	-0.002	-0.001	0.107	0.133
	(0.011)	(0.010)	(0.124)	(0.127)
Prague	0.007	0.006	0.106	0.080
	(0.008)	(0.005)	(0.106)	(0.079)
Share empty holdings 1654	0.506	0.112	-10.836	-22.365
	(1.734)	(1.606)	(26.831)	(25.282)
Latitude	0.997	0.969	85.873	89.146
	(6.343)	(5.880)	(87.526)	(91.856)
Longitude	2.030	2.381	-75.882	-67.659
	(4.918)	(4.731)	(47.825)	(49.962)
Fragmented lordship	-2.692***	-2.566***	-33.283***	-30.667***
	(0.855)	(0.860)	(11.819)	(11.167)
p value of test of exogeneity	0.701		0.011	

Notes. The number of observations for all regressions is 5,199. All regressions also include the estate means of the variables specified in the table, the coefficients of which are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (5.1) and (5.3) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

which might be correlated with the land-labour ratio, so that when this ratio is treated as exogenous and additional influences are included in the extended specification, the estimated effects of the land-labour ratio on labour coercion change.

The *p* values of the test of the null hypothesis that the land-labour ratio in 1757 and its square can be treated as exogenous regressors in the extended specification show that this

hypothesis cannot be rejected when human coerced labour is the dependent variable, but is rejected when human-animal coerced labour is the dependent variable. The economic significance of the differences between the estimated effects of the land-labour ratio according to whether it is treated as an endogenous or exogenous regressor can be seen in Figure 2. This shows the elasticity of coerced labour with respect to the land-labour ratio implied by the various estimates in Table 5 at different values of this ratio, with all other variables at their sample mean values.

When the land-labour ratio is treated as endogenous, the point estimates of the elasticity of labour coercion with respect to this ratio implied by the results from the extended specification are, for most observed values of the land-labour ratio ratio, a little larger than those implied by the results of the basic specification. In contrast, when the land-labour ratio is regarded as exogenous, the point estimates of this elasticity from the extended specification are noticeably larger than those from the basic specification. Consequently, the differences

Figure 2:
Elasticity of Coerced Labor with Respect to the Land-Labour Ratio, Bohemia 1757: Estimates from Extended Specification
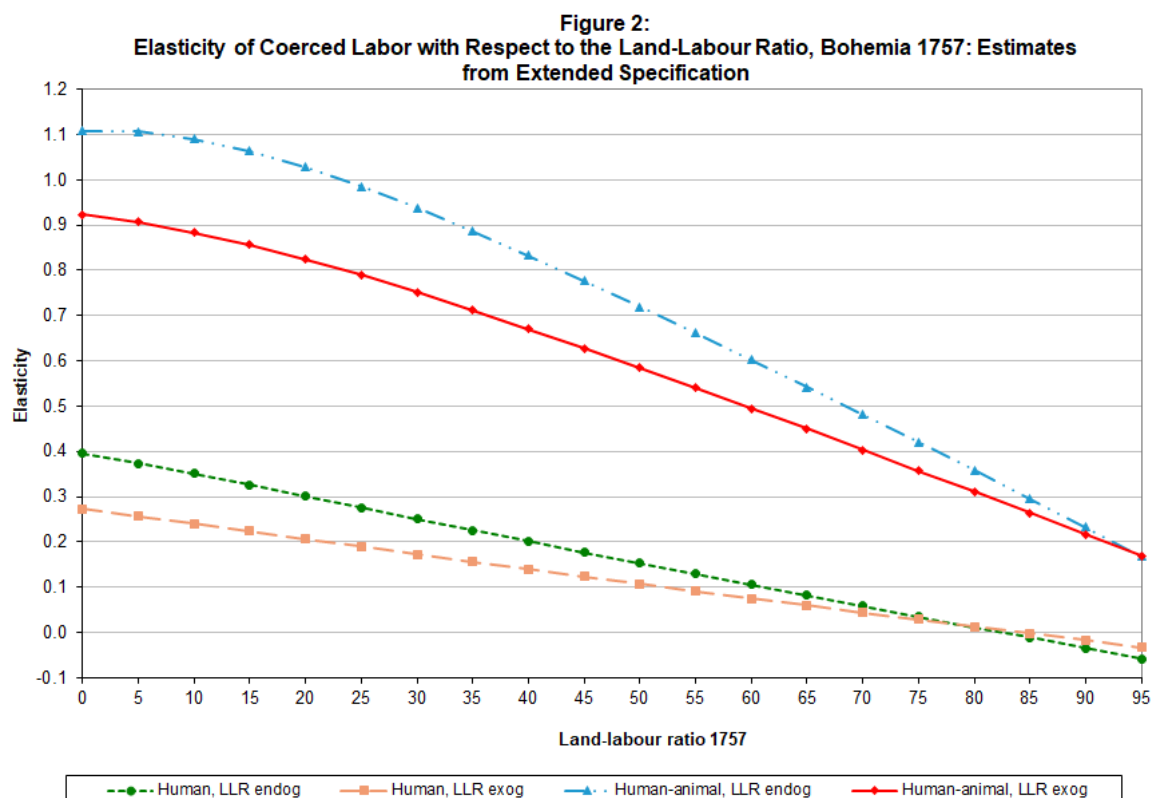
between the elasticity estimates obtained according to whether the land-labour ratio is treated as endogenous or endogenous are smaller for the extended than for the basic specification. The largest difference between the IV and no-IV point estimates of the elasticity of human-only coerced labour with respect to the land-labour ratio implied by the extended specification is 0.12, when this ratio is just above zero. This difference falls to 0.03 when the land-labour ratio is 60, above the 95th percentile of the observed distribution. As the p value of the exogeneity test in Table 5 shows, these differences are not statistically significant, and their economic significance is modest at best. For human-animal coerced labour, the largest difference between the IV and no-IV point estimates of the elasticity with respect to the land-labour ratio is 0.21, when this ratio is 15, and the difference is still 0.11 when the land-labour ratio is 60. As well as being statistically significant (shown by the p value in Table 5), these differences are thus also economically significant.

The results of estimating the extended specification confirm the conclusions from the basic specification. There is clear evidence that increases in the land-labour ratio increased labour coercion. The p values of the estimated elasticities from both equations (5.1) and (5.2) are below 0.05 until the land-labour ratio reaches 65. For equation (5.3), these p values are below 0.05 until the land-labour ratio reaches 95, while for (5.4) they are below 0.05 for all values of this ratio including 95. The evidence from the extended specification also confirms that the effect of the land-labour ratio on human-animal coerced labour is much stronger than it is on human-only coerced labour, and that it declined as the land-labour ratio rose.

In the Appendix, we show that, just as for the basic specification, the relationship between labour coercion and the land-labour ratio implied by the extended specification of the two-part model holds for each part separately. The probability of a village having coerced labour obligations and the size of such obligations conditional on their being positive both increased with the land-labour ratio, but at a diminishing rate. The effect of the land-labour

ratio on the amount of coerced labour conditional on this being positive was stronger than the effect on the probability of having any coerced labour.

Turning to the village size and urban potential variables that are included as regressors in the extended specification, we reiterate that we are hesitant to give the estimates in Table 5 a causal interpretation. However, even regarded as associations, these estimates are interesting. Unsurprisingly, the total amount of coerced labour extracted from a village, whether human-only or human-animal, is strongly associated with village size. The point estimates of village size in 1757 in Table 5 correspond to elasticities at sample mean values of 0.93-0.94 for equations (5.1) and (5.2), and 1.14-1.17 for (5.3) and (5.4). However, there is only limited evidence that the association with village size is non-linear. The point estimates of the square of village size in (5.1) and (5.2) are poorly determined and correspond to elasticities of about -0.04. In (5.3) and (5.4) these point estimates are rather more precisely estimated and correspond to elasticities of about -0.13. The estimated associations between labour coercion and village size are discussed more fully in the Appendix, where it is shown that there is little variation in the size of these associations for the vast majority of observed village sizes.

There is also very little evidence of any association between labour coercion in Bohemian villages and the extent to which towns provided outside opportunities for serfs and landlords. The estimated association between the urban potential of five of the six different types of town and coerced labour is imprecisely estimated in all four regressions reported in Table 5. The elasticities at sample mean values correponding to the point estimates of these five urban potential variables are below 0.1 in (5.1) and (5.2), so the estimated associations are economically and statistically insignificant in the case of human-only coerced labour. However, in (5.3) and (5.4), the point estimates of agro-towns outside the estate, though poorly determined, correspond to an elasticity of about 0.5.

The one urban potential variable whose association with labour coercion is precisely estimated in Table 5 is full towns outside the estate. The elasticities corresponding to the point estimates for this variable are about 0.27 in (5.1) and (5.2) and 0.4 in (5.3) and (5.4), so this association is economically as well as statistically significant. It is positive, so that greater urban potential from full towns outside the estate is associated with higher labour coercion. The relatively large, though poorly-determined, association between human-animal coerced labour and the urban potential of agro-towns outside the estate is also positive. To the extent that towns in Bohemia had any effect on labour coercion, these positive associations are consistent with towns offering opportunities to landlords rather than serfs. This is not surprising, since historical evidence shows both seigneurial and royal towns in Bohemia taking actions that stifled rather than increased the outside options open to serfs, specifically by restricting serf crafts and trades that competed with those practised by town burghers (Cerman 1996; Ogilvie 2001; Klein and Ogilvie 2016). However, we recognise that further work is required in order to establish the causal effect of towns on labour coercion in Bohemia. The same remark applies to the overall finding in Table 5 about the effect of towns on labour coercion. The association between urban potential and coerced labour is weak for four of the six measures, and this is consistent with the fact that, as discussed in Section 3, towns in eighteenth-century Bohemia were few and feeble by European standards.

8. Conclusion

This paper investigates the effect of the land-labour ratio on labour coercion under serfdom, controlling for the political and institutional influences on coerced labour. Recognising that Domar's conjecture assumes a particular institutional framework, we hold the institutional framework constant by analyzing a specific serf society. Failure to control for political and institutional differences across countries, we argue, has obscured the impact of

the land-labour ratio on labour coercion in previous considerations of this question based on cross-country comparisons.

Our econometric analysis of Bohemian villages in the eighteenth century shows that the net effect of a higher land-labour ratio was to increase labour coercion. In theory, a higher land-labour ratio exerts an ambiguous net effect on coerced labour because it changes the incentives of landlords to demand coerced relative to hired labour, and serfs to supply the two types of labour. But in the concrete empirical setting of eighteenth-century Bohemia, the net effect of a higher land-labour ratio was to increase labour coercion – both the probability of a village having coerced labour at all, and the amount of coerced labour extracted conditional on its existence. Furthermore, both historical evidence and instrumental variable analysis demonstrate that this effect can be interpreted as causal: higher land-labour ratios gave rise to higher labour coercion.

Our results also bring to light two previously unrecognised features of how the land-labour ratio affected labour coercion. First, the land-labour ratio affected coercion of human-animal labour much more strongly than human-only labour. Analyses of serfdom that focus solely on human labour thus neglect a crucial component of the extraction of work energy from serf households. Analysing human work energy alone may seriously under-estimate the damage labour coercion inflicted on the peasant economy under serfdom.

Second, our results show that the impact of the land-labour ratio on coercion declined as the land-labour ratio rose. This finding, we suggest, can be explained in terms of the marginal profitability of coerced labour falling relative to the marginal profitability of hired labour as the village land-labour ratio rose and the productivity of serf labour on their own holdings increased. An important avenue for future research, therefore, is to analyze the influences on the marginal profitability of landlords' use of coerced and hired labour, and in

particular whether serf labour became more costly relative to hired labour as the opportunity cost of serf working time rose.

Another area where further research is needed is the relationship between towns and serfdom. Towns are usually assumed to have weakened labour coercion by offering outside options to serfs. However, it is not always recognized that towns also offered economic opportunities to landlords, for instance to sell the output of manorial enterprises, so the presence of towns could increase landlords' incentives to extract coerced labour. Our tentative analysis showed hardly any association between the urban potential of villages and the amount of coerced labour in them. This might simply be because towns in Bohemia were few and weak, but it might also be because towns created opportunities for landlords as well as serfs, or because towns used their institutional privileges to constrain serf activities that competed with those of urban citizens. Whether the growth of towns influenced labour coercion, and how any such effect differed across serf societies, are important questions for future research.

The final and most general implication of our results is that a basic economic feature, the land-labour ratio, affects institutions. Serfdom is arguably the most important labour-coercion institution ever observed as far as long-term growth effects are concerned. But economic historians have largely dismissed the land-labour ratio as an influence on it. Because similar increases in land-labour ratios after the Black Death were followed by a decline of serfdom in some societies and an intensification in others, the land-labour ratio was thought to exercise no impact. Serfdom, it was believed, intensified and declined because of class struggle, royal strength, or other society-specific variables. Our findings, by contrast, show that when such variables are held constant by carrying out an analysis inside a particular society, the land-labour ratio did indeed affect serfdom. Although idiosyncratic, society-specific variables were unquestionably important in explaining differences in serfdom

across countries, our findings show that Domar was right in conjecturing that the land-labour ratio also played an explanatory role. Institutional variables influenced whether landlords were entitled to coerce labour, but the degree to which they exercised this entitlement were influenced by the land-labour ratio. In turn, this had the potential to intensify landlords' incentives to bring pressure to bear for such entitlements to be created, strengthened, and maintained. The land-labour ratio is therefore part of the explanation for serfdom as a broader institutional system. Economic fundamentals, our findings suggest, can influence institutions.

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Appendix

      This Appendix provides greater detail on a number of points in the main text. Section A1 provides the information about Bohemian towns and settlements that underlies the discussion in Section 3.4 of the main text. Section A2 sets out the theoretical model of landlord use of coerced and hired labour which forms the basis for the discussion in Section 4 of the main text. Section A3 explains how we converted coerced animal labour into its human labour equivalent. In Section A4 we show that the regression results in the main text are essentially unaffected if an alternative measure of the village land-labour ratio is used. Section A5 reports the results of using Tobit rather than two-part regression models for our analysis of the relationship between coerced labour and the land-labour ratio. In Section A6 we present the results of estimating the two separate parts of the regression models which are reported in Tables 4 and 5 of the main text, and in Section A7 we provide more detail about the association between coerced labour and village size reported in Table 5 of the main text.

A1. Towns in Bohemia, 1757

      Tables A1 and A2 present information extracted from the Theresian Cadaster about the characteristics of Bohemian towns other than Prague. These tables form the basis for the discussion in Section 3.4 of the main text. Table A1 reports the number and size of seigneurial agro-towns, seigneurial full towns, and royal towns. It also shows, for each of the three types of town, the average percentage of households holding more than 15 *strych* of arable land. As 15 *strych* is considered to be the minimum amount of land that a household required to be able to earn its living solely from agriculture, this measure indicates the importance of agriculture in the economies of each type of town.

      Table A2 shows the distribution of population in Bohemia by the type of settlement. In 1757, of the total number of households in Bohemia outside Prague, 72 per cent were serf

Table A1:
Characteristics of Towns, Bohemia 1757

Characteristic	Seigneurial agro-town (*městys*)	Seigneurial full town (*město*)	Royal town
Number of towns of that type	328	168	43
% of towns of that type	60.9	31.2	8.0
Total number of households in that type of town	19,791	26,457	12,517
% of total urban households in that type of town	33.7	45.0	21.3
Mean number of households per town of that type	60.3	157.5	291.1
Maximum number of households per town of that type	282	535	749
Minimum number of households per town of that type	3	17	113
Mean % households with more than 15 *strych* arable land	32.8	18.0	16.9

Note: Excludes Prague.

Source: Tereziánský katastr 1757.

Table A2:
Distribution of Population by Type of Settlement, Bohemia 1757

Total households living in:	No.	%	
Villages	152,851	72.2	
Any type of seigneurial town, of which:	46,248	21.9	
Agro-town (*městys*)	19,791		9.4
Full town (*město*)	26,457		12.5
Royal towns	12,517	5.9	
All types of settlement	211,616	100.0	
Total village households living on estates with:	**No.**	**%**	
No type of town	65,835	43.1	
Any type of town, of which:	87,016	56.9	
Agro-towns only	39,232		25.7
Full towns only	19,651		12.9
Both agro-towns and full towns	28,133		18.4
Total households in villages	152,851	100.0	

Notes: For definitions of different types of settlement, see Section 3.4 of main text. Excludes Prague.

Source: Tereziánský katastr 1757.

households living in villages and the remaining 28 per cent lived in towns. Of the serf

households in villages, 43 per cent lived on estates which had no towns.

A2. A Model of Landlord Use of Coerced and Hired Labour

The landlord in a village uses hired labour L_h and coerced labour L_c to produce output. The cost of a unit of hired labour is $w(L_h, l)$, where l is the exogenously-given land-labour ratio in the village, and $\frac{\partial w}{\partial L_h} \geq 0$, so that the cost of a unit of hired labour is non-decreasing in the quantity of hired labour. We therefore allow for the possibility that the landlord has monopsony power and recognises that greater use of hired labour would increase its unit cost. The cost of a unit of coerced labour is $c(L_c, l)$, where $\frac{\partial c}{\partial L_c} \geq 0$, so that the cost of a unit of coerced labour is non-decreasing in the quantity of coerced labour. The cost of a unit of coerced labour can be thought of as the cost of monitoring it to prevent shirking while it is working for the landlord, and the cost of ensuring that coerced labour actually turns up at the prescribed time and place. We allow for the possibility that the cost of a unit of coerced labour increases as the quantity of coerced labour increases, because of greater incentives to shirk and to evade coerced labour as more is extracted.

The landlord's revenue from output produced is $R(L_h, L_c, l)$. We assume that the marginal revenue product of both hired and coerced labour is always positive, so $R_1 \equiv \frac{\partial R}{\partial L_h} > 0$ and $R_2 \equiv \frac{\partial R}{\partial L_c} > 0$. We also assume that these marginal revenue products are decreasing, $R_{11} < 0$ and $R_{22} < 0$, and $R_{12} = R_{21} < 0$. This last assumption says that the marginal revenue product of one type of labour will be lowered by a marginal increase in the use of the other type of labour.

The landlord chooses the amounts of hired and coerced labour to maximise profit. Thus the landlord's problem is

$$\max_{L_h, L_c} R(L_h, L_c, l) - w(L_h, l)L_h - c(L_c, l)$$

which has first-order conditions

$$R_1 - w - \frac{\partial w}{\partial L_h} L_h = 0$$

$$R_2 - c - \frac{\partial c}{\partial L_c} L_c = 0$$

and the second-order condition is assumed to be satisfied, so that $|H| > 0$, where H is the Hessian matrix of second derivatives. The first-order conditions say that at the profit-maximising choices of labour, the marginal revenue product of each type of labour equals its marginal cost. The marginal cost of a unit of each type of labour is the cost of that unit (w or c) plus any increased cost of units already used that occurs because cost depends on the quantity of labour ($\frac{\partial w}{\partial L_h} L_h$ or $\frac{\partial c}{\partial L_c} L_c$).

Because $|H| > 0$, the first-order conditions implicitly define functions expressing the landlord's profit-maximising choice of labour in terms of l: $L_h(l), L_c(l)$:

$$R_1(L_h(l), L_c(l), l) - w(L_h(l), l) - \frac{\partial w(L_h(l), l)}{\partial L_h} L_h(l) \equiv 0$$

$$R_2(L_h(l), L_c(l), l) - c(L_c(l), l) - \frac{\partial c(L_c(l), l)}{\partial L_c} L_c(l) \equiv 0$$

Differentiating these identities with respect to l gives

$$\begin{bmatrix} R_{11} - 2\frac{\partial w}{\partial L_h} - \frac{\partial^2 w}{\partial L_h^2} L_h & R_{12} \\ R_{21} & R_{22} - 2\frac{\partial c}{\partial L_c} - \frac{\partial^2 c}{\partial L_c^2} L_c \end{bmatrix} \begin{bmatrix} \frac{\partial L_h}{\partial l} \\ \frac{\partial L_c}{\partial l} \end{bmatrix} = \begin{bmatrix} \frac{\partial w}{\partial l} + \frac{\partial}{\partial l}\left(\frac{\partial w}{\partial L_h}\right) L_h - \frac{\partial}{\partial l} R_1 \\ \frac{\partial c}{\partial l} + \frac{\partial}{\partial l}\left(\frac{\partial c}{\partial L_c}\right) L_c - \frac{\partial}{\partial l} R_2 \end{bmatrix} \quad (1)$$

Define $\frac{\partial MC_h}{\partial l} \equiv \frac{\partial w}{\partial l} + \frac{\partial}{\partial l}\left(\frac{\partial w}{\partial L_h}\right) L_h$ as the change in the marginal cost of hired labour, evaluated at the profit-maximising choices corresponding to the initial value of the land-labour ratio, when there is a marginal increase in this ratio. Similarly, define $\frac{\partial MC_c}{\partial l} \equiv \frac{\partial c}{\partial l} + \frac{\partial}{\partial l}\left(\frac{\partial c}{\partial L_c}\right) L_c$ as the change in the marginal cost of coerced labour, evaluated at the profit-maximising choices corresponding to the initial value of the land-labour ratio, when there is a marginal increase in this ratio. Also define $\frac{\partial MR_h}{\partial l} \equiv \frac{\partial}{\partial l} R_1$ as the change in the marginal revenue product of hired

labour, evaluated at the profit-maximising choices corresponding to the initial value of the land-labour ratio, when there is a marginal increase in this ratio, and $\frac{\partial MR_c}{\partial l} \equiv \frac{\partial}{\partial l} R_2$ as the change in the marginal revenue product of coerced labour, evaluated at the profit-maximising choices corresponding to the initial value of the land-labour ratio, when there is a marginal increase in this ratio. Then, using Cramer's rule, (1) can be solved to give

$$
\frac{\partial L_h}{\partial l} = \frac{\begin{vmatrix} \frac{\partial MC_h}{\partial l} - \frac{\partial MR_h}{\partial l} & R_{12} \\ \frac{\partial MC_c}{\partial l} - \frac{\partial MR_c}{\partial l} & R_{22} - 2\frac{\partial c}{\partial L_c} - \frac{\partial^2 c}{\partial L_c^2} L_c \end{vmatrix}}{|H|}
$$

$$
\frac{\partial L_c}{\partial l} = \frac{\begin{vmatrix} R_{11} - 2\frac{\partial w}{\partial L_h} - \frac{\partial^2 w}{\partial L_h^2} L_h & \frac{\partial MC_h}{\partial l} - \frac{\partial MR_h}{\partial l} \\ R_{21} & \frac{\partial MC_c}{\partial l} - \frac{\partial MR_c}{\partial l} \end{vmatrix}}{|H|}
$$

Since $|H| > 0$, the sign of these derivatives is given by the sign of the determinant in the relevant numerator.

Thus the sign of $\frac{\partial L_c}{\partial l}$ is given by the sign of

$$
\left(R_{11} - 2\frac{\partial w}{\partial L_h} - \frac{\partial^2 w}{\partial L_h^2} L_h \right)\left(\frac{\partial MC_c}{\partial l} - \frac{\partial MR_c}{\partial l} \right) - R_{21}\left(\frac{\partial MC_h}{\partial l} - \frac{\partial MR_h}{\partial l} \right)
$$

Define $\frac{\partial MP_h}{\partial l} \equiv \frac{\partial MR_h}{\partial l} - \frac{\partial MC_h}{\partial l}$ as the change in the marginal profitability of using hired labour, evaluated at the profit-maximising choices corresponding to the initial value of the land-labour ratio, when there is a marginal increase in this ratio, and $\frac{\partial MP_c}{\partial l} \equiv \frac{\partial MR_c}{\partial l} - \frac{\partial MC_c}{\partial l}$ as the change in the marginal profitability of using coerced labour, evaluated at the profit-maximising choices corresponding to the initial value of the land-labour ratio, when there is a marginal increase in this ratio. Then the sign of $\frac{\partial L_c}{\partial l}$ is given by the sign of

$$
-\left(R_{11} - 2\frac{\partial w}{\partial L_h} - \frac{\partial^2 w}{\partial L_h^2} L_h \right)\frac{\partial MP_c}{\partial l} + R_{21}\frac{\partial MP_h}{\partial l} \tag{2}
$$

The sign of (2) depends on whether

$$\frac{\partial MP_h}{\partial \alpha_i} \begin{array}{c} < \\ = \\ > \end{array} \frac{R_{11} - 2\frac{\partial w}{\partial L_h} - \frac{\partial^2 w}{\partial L_h^2}L_h}{R_{21}}\frac{\partial MP_c}{\partial \alpha_i} \tag{3}$$

The term $R_{11} - 2\frac{\partial w}{\partial L_h} - \frac{\partial^2 w}{\partial L_h^2}L_h$ in (3) is negative, from the second-order condition for profit maximisation, and R_{21} is also negative, so the term multiplying $\frac{\partial MP_c}{\partial \alpha_i}$ on the right-hand side of (3) is positive. An increase in the land-labour ratio is likely to increase the marginal cost of hired labour at the initial profit-maximising choices (because the marginal product of labour in the village is higher and hence serfs produce more on their own holdings, raising their reservation wage). But it is also likely to alter the marginal revenue product of hired labour, though it is not clear in which direction, since the greater return to serf labour on serf land holdings may or may not increase the demand for the landlord's output. Thus the sign of $\frac{\partial MP_h}{\partial l}$ is ambiguous in general. So too is the sign of $\frac{\partial MP_c}{\partial l}$. An increase in the land-labour ratio is likely to increase the marginal cost of coerced labour: if serfs can produce more on their own holdings, their incentive to shirk and evade coerced labour obligations will increase, requiring greater monitoring. The marginal revenue product of using coerced labour is also likely to change, though for the same reasons as just mentioned for hired labour, the sign of this change is unclear. Thus the effect of an increase in the land-labour ratio is theoretically ambiguous in general.

The condition (3) shows that coerced labour must increase when the village land-labour ratio increases if $\frac{\partial MP_h}{\partial l} < 0$ and $\frac{\partial MP_c}{\partial l} > 0$, and must decrease if $\frac{\partial MP_h}{\partial l} > 0$ and $\frac{\partial MP_c}{\partial l} < 0$. When both $\frac{\partial MP_h}{\partial l}$ and $\frac{\partial MP_c}{\partial l}$ take the same sign, the effect of an increase in the land-labour ratio depends on the precise values of the terms in (3). The effect of an increase in the land-labour ratio is therefore an empirical question.

A3. Conversion between Human and Animal Labour

As discussed in the main text, we define coerced labour obligations in two ways: first, in terms of human workers only; and second, taking into account the fact that all but one category of coerced labour recorded in the 1757 Theresian Cadaster required serfs to send draft animals along with human workers. The first definition focuses solely on the coercive extraction of human time, while the second measures the total work energy that landlords were extracting from serf households. Such work energy was often delivered by human-animal teams. Both landlords and serfs at the time regarded human and animal energy as fungible. This is also the view taken in modern economic studies (see, for instance, United Nations Statistical Office 1987).

In the Theresian Cadaster, the coerced labour (*robota*) which serfs were required to carry out for landlords fell into nine categories: labour provided by a human worker (known as "hand labour"); labour provided by a human worker together with one, two, three, or four horses; and labour provided by a human worker together with one, two, three, or four oxen. With few exceptions (see below), the cadaster recorded the number of serf households in each village that had to provide each category of coerced labour, and the number of days they had to do it each week.

We convert animal to human energy using a conversion factor drawn from medieval England, which treated a horse as equivalent to 12.5 men and an ox to 6.6 (Campbell 2003, Table 1). On the grounds that both medieval England and eighteenth-century Bohemia pre-dated the Agricultural Revolution and the Industrial Revolution, and both were subject to the institutional framework of serfdom, we assume that agricultural practice, technology, incentives, and relative size and strength of animals and human beings in eighteenth-century Bohemia are likely to have closely resembled those in medieval England. We therefore calculate human-animal coerced labour based on the conversion factor in Campbell (2003).

As noted above, for most villages the cadaster recorded the number of serfs in each coerced labour category and the number of days the serfs in that category had to work for the landlord each week. For a small subset consisting of 195 villages, the cadaster recorded an aggregate number of days of coerced labour for the whole village for the year, but did not specify how many days were owed by each coerced labour category. In those 195 cases, we allocate the aggregate number of days of coerced labour across the different coerced labour categories that were present in that particular village according to the number of serfs in each category. In a few villages, the cadaster did not record the number of serfs in all coerced labour categories; in those cases, we assume that there was one serf in each coerced labour category involving animal labour that existed in that village, and that all other serfs in that village owed only human ("hand") labour; this yielded a minimum calculation of the amount of animal labour the village had to deliver to the landlord.

A4. Regression Results using the Maximal Land-Labour Ratio

In the main text, we measure the village land-labour ratio in 1757 in terms of arable (crop-growing) land. We do so because arable cultivation was the most important livelihood source in early modern European rural economies and, as Table 2 of the main text shows, arable fields comprised the overwhelming majority of land in Bohemian villages in 1757. Furthermore, our instrumental variable, the normal land-labor ratio in 1654, has to be defined in terms of arable land only because of data availability. To check the robustness of the results reported in Section 7 of the main text which use the arable-only land-labour ratio, we also estimated the basic and extended regression specifications using an alternative definition of the village land-labour ratio in 1757. This is the maximal land-labour ratio, in which the numerator consists of all land – arable, pasture, meadow, and forest – in the village.
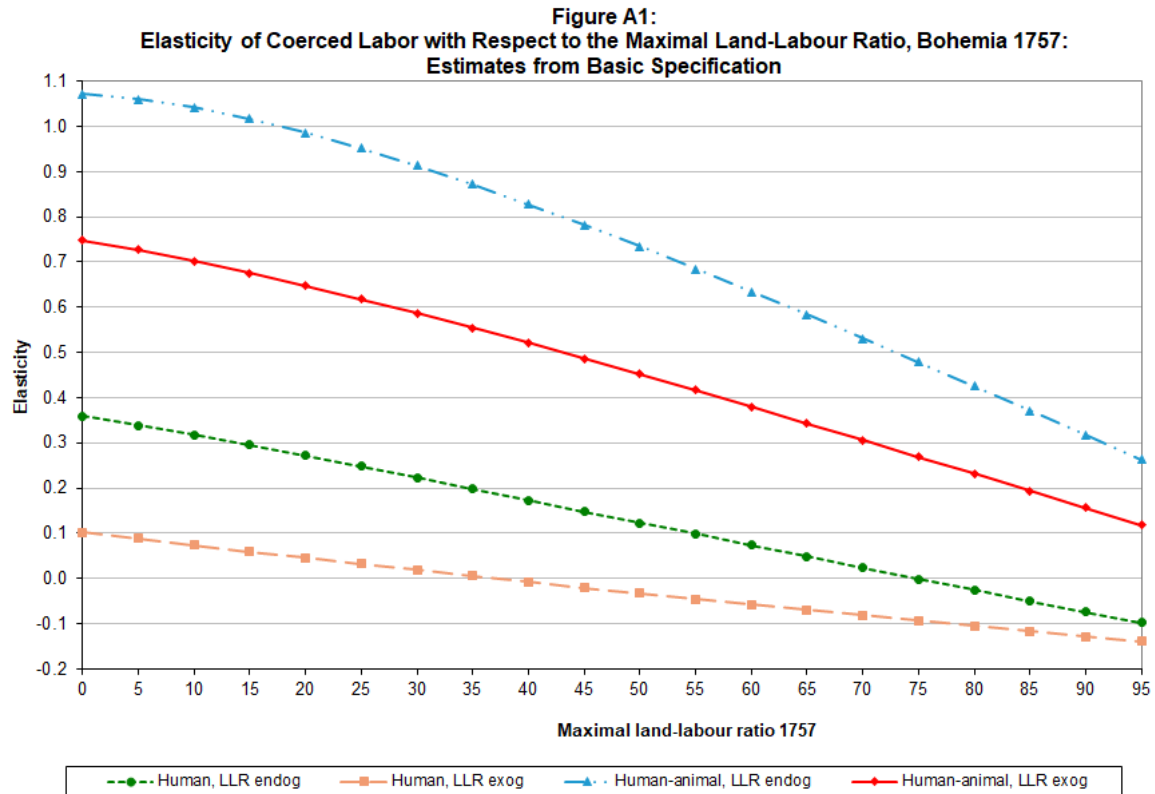
Table A3 reports the results obtained when the basic specification of the two-part regression model was estimated using the maximal land-labour ratio in 1757 rather than the arable one, and Figure A1 shows the elasticities of coerced labour with respect to the land-labour ratio implied by these results (with all regressors other than the land-labour ratio at their sample mean values). These results are very similar to those in Table 4 and Figure 1 of the main text. When the maximal land-labour ratio in 1757 is treated as an endogenous regressor, its effects on both types of coerced labour are greater, by economically and statistically significant amounts, than the effects when it is treated as an exogenous regressor. The estimated effects on human-animal coerced labour are substantially larger than those on human-only coerced labour. These effects fall as the village land-labour ratio increases, and for human-only coerced labour become negative at large values of the land-labour ratio. The

Table A3. Regression Analysis of Coerced Labour in Bohemia 1757 using Maximal Land-Labour Ratio: Basic Specification

	Dependent Variable			
	Human coerced labour		Human-animal coerced labour	
	LLR 1757 endogenous (A3.1)	LLR 1757 exogenous (A3.2)	LLR 1757 endogenous (A3.3)	LLR 1757 exogenous (A3.4)
Land-labour ratio 1757	0.336***	0.083	13.217***	8.699***
	(0.125)	(0.056)	(1.743)	(1.034)
Land-labour ratio 1757 squared	-0.002**	-0.001***	-0.055***	-0.039***
	(0.001)	(0.0004)	(0.016)	(0.008)
Share of empty holdings 1654	4.907**	3.535*	46.997	20.754
	(2.002)	(2.021)	(30.217)	(30.020)
Latitude	11.225	11.260	207.777*	206.728*
	(8.778)	(9.002)	(107.465)	(109.898)
Longitude	4.380	4.771	-52.269	-45.331
	(7.097)	(7.134)	(70.313)	(73.841)
Fragmented lordship	-10.588***	-10.436***	-136.436***	-132.719***
	(1.018)	(1.083)	(14.144)	(14.104)
p value of test of exogeneity	0.016		0.000	

Notes. The number of observations for all regressions is 5,199. All regressions also include the estate means of the variables specified in the table, the coefficients of which are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (A3.1) and (A3.3) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure A1:
Elasticity of Coerced Labor with Respect to the Maximal Land-Labour Ratio, Bohemia 1757:
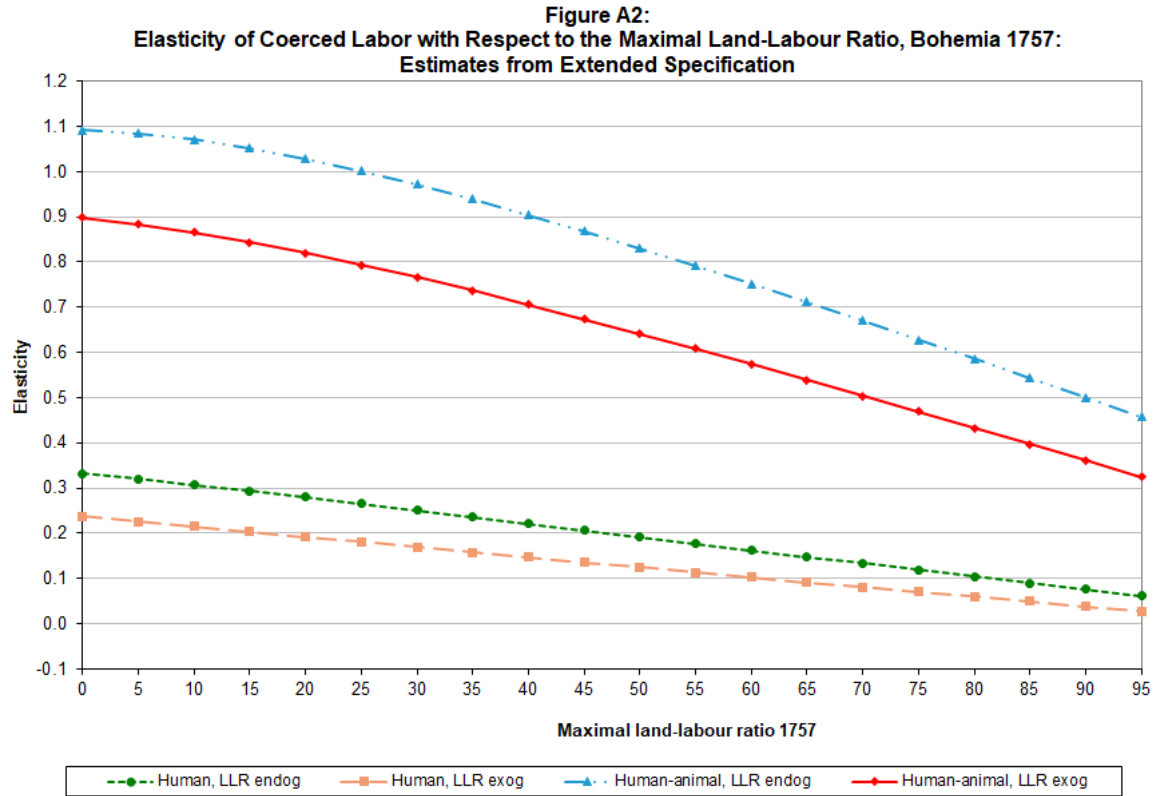**Estimates from Basic Specification**

mean and median values of the maximal land-labour ratio in 1757 in the matched sample of

5,199 villages are 33.94 and 30.10 respectively. The values of 35, 40, 50, 60, 80 and 95 for

the land-labour ratio correspond respectively to the following percentiles of its distribution:

60.6, 70.0, 83.3, 90.7, 96.9 and 98.6. Comparisons between the elasticities shown in Figure

A1 and those in Figure 1 of the main text must therefore be made taking account of the

differences in the sample distribution of the maximal and arable land-labour ratios. The sizes

of the estimated elasticities with respect to the maximal land-labour ratio at different

percentiles of its sample distribution are only a little different from those with respect to the

arable land-labour ratio at the corresponding percentiles of its sample distribution.

Table A4 and Figure A2 show the results obtained when the maximal land-labour

ratio is used in the extended specification. Once again the results using the maximal land-

labour ratio are very similar to those using the arable land-labour ratio. The conclusions

drawn in the main text about the relationship between the village land-labour ratio and

Table A4. Regression Analysis of Coerced Labour in Bohemia 1757 using Maximal Land-Labour Ratio: Extended Specification

	Dependent Variable			
	Human coerced labour		Human-animal coerced labour	
	LLR 1757 endogenous (A4.1)	LLR 1757 exogenous (A4.2)	LLR 1757 endogenous (A4.3)	LLR 1757 exogenous (A4.4)
Land-labour ratio 1757	0.311***	0.218***	13.134***	10.494***
	(0.089)	(0.043)	(1.415)	(0.879)
Land-labour ratio 1757 squared	0.001*	-0.001***	-0.044***	-0.038***
	(0.0007)	(0.0003)	(0.013)	(0.007)
Village size 1757	2.021***	1.998***	29.492***	28.759***
	(0.301)	(0.324)	(2.617)	(2.787)
Village size 1757 squared	-0.003	-0.003	-0.129**	-0.123**
	(0.008)	(0.008)	(0.059)	(0.063)
Full towns inside estate	0.023	0.023	0.162	0.167
	(0.015)	(0.015)	(0.163)	(0.176)
Agro-towns inside estate	-0.041	-0.043	-0.209	-0.264
	(0.042)	(0.046)	(0.393)	(0.407)
Full towns outside estate	0.025***	0.026***	0.428***	0.442***
	(0.009)	(0.008)	(0.138)	(0.127)
Agro-towns outside estate	-0.011	-0.012	0.696	0.649
	(0.038)	(0.043)	(0.525)	(0.605)
Royal towns	-0.001	-0.001	0.119	0.146
	(0.011)	(0.010)	(0.124)	(0.129)
Prague	0.007	0.006	0.106	0.081
	(0.008)	(0.005)	(0.102)	(0.079)
Share empty holdings 1654	0.484	-0.002	-10.700	-25.157
	(1.731)	(1.610)	(27.024)	(25.698)
Latitude	1.314	1.311	107.156	107.407
	(6.305)	(5.912)	(88.333)	(94.421)
Longitude	2.554	2.682	-59.827	-55.870
	(4.937)	(4.716)	(48.507)	(50.853)
Fragmented lordship	-2.502***	-2.478***	-27.243***	-26.538***
	(0.848)	(0.872)	(12.024)	(11.465)
p value of test of exogeneity	0.499		0.001	

Notes. The number of observations for all regressions is 5,199. All regressions also include the estate means of the variables specified in the table, the coefficients of which are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (A4.1) and (A4.3) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure A2:
Elasticity of Coerced Labor with Respect to the Maximal Land-Labour Ratio, Bohemia 1757:
Estimates from Extended Specification

coerced labour do not depend on the particular measure of the land-labour ratio used in the regression analysis.
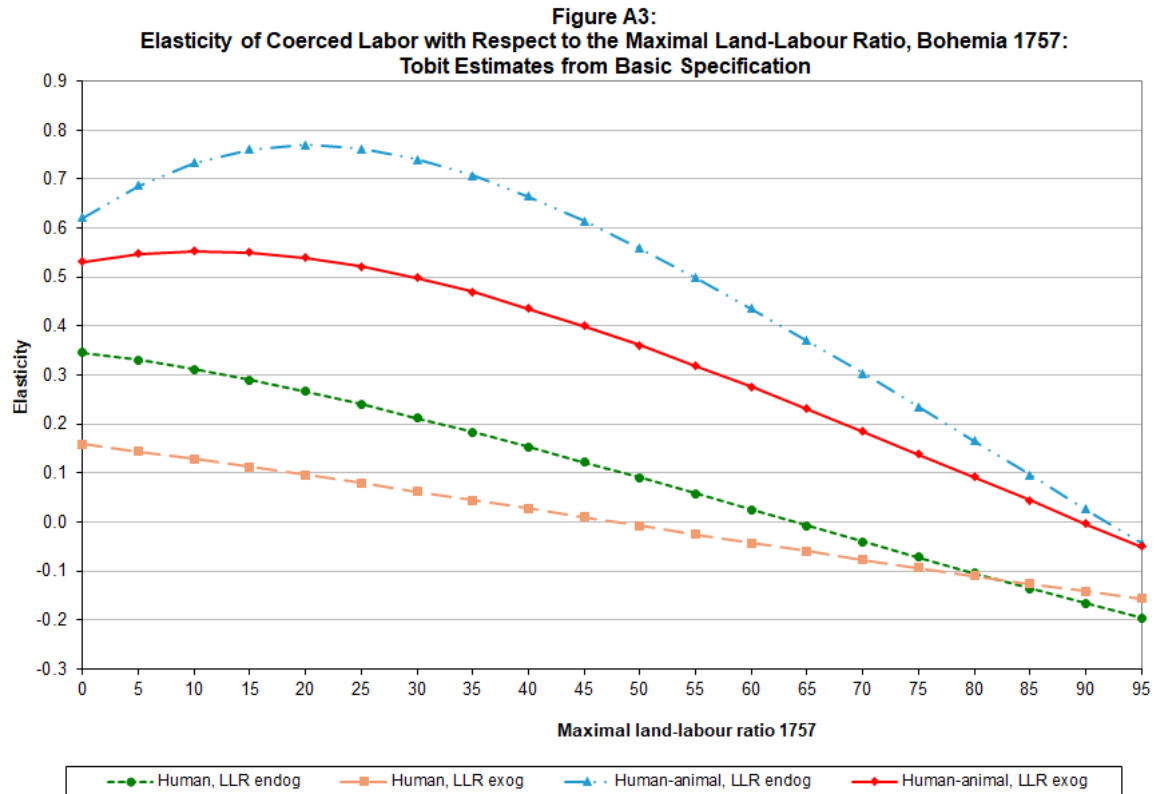

A5. Tobit Regression Results

In the main text, we analyse the effect of the village land-labour ratio on labour coercion using a two-part regression model, which allows us to estimate the effect of the land-labour ratio on both the probability of a village having coerced labour obligations and the size of such obligations conditional on their being positive. However, the two-part regression model is not the only one that can be used to analyse a data set in which the values of the dependent variable are concentrated at zero. In order to assess whether the results in the main text are robust to the use of alternative regression models, we also estimated the basic and extended specifications using a Tobit model.

Table A5 reports the Tobit estimates of the basic regression specification, and Figure A3 shows the elasticities of coerced labour with respect to the arable land-labour ratio implied by these results (with all regressors other than the land-labour ratio at their sample mean values). There are economically and statistically significant differences between the estimated effects of the land-labour ratio in 1757 on coerced labour according to whether this ratio is treated as an endogenous or exogenous regressor. The effect of the land-labour ratio on human-animal coerced labour is larger than that on human-only coerced labour, but the sizes of the elasticities of human-animal coerced labour with respect to the land-labour ratio implied by the Tobit estimates are smaller than those implied by the two-part model that are shown in Figure 1 of the main text. In contrast, the Tobit estimates of the elasticities of human-only coerced labour in Figure A3 are similar to the two-part estimates in Figure 1.

Table A5. Tobit Regression Analysis of Coerced Labour in Bohemia 1757: Basic Specification

	Dependent Variable			
	Human coerced labour		Human-animal coerced labour	
	LLR 1757 endogenous (A5.1)	LLR 1757 exogenous (A5.2)	LLR 1757 endogenous (A5.3)	LLR 1757 exogenous (A5.4)
Land-labour ratio 1757	0.420***	0.177**	13.339***	9.172***
	(0.108)	(0.073)	(1.321)	(1.263)
Land-labour ratio 1757 squared	-0.003***	-0.002***	-0.073***	-0.051***
	(0.001)	(0.0007)	(0.013)	(0.011)
Share of empty holdings 1654	3.899**	2.908	42.347*	23.876
	(1.681)	(1.767)	(24.977)	(25.231)
Latitude	8.598	8.804	144.293	146.138
	(7.417)	(7.471)	(95.966)	(94.060)
Longitude	2.005	2.629	-68.854	-56.805
	(5.585)	(5.517)	(61.612)	(63.146)
Fragmented lordship	-10.152***	-10.022***	-131.429***	-127.912***
	(0.926)	(0.990)	(12.286)	(12.655)
p value of test of exogeneity	0.071		0.001	

Notes. The number of observations for all regressions is 5,199. All regressions also include the estate means of the variables specified in the table, the coefficients of which are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (A5.1) and (A5.3) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure A3:
Elasticity of Coerced Labor with Respect to the Maximal Land-Labour Ratio, Bohemia 1757:
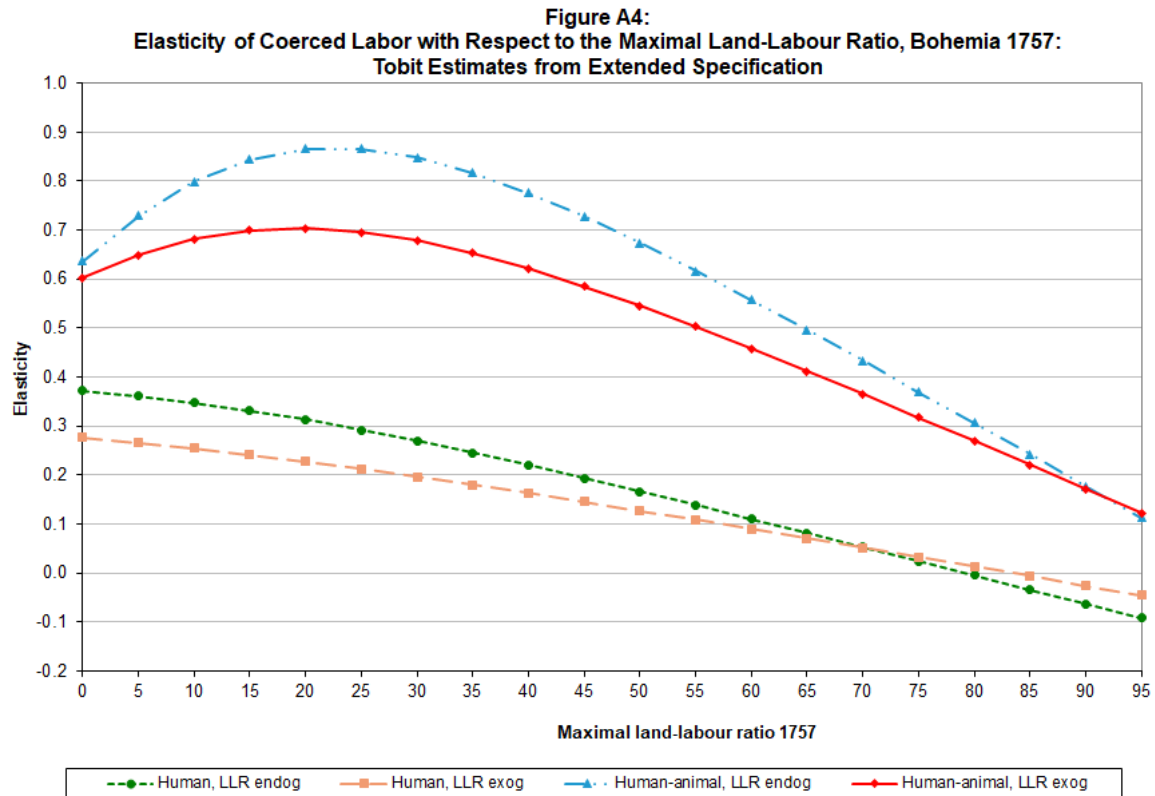**Tobit Estimates from Basic Specification**

Thus the Tobit estimates suggest a less pronounced difference between the effect of the land-labour ratio on human-animal and human-only coerced labour than do the two-part estimates.

A further difference between the Tobit and two-part estimates is that the effect of the land-labour ratio on human-animal coerced labour does not uniformly decline with the land-labour ratio in Figure A3, while it does in Figure 1 of the main text. This is particularly so when the land-labour ratio is treated as an endogenous regressor: in this case, the Tobit estimates imply that the effect of the land-labour ratio on coerced labour increases over the first 35-40 per cent of the sample distribution of values of the land-labour ratio, before it starts to decline as the land-labour ratio rises further. Despite these differences, the Tobit estimates of the basic specification lead to similar broad conclusions about the relationship between labour coercion and village land-labour ratios as do the two-part estimates discussed in the main text.

Table A6. Tobit Regression Analysis of Coerced Labour in Bohemia 1757: Extended Specification

	Dependent Variable			
	Human coerced labour		Human-animal coerced labour	
	LLR 1757 endogenous	LLR 1757 exogenous	LLR 1757 endogenous	LLR 1757 exogenous
	(A6.1)	(A6.2)	(A6.3)	(A6.4)
Land-labour ratio 1757	0.451***	0.321***	14.314***	11.354***
	(0.093)	(0.067)	(1.209)	(1.206)
Land-labour ratio 1757 squared	0.003***	-0.002***	-0.067***	-0.053***
	(0.0008)	(0.0007)	(0.012)	(0.011)
Village size 1757	1.958***	1.944***	26.193***	25.736***
	(0.280)	(0.264)	(2.279)	(2.100)
Village size 1757 squared	-0.007	-0.007	-0.131***	-0.128***
	(0.006)	(0.005)	(0.045)	(0.040)
Full towns inside estate	0.024	0.025*	0.225	0.232*
	(0.013)	(0.014)	(0.139)	(0.139)
Agro-towns inside estate	-0.038	-0.040	-0.187	-0.240
	(0.038)	(0.042)	(0.369)	(0.394)
Full towns outside estate	0.024***	0.024***	0.388***	0.404***
	(0.009)	(0.008)	(0.122)	(0.117)
Agro-towns outside estate	0.012	0.011	0.794*	0.757
	(0.033)	(0.036)	(0.448)	(0.476)
Royal towns	0.003	0.004	0.125	0.145
	(0.008)	(0.007)	(0.102)	(0.096)
Prague	0.006	0.005	0.092	0.074
	(0.007)	(0.006)	(0.097)	(0.064)
Share empty holdings 1654	0.185	-0.127	-4.535	-14.393
	(1.573)	(1.602)	(22.936)	(22.592)
Latitude	1.488	1.490	67.064	68.257
	(5.567)	(5.265)	(81.018)	(79.819)
Longitude	0.543	0.856	-80.645*	-72.522
	(4.396)	(4.267)	(46.022)	(47.298)
Fragmented lordship	-2.691***	-2.617***	-36.231***	-34.608***
	(0.821)	(0.810)	(10.503)	(10.346)
p value of test of exogeneity	0.627		0.016	

Notes. The number of observations for all regressions is 5,199. All regressions also include the estate means of the variables specified in the table, the coefficients of which are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (A6.1) and (A6.3) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure A4:
Elasticity of Coerced Labor with Respect to the Maximal Land-Labour Ratio, Bohemia 1757:
Tobit Estimates from Extended Specification

The same is true of the Tobit estimates of the extended specification, shown in Table A6 and Figure A4. These estimates of the effect of the land-labour ratio in 1757 on labour coercion differ from the two-part estimates of this effect obtained from the extended specification in the same way that the Tobit estimates from the basic specification differ from the two-part estimates. But both the Tobit and the two-part estimates show that the village land-labour ratio has a positive effect on labour coercion for most observed values of the land-labour ratio, and that this effect is larger for human-animal than human-only coerced labour.

A6. The Effects of the Land-Labour Ratio on the Separate Components of the Two-Part Regression Model

Tables 4 and 5 of the main text report the results of estimating the basic and extended specifications of the two-part regression model of labour coercion, but do not present the

results from the two parts separately. This Appendix reports the separate results from the two parts of the model.

Table A7 reports the results of estimating the two separate parts of the basic specification. Equations (A7.1) and (A7.2) show that the marginal effect of the land-labour ratio in 1757 on the probability of a village having coerced labour is positive, and the marginal effect of its square is negative, irrespective of whether this ratio is treated as an endogenous or exogenous regressor. These estimates are statistically significant, and their economic significance can be seen in Figure A5, which shows, at different values of the land-labour ratio in 1757, the elasticity of the probability of having labour coercion with respect to this ratio implied by these estimates. These elasticities are computed at sample mean values. They are never very large, though the p values of the estimates are below 0.05 for values of the land-labour ratio up to 50 (approximately the 90th percentile of the observed distribution) when the land-labour ratio is treated as endogenous, and up to 55 (above the 90th percentile) when it is treated as exogenous. Thus there is a small, but precisely estimated, positive effect of the land-labour ratio on the probability of a village having coerced labour obligations for the vast majority of observed land-labour ratios. Figure A5 shows that the estimates of this effect are a little different according to whether the land-labour ratio is regarded as endogenous or exogenous, especially at low values of this ratio. However, the p value of the test of the null hypothesis that the land-labour ratio and its square can be regarded as exogenous show that these differences are not statistically significant.
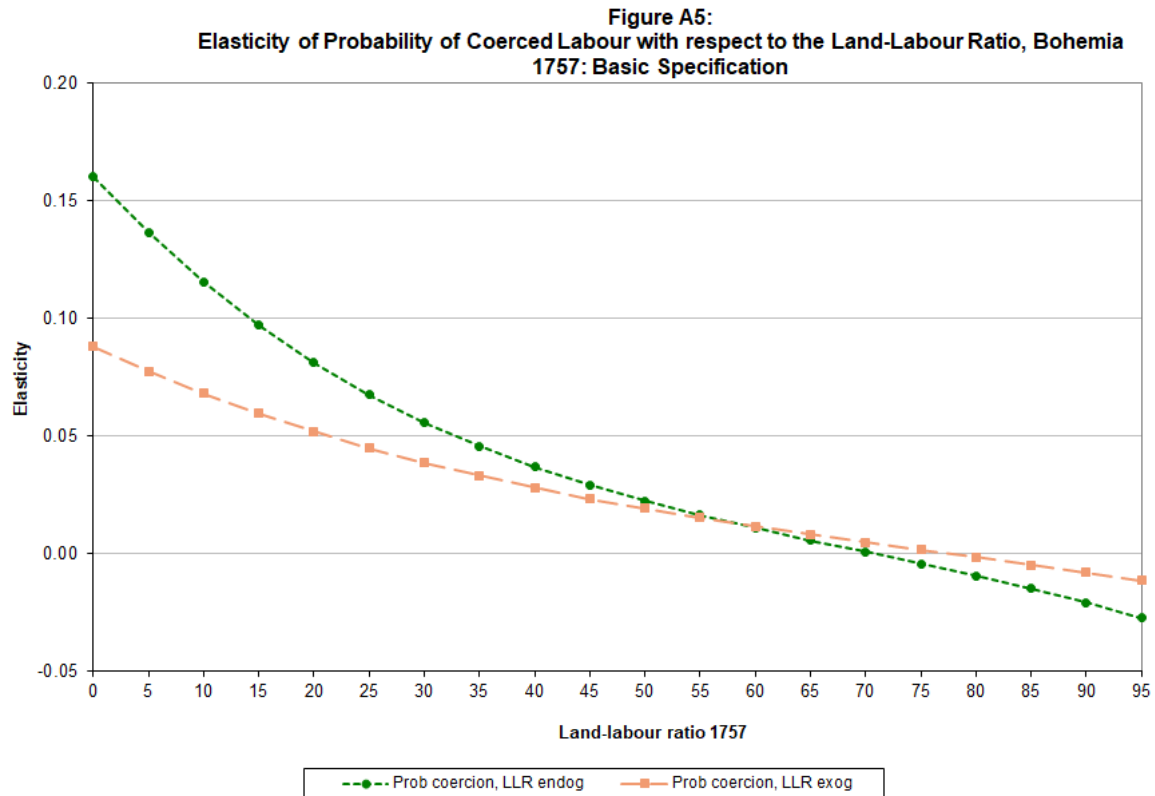
The estimated effects of the land-labour ratio in 1757 and its square on the amount of labour coercion in those Bohemian villages that had coerced labour obligations are shown in equations (A7.3)-(A7.6) of Table A7. Whether the land-labour ratio is treated as endogenous or exogenous makes a clear difference in the estimated effects of the land-labour ratio on
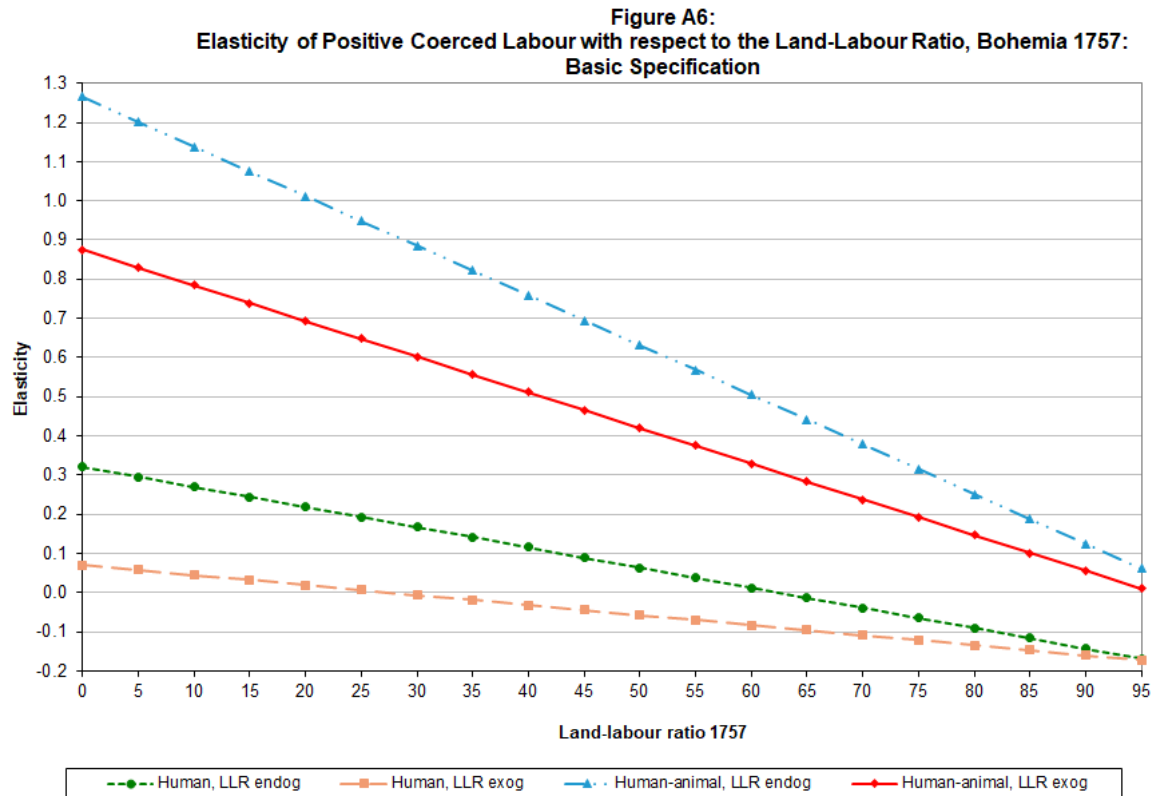
Table A7. Separate Components of the Two-Part Regression Model of Coerced Labour in Bohemia 1757: Basic Specification

	Dependent variable					
	Probability of having coerced labour		Conditional on there being any coerced labour			
			Human		Human-animal	
	LLR 1757 endogenous (A7.1)	LLR 1757 exogenous (A7.2)	LLR 1757 endogenous (A7.3)	LLR 1757 exogenous (A7.4)	LLR 1757 endogenous (A7.5)	LLR 1757 exogenous (A7.6)
Land-labour ratio 1757	0.0033***	0.0021***	0.346***	0.076	16.051***	11.106***
	(0.0009)	(0.0006)	(0.130)	(0.075)	(1.644)	(1.284)
Land-labour ratio 1757 squared	-0.00002**	-0.00001**	-0.003***	-0.001***	-0.080***	-0.058***
	(0.00001)	(0.000005)	(0.0008)	(0.0005)	(0.014)	(0.011)
p value of test of exogeneity	0.727		0.009		0.002	
Number of observations	5,199	5,199	4,617	4,617	4,617	4,617

Notes. All regressions include as regressors the share of unoccupied holdings in 1654, latitude, longitude, and a dummy variable for fragmented lordship. They also include the estate means of all these variables as well as of the land-labour ratio in 1757 and its square. The coefficients of these variables are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (A7.1), (A7.3) and (A7.5) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure A5:
Elasticity of Probability of Coerced Labour with respect to the Land-Labour Ratio, Bohemia 1757: Basic Specification

coerced labour conditional on this being positive. The null hypothesis that the land-labour ratio and its square are exogenous is strongly rejected. The differences between the estimated effects of the land-labour ratio according to whether it is regarded as endogenous or exogenous are economically significant. Figure A6 shows the elasticity of labour coercion with respect to the land-labour ratio implied by the various estimates in (A7.3)-(A7.6). To be comparable with the other elasticity estimates reported in this paper, the elasticities in Figure A6 are computed using the mean values from the sample of 5,199. The estimated elasticities of both human-only and human-animal coerced labour are considerably larger when the land-labour ratio is treated as endogenous rather than exogenous. For human-only labour coercion, the p values of these estimates are below 0.05 for land-labour ratio values up to 25 (approximately the 50th percentile of the observed distribution) when this ratio is treated as endogenous. By contrast, when the land-labour ratio is treated as exogenous none of the positive estimates has a p value below 0.05. For human-animal coerced labour, the estimated

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Figure A6:
Elasticity of Positive Coerced Labour with respect to the Land-Labour Ratio, Bohemia 1757:
Basic Specification

elasticities are much larger. When the land-labour ratio is treated as endogenous, the *p* values of these estimates are below 0.05 for values up to 80 (approximately the 98th percentile of the distribution). When it is treated as exogenous, the elasticity estimates are substantially lower, though the *p* values are below 0.05 for values of the land-labour ratio up to 75 (approximately the 97.5th percentile).

The land-labour ratio in 1757 thus had a positive, though small, effect on the probability of having coerced labour obligations for about 90 per cent of the Bohemian villages in our sample. For those villages with positive labour coercion, the land-labour ratio had a non-trivial, though not large, positive and well-determined effect on the amount of human-only labour coercion for the 50 per cent of the villages with the smallest land-labour ratios. By contrast, the effect of the land-labour ratio on human-animal coerced labour was much greater, being positive and precisely estimated for almost all villages, and corresponding to an elasticity of 0.5 or more for about 95 per cent of them.

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Table A8 shows the estimates of the two separate parts of the extended specification. In most cases, these are not very different from the corresponding estimates of the basic specification reported in Table A7. The only differences of note are that the estimated coefficient of the land-labour ratio in equation (A8.4) is much larger than that in (A7.4), and in (A8.6) the estimated coefficient of the land-labour ratio is somewhat larger than in (A7.6). The first of these differences is also reflected in the failure to reject the null hypothesis that the land-labour ratio and its square are exogenous regressors in (A8.3).

Figures A7 and A8 show the estimated effects of the land-labour ratio on the probability of a village having coerced labour and the amount of coerced labour conditional on this being positive implied by the regression results in Table A8. Again, the elasticities in these figures are computed at the mean values of the sample of 5,199. In Figure A7, the estimated elasticities of the probability of having coerced labour obligations hardly differ from those in Figure A5. These elasticities are positive and precisely estimated, though small, for values of the land-labour ratio up to 55 (approximately the 92.5th percentile of the observed distribution) when this ratio is treated as endogenous, and 65 (approximately the 96th percentile of the observed distribution) when it is treated as exogenous.

The main difference between the estimated elasticities with respect to the land-labour ratio shown in Figure A8 and Figure A6 is that those in Figure A8 are consistently larger. The difference is not very great when the land-labour ratio is treated as endogenous, but it is substantial when this ratio is treated as exogenous. For human-only labour coercion, the p values of these estimates are below 0.05 for land-labour ratio values up to 60 (approximately the 95th percentile of the observed distribution) when this ratio is treated as endogenous, and for values of up to 55 (approximately the 92.5th percentile of the observed distribution) when it is treated as exogenous. For human-animal labour coercion, the the p values of these

Table A8. Separate Components of the Two-Part Regression Model of Coerced Labour in Bohemia 1757: Extended Specification

	Dependent variable					
	Probability of having coerced labour		Conditional on there being any coerced labour			
			Human		Human-animal	
	LLR 1757 endogenous (A8.1)	LLR 1757 exogenous (A8.2)	LLR 1757 endogenous (A8.3)	LLR 1757 exogenous (A8.4)	LLR 1757 endogenous (A8.5)	LLR 1757 exogenous (A8.6)
Land-labour ratio 1757	0.0030***	0.0021***	0.362***	0.241***	16.351***	13.071***
	(0.0009)	(0.0005)	(0.094)	(0.060)	(1.361)	(1.140)
Land-labour ratio 1757 squared	-0.00002**	-0.00001**	-0.002***	-0.001***	-0.072***	-0.057***
	(0.000009)	(0.000005)	(0.0007)	(0.0005)	(0.012)	(0.010)
p value of test of exogeneity	0.573		0.724		0.013	
Number of observations	5,199	5,199	4,617	4,617	4,617	4,617

Notes. All regressions include as regressors the share of unoccupied holdings in 1654, latitude, longitude, a dummy variable for fragmented lordship, village size in 1757 and its square, the urban potential of full towns inside and outside the estate, agro towns inside and outside the estate, royal towns, and Prague. They also include the estate means of all these variables as well as of the land-labour ratio in 1757 and its square. The coefficients of these variables are not reported. Figures in parentheses are standard errors clustered at the estate level. In equations (A8.1), (A8.3) and (A8.5) the standard errors are obtained by bootstrapping with 500 replications. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels respectively.

Figure A7:
Elasticity of Probability of Coerced Labour with respect to the Land-Labour Ratio, Bohemia 1757: Extended Specification
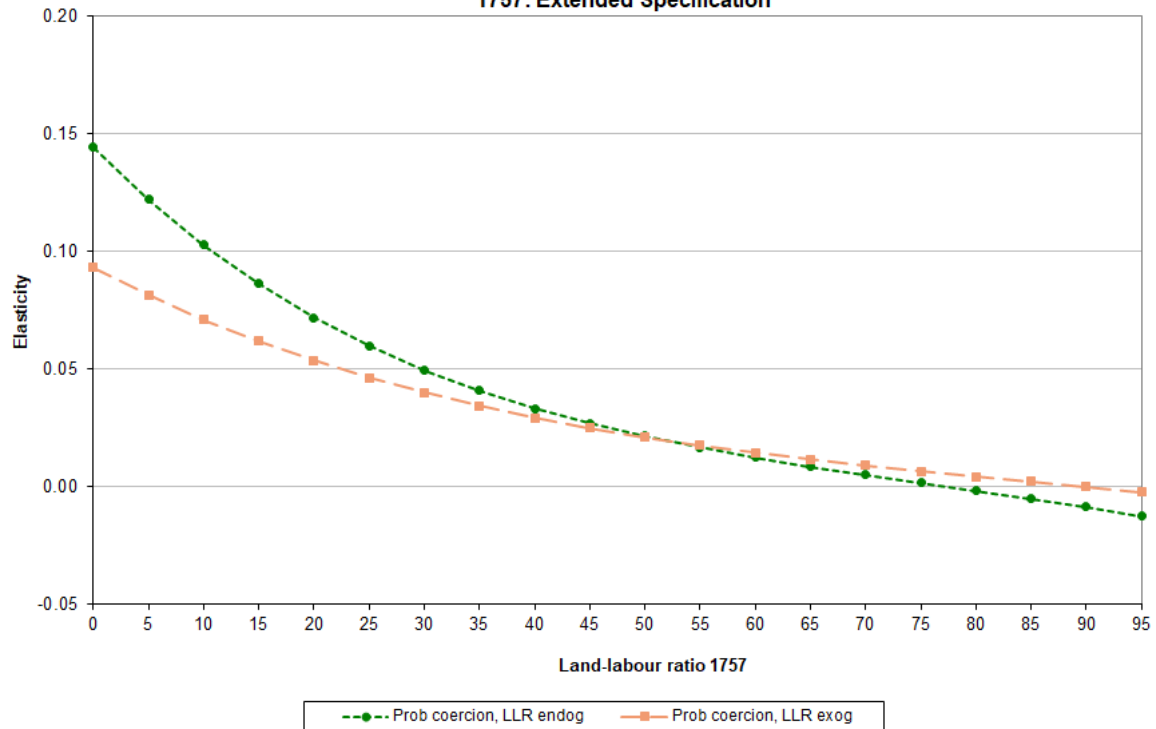
Figure A8:
Elasticity of Positive Coerced Labour with respect to the Land-Labour Ratio, Bohemia 1757: Extended Specification
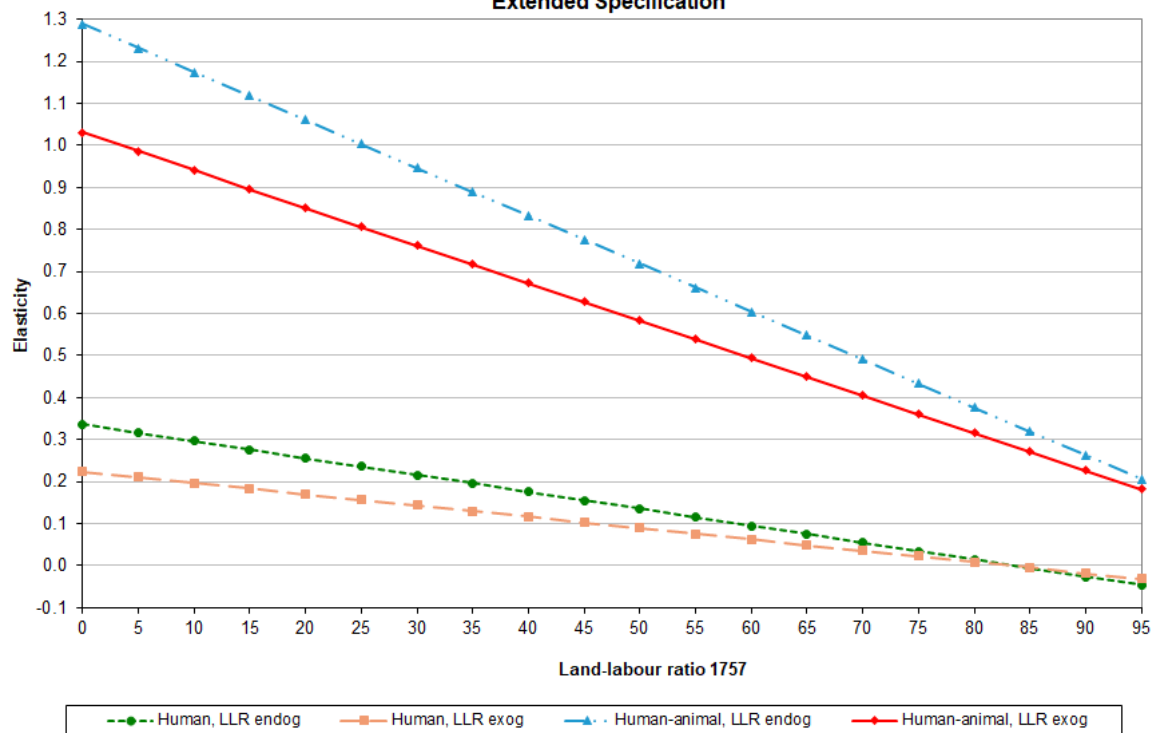
estimates are below 0.05 for all land-labour ratio values up to 95 (approximately the 99th percentile of the observed distribution).

The estimates from both the basic and the extended specifications of the two-part regression model produce very similar conclusions. In mid-eighteenth-century Bohemia, there is evidence of a Domar effect operating both on the probability of a village having coerced labour obligations at all, and on the size of these obligations conditional on their being positive. The Domar effect on the amount of labour coercion conditional on its being positive was stronger than that on the probability of a village having such coercion at all, especially for human-animal coerced labour. The effect of an increase in the land-labour ratio on both the probability of having coerced labour and the amount of labour coercion conditional on it being positive decreased as the land-labour ratio increased. Thus the main features of the results of estimating the two-part model reported in the main text were also present for the two parts separately.

A7. The Association between Village Size and Coerced Labour

Figure A9 shows the elasticities, at different values of village size, of human-only and human-animal coerced labour with respect to village size implied by the estimates reported in Table 5 of the main text. These elasticities are computed with all other variables at their sample mean values. The mean and median values of village size in 1757 in the sample of 5,199 are 14.46 and 11 respectively. The values of 20, 30, 40, 50 and 75 correspond respectively to the following percentiles of the sample distribution of village size: 80.5, 91.9, 96.1, 97.6, and 99.1.

Figure A9 shows that there is essentially no difference between the estimated elasticities of coerced labour with respect to village size according to whether the land-labour ratio in 1757 is treated as endogenous or exogenous. However, the estimated elasticities of

Figure A9:
Elasticity of Coerced Labor with Respect to Village Size, Bohemia 1757: Estimates from Extended Specification
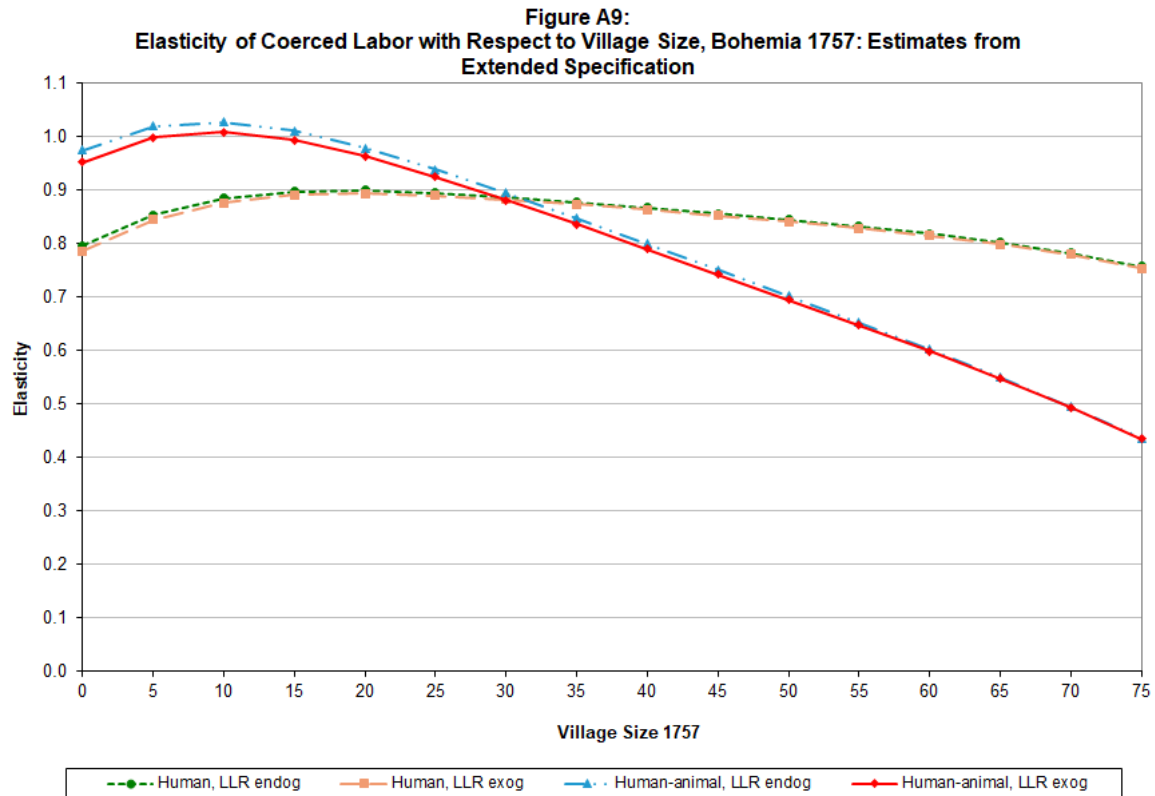
human-only coerced labour are somewhat different from those of human-animal coerced labour. The association between human-only coerced labour and village size increases slightly at low values of village size, but is almost unchanged for the majority of observed village sizes, and decreases only after about the 96th percentile of the sample distribution. None of these small differences at different village sizes in the elasticities of human-only coerced labour with respect to village size are statistically significant. By contrast, the association between human-animal coerced labour and village size is largest at about the sample median value of village size, and then decreases noticeably. The elasticities of human-animal coerced labour with respect to village size at the very highest observed values of village size are approximately half of the largest such elasticity, and the p values of the differences are below 0.10. But for about 90 per cent of the sample distribution of village size, these estimated elasticities vary little. For much of the sample, the differences in the association between village size and the two types of coerced labour are not great.