Prices and production: agricultural supply response in fourteenth-century England

PRICES AND PRODUCTION: AGRICULTURAL SUPPLY RESPONSE IN FOURTEENTH-CENTURY ENGLAND

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Abstract

This paper challenges the growing consensus in the literature (Stone, 2001, 2005) that medieval manorial managers were price responsive in their production decisions. Using prices of and acreages planted with wheat, barley, and oats on manors held by the bishop of Winchester from 1325-70, I estimate price elasticities of supply for each grain in aggregate and on each particular manor. Aggregate price elasticities of supply for wheat, barley and oats were rarely statistically significant and when significant were very low compared with elasticities estimated for developing and developed countries in the nineteenth and twentieth centuries. The low levels of agricultural supply response in fourteenth-century England suggest that commercialisation was not as dominant in the medieval economy as has been argued. Thus, structural changes in the economy such as the leasing of demesnes, the growth of wage labour, and the end of villeinage may have been more important in driving long-run economic change after the Black Death than price fluctuations. Likewise, a shift from low price responsiveness to higher price responsiveness could have been an important part of the capitalist transformation of agriculture in the early modern period.

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Over the past thirty years, medieval economic historians have challenged the opinions of earlier scholars that the medieval economy was a 'natural economy' devoid of significant money relations and commerce, arguing that commercialization played a strong role in medieval economic development. Britnell used new sources and methodologies to measure the proliferation of markets in England.[2] Campbell *et al*. studied how the counties surrounding London developed a unique economic structure in order to provide for the demand for agricultural commodities in the capital.[3] Masschaele and Kowaleski have described inland and overseas trade in their studies of markets and the marketing of goods in the late Middle Ages.[4] Clark, Galloway, and Bateman have argued that markets were relatively well integrated in late medieval England.[5] Briggs has described credit relations in medieval English villages.[6] Stone and Dodds have emphasized the remarkable flexibility and price responsiveness of seigniorial and peasant agriculture.[7] The growing consensus in medieval English history is that the late medieval period was characterized by well-developed commercial processes.[8]

However, there is reason to be suspicious of overly rosy views of the extent of commercialisation in medieval England. Britnell's more limited, localised interpretation of markets and trade and Kanzaka's findings that villain rents were mainly determined by custom rather than economic factors confirm this suspicion.[9] Essentially, the existence of money, markets, and trade does not mean that these forces were strongly or actively influencing economic development. Thus, this paper will test the degree of commercialisation in the medieval economy by measuring price responsiveness, or agricultural supply response, in seigniorial agriculture.

Development economists first developed methodologies for measuring price responsiveness in the late 1950s with Nerlove's seminal study of agricultural supply response.[10] Thus, price elasticities of supply have been estimated for a wide range of crops in many countries, including several historical calculations of elasticities in the late nineteenth century.[11] Generally, development economists have found positive price elasticities of supply for agriculture, suggesting that even in developing economies, farmers were price responsive. The elasticities for peasant production were lower than the elasticities for industrial farming, but they suggested that the picture of the risk-averse, non-profit maximizing peasant was largely a myth.[12]

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[2] Britnell, 'Proliferation', 209-21.

[3] Campbell *et al.*, *Medieval Capital*, 171-83.

[4] Masschaele, *Peasants*; Kowaleski, *Local Markets*.

[5] Clark, 'Markets'; Bateman, 'Evolution'; Galloway, 'One Market'.

[6] Briggs, *Credit*, 214-23.

[7] Stone, *Decision-Making*; Dodds, *Peasants.*

[8] Bailey, 'Historiographical Essay', 304-5.

[9] Britnell, 'Urban', 1-9; Kanzaka, 'Villein', 617.

[10] Nerlove, *Dynamics*; Askari and Cummings, 'Estimating', 257.

[11] Askari and Cummings, *Agricultural*; Schuh and Brandão, 'Theory', 660-65.

[12] Rao, 'Agricultural Supply Response', 5-6.

Medieval economic historians have also both implicitly and explicitly studied price responsiveness of manorial managers, reeves, with two schools of thought emerging. The older generation of medieval economic historians who mostly came before the commercialisation turn in the literature argued that reeves were unlikely to be profit-maximizers because strong institutional structures misaligned their incentives: reeves were not given a share of manorial profits, their responsibilities were onerous, and they were held personally liable for any losses during their tenure.[13] Likewise, the manorial account system developed by the lords and their representatives to monitor the reeves did not measure manorial profits but instead sought to protect the lord from fraud at the local level.[14] Biddick was the first to statistically test price responsiveness on nine manors held by the bishop of Winchester from 1209-37, and her findings generally confirmed the older generation's intuitions. Acreages planted with a particular crop were more highly correlated with the percentage of the harvest consumed by the bishop than with prices. Thus, price variations had a relatively low impact on reeves' planting decisions.[15]

However, in the last decade several historians have begun to refute this earlier consensus, using evidence of price responsiveness to argue for an expanded role of commercialization in medieval economic development. Dodds reconstructed peasant production from the tithe receipts of Durham Cathedral Priory and argued that peasants were price responsive in their production decisions because, for instance, the percentage of wheat out of the total tithe output was correlated with lagged wheat prices.[16] In addition, Stone has pieced together an extremely detailed picture of the managerial decision-making on the fenland manor of Wisbech Barton, arguing that reeves could be exceptionally good managers and were price responsive in the way they planted their fields. Stone extended this argument to a number of manors across Southern England, suggesting that good management and with it, price responsiveness, were widespread in seigniorial agriculture.[17]

Biddick, Stone and Dodds's research is very interesting and fruitful, but it raises concerns for several reasons. First, Stone only looked at a small sample of manors, which were not representative of the country or seigniorial agriculture as a whole. Second, Stone found that all of the manors had elements of price responsiveness, but they were all responsive in different ways. Some reeves were responsive in their planting decisions, for instance at Hambledon, Hinderclay, and Hanford manors, but others were responsive in the way they managed livestock, for instance pigs on Cuxham manor and sheep on Kinsbourne manor.[18] These results highlight good managerial practices in different aspects of manorial production, but they do not allow historians to understand the important economic question of whether price elasticities of supply for each particular good produced were

[13] Stern, *Hertfordshire*, 64-6; Robo, *Farnham*, 26-7; Drew, 'Manorial', 12-3; Harvey, *Medieval*, 63-74; Bailey, *Manor*, 31, 99.

[14] Postles, 'Perception', 23; Drew, 'Manorial', 16; Harvey, *Manorial*, 30-31.

[15] Biddick, 'Agrarian Productivity', 109-12.

[16] Dodds, *Peasants*, 161.

[17] Stone, *Decision-Making*, 206-12.

[18] Stone, 'Medieval', 619-23; Stone, *Decision-Making*, 189-212.

significantly different than zero in aggregate: i.e. was the price response in grain and livestock production substantial on the majority of manors across the country? Finally, neither Stone, Biddick, nor Dodds tested price responsiveness in a specific theoretical framework with robust econometric techniques. The correlations they cite as proof of price responsiveness are only a first step, which can be improved by estimating price elasticities of supply for the various crops.

This paper will thus expand upon existing work by testing whether reeves on the manors held by the Bishop of Winchester between 1325 and 1370 responded to annual price fluctuations in the way that they planted their fields. This may seem a rather narrow view of commercialisation, but agricultural price responsiveness was crucially important for economic development and growth. If producers were not price responsive, then planting decisions were on average determined by the crop rotations in practice and other non-market factors, not by prices or input costs. This would call into question producers' ability to adopt innovative technology or increase productivity in the absence of institutional or structural changes in the economy and would, therefore, weaken the influence of commercialization in the economy. However, if agricultural producers responded to prices or input costs in an attempt to maximize profit, then changes in prices and wages could have a significant influence on the development of agriculture and the medieval economy as a whole.[19]

I

The fourteenth century was a period of economic and social upheaval. There was a massive famine (1315-17) in which perhaps ten to fifteen per cent of the population of England died and a cattle plague beginning in 1319, which destroyed approximately half of the cattle population.[20] Later in the study period, the Black Death (1348-50) killed off at least 30 per cent of the population of England, and this number was only increased with recurrences of the plague in the 1361, 1369 and 1375.[21] The period was also punctuated by periods of exceptionally bad weather.[22] Conditions were quite different before and after the Black Death. In 1325, when this study begins, the economy was still recovering from the Great Famine and the cattle murrain, but although the landlords were squeezed by deflation and low prices in the 1330s, the seigniorial system continued as normal.[23] Following the Black Death, labour shortages forced wages up and landlords had a harder time maintaining the work force on their manors. This eventually threatened the profitability of the direct management of estates leading lords to lease out their manors at the end of the fourteenth and in the fifteenth centuries.[24] However, the twenty years or so following the Black Death saw a reinforcement of the manorial system sometimes called the

[19] Yotopoulos and Nugent, *Economics*, 135-7; Schuh and Brandão, 'Theory', 655-8.

[20] Campbell, 'Nature', 9-10; Newfield, 'Cattle', 171-80; Slavin, 'Great Bovine Pestilence', pp. 1241-43.

[21] Campbell, *English*, 6-7; Hatcher, *Plague*, 21-6; Keen, *English*, 27-9.

[22] Campbell, 'Nature'; Campbell, 'Grain'.

[23] Campbell, *English*, 4-7.

[24] Campbell, *English*, 6-10; Hare, 'Bishop', 209-11.

'Indian summer of demesne farming' as lords were able to maintain direct management without major interruptions.[25]

The shocks of the fourteenth century greatly affected the economic system and surely affected the production decisions that reeves and estate managers were making at the local and estate level respectively.[26] However, rather than investigating the influence of these shocks, this paper seeks to understand whether reeves considered annual price variation when making their production decisions. Thus, it tests the more incremental argument of the commercialization model that individuals' responses to market forces drove economic development. Therefore, although the years studied here cover periods of economic turmoil, they can still serve to test whether reeves were price responsive in their production decisions. [27]

The manorial accounts which form the primary source on medieval farming for this paper were an annual account through which the lord's representative, the steward, scrutinized how each of the lord's manors was managed. These accounts were enrolled in the Winchester Pipe Rolls for a majority of the manors held by the Bishop of Winchester and contain a wealth of information about the seigniorial agricultural economy, including crop yields, acreages sown with various crops, seed rates, grain prices, and piece wages for a large number of manors across the southern and southwestern counties of England.[28] From these accounts, we can then construct a detailed picture of how manorial management worked.

The bishop of Winchester's steward managed all of his estates with bailiffs usually in charge of a couple of manors.[29] Although there is evidence that these officials had control over the bishop's flocks of sheep, there is little evidence to suggest that the central authorities interfered in annual planting decisions on individual manors.[30] Therefore, planting decisions, along with all other day-to-day management of the demesne, the lord's land on each manor, were left to the reeve. Reeves were typically elected from the ranks of local customary tenants. Contemporary treatises on manorial management suggest that the reeve's position should have passed to a different person every year unless the reeve had 'proved very capable, just in his actions, and well able to further the lord's interests'.[31] In practice, however, the reeve's position often fell to those who had proven their ability to manage the demesne well, and these individuals stayed in post for a number of years.[32]

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[25] Bridbury, 'Black Death', 584; Hatcher, 'England', 6; Stone, *Decision-Making*, 82-4.

[26] Campbell, *English*, 375-6; Titow, *English*, 49; Campbell, 'Grain', 156-161.

[27] Ó Gráda, *Famine*, 143-55.

[28] Titow, *English*, 24-9; Farmer, 'Prices', (1988), 715-16; Harvey, *Manorial*, 25-37.

[29] Page, 'William Wykeham', 105; Page, *Medieval Bishops,* 8-11; Thornton, 'Determinants', 201-2.

[30] Thornton, 'Efficiency', 32, 42-4; Hare, 'Bishop', 205; Page, 'Technology', 140-3; One example of interference was that the sub-manors of Taunton were originally managed centrally from Taunton Castle, but in the late thirteenth century, the manors were reorganized to be managed at the local level. Thornton, 'Level', 113-5.

[31] Oschinsky, *Walter*, p. 279.

[32] The Merton College manor of Cuxham had two reeves in the pre-Black Death period (1288-1349), one serving c. 21 years and the other serving c. 38 years. The average length of time spent could

Reeves did have some incentives to be price responsive. In return for their services, they were exempt from customary manorial fees and labour obligations and received some food and other small bonuses at harvest time.[33] Reeves were also occasionally allowed to keep production above a certain level; for instance, St. Swithun's Priory allowed reeves to keep production above 60 piglets, 28 goslings, 60 chickens, and 300 eggs, giving reeves on their manors some incentives to produce above this level to gain profit themselves.[34] Finally, reeves could use their authority to gain influence in the community and to embezzle goods or money from the lord.[35] Reeves also continued to farm their own plot while managing the demesne and thus, had no subsistence related risk aversion often attributed to peasants when making decisions about demesne land.[36] Thus, reeves had some incentives to consider prices when making production decisions, though these incentives likely changed over time based on the relative burden of manorial obligations and the time required to manage the demesne.

However, there were also clear limitations to the reeve's incentives and production flexibility. Although reeves received remuneration for their services, the job was very onerous, and it is not clear that the exemptions reeves received for taking on the position would equal or exceed the losses they likely faced from lost labour and time on their own plots; there are several known cases where customary tenants paid a substantial fee to avoid serving as the reeve.[37] In addition, reeves were held personally responsible for any losses, real or perceived, that came up in the audit, but they received no extra bonuses if they managed the manor efficiently. In fact, the definition of 'efficient' management appears to have been very different than the modern profit-maximizer's calculation. The main purpose of manorial accounts was not to measure profit or loss (profit calculations varied across estates and were not even calculated for some estates) but instead to ensure that the lord was not being defrauded by the local officials.[38] Thus, reeves' performance was not judged on their ability to measure opportunity cost and take prudent decisions in response to market forces.

In addition, there was some path dependency in the production strategies that would have limited the reeves' ability to adjust the acreage planted on a year-to-year basis. Basic crop rotation and fallowing was necessary to maintain the nutrient content of the soil. In its simplest form, this rotation consisted of three fields: one sown with a winter crop such as wheat, one sown with spring crops such as barley and oats, and one left fallow to regain some of its nutrients. Clearly, in this system reeves could not switch all of their production to wheat in response to climbing wheat

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be much lower, though, with reeves at Kinsbourne manor from 1293-1397 serving an average of 3 years. Harvey, *Medieval*, 64; Stern, *Hertfordshire*, 65; Stone, *Decision-Making*; Bailey, *Manor*, 99.

[33] Bailey, *Manor*, 98-9; Harvey, *Medieval*, 69-71; Drew, 'Manorial', 27-9.

[34] Drew, 'Manorial', 28.

[35] Harvey, *Medieval*, 69-71; Drew, 'Manorial', 27-9.

[36] Page, *Medieval Bishops*, 8-11, 22; Page, 'William Wykeham', 106-7; Titow, *Winchester*, 2-3; Stone, *Decision-Making*, 169-70; Thornton, 'Determinants', 186, 202.

[37] Drew, 'Manorial', 27; Bailey, 31, 98-9; Harvey, *Medieval*, 65-6.

[38] Stern, *Hertforshire*, 64-6; Harvey, *Manorial*, 28-9; Drew, 'Manorial', 16; Bailey, *Manor*, 98-9.

prices.[39] Likewise, reeves' flexibility was limited by their requirement to provide for the consumption of the lord's household. This might mean providing lambs for meat, wheat for bread, or oats as fodder for the lord's horses.[40] Finally, reeves may have avoided major investment that could not be recuperated quickly in order to avoid falling into arrears. This would be especially true of large capital outlays, though it makes less sense for grain planting decisions since the grain was normally sold within a year of the harvest.[41]

Having discussed the responsibilities of reeves, we can move on to discuss the specific context of the Winchester estates. Unfortunately, the Winchester manors were not representative of seigniorial agriculture across England. Large ecclesiastical manors made up a minority of seigniorial land, and seigniorial land itself was dwarfed by the peasant agricultural sector.[42] Even for ecclesiastical manors, the Winchester manors were larger than average, both in terms of the grand scale of the estate as a whole and individual manors. The Winchester estate was also held in direct management for longer than almost any other estate whose records survive and relied more heavily on labour obligations than other estates, which had to hire labour.[43] The large size of the Winchester estates also meant that from a very early date they sold larger amounts of their produce than other seigniorial estates: 66 per cent of the wheat harvest was sold between 1209 and 1237 on Biddick's nine Winchester estates, and 64 per cent of the net crop was sold circa 1300 on thirteen of the bishop's manors near London.[44] In terms of cropping patterns, many of the manors followed three-course rotations or sowed almost exclusively wheat, barley and oats. This pattern was fairly common throughout Southern England with 53.3 per cent of demesnes in Campbell's demesne dataset falling into these production types.[45] However, the Winchester manors along the Thames and in the Chilterns and Cotswolds sowed large amounts of mixed grains and had a ready market for their produce in London, making them similar in some ways to the productive and commercialized manors of East Anglia and Kent.[46] Despite this diversity, the composition of cropping and husbandry types does not follow the national pattern. More intensive cropping and mixed-farming types are underrepresented in the sample.[47]

The 'uniqueness' of the Winchester estates makes it difficult to extend all findings from the Winchester manors to a broader context of fourteenth-century England.[48] However, it is possible to speculate about how this uniqueness would have affected their relative price responsiveness. The size and market orientation of the manors would suggest that the Winchester estates were more likely to be price

[39] Titow, *English*, 19-21; Campbell, *English*, 10-16; Thornton, 'Determinants', 184-7.

[40] Biddick, 'Agrarian Productivity', 104; Harvey, *Medieval*, 75-9; Campbell, *English*, 55-6.

[41] Farmer, 'Marketing', 358-63.

[42] Campbell, *English*, 60; Dodds, 'Demesne', 124; Campbell, 'Unique', 22-4.

[43] Campbell, 'Unique', 26-7; Farmer, '*Famuli*', 211.

[44] Biddick, 'Agrarian Productivity', 106; Campbell, 'Measuring', 158-60; Campbell, 'Unique', 29.

[45] Campbell, *English*, 277.

[46] Titow, *Winchester*, 23, 73-81.

[47] Campbell, *English*, 277.

[48] Campbell, 'Unique', 39-43.

responsive because there would be greater gains from price responsiveness with greater output marketed. The bishopric's reliance on forced labour throughout the fourteenth century may have made them less responsive to changes in prices relative to wages, but this should not have affected the incentives of reeves to respond to prices or relative prices as described below. On the other hand, the conservative and extensive crop rotations may have limited reeves flexibility in adjusting their cropping patterns more than the intensive systems predominant in East Anglia, lowering their ability to be price responsive. On balance, then, there were factors that would have made the Winchester estates more and less price responsive than the average manor. It would be ideal to conduct a similar study on a wider range of manors, but the Winchester manors can provide a useful starting point for robustly measuring agricultural supply response in fourteenth-century England.

I did not collect the data used for this dataset from the original documents, instead drawing extensively on the notes of D. L. Farmer held in the archives at the University of Saskatchewan and the notes of Jan Titow held in the Hampshire Record Office.[49] The paper is based upon two datasets of manors held by the bishop of Winchester: a panel dataset of 31 manors from 1325 to 1348 and a panel dataset of 49 manors (including the initial 31) from 1349-70. When estimated separately, the panels are strongly balanced but do have some missing data because the manorial accounts were damaged or have not survived. This paper relies upon two main aspects of the accounts: the acreage planted with wheat, barley, and oats; and the respective prices of these grains. As mentioned above, other grains such as fodder crops and mixed grains were also planted on the Winchester estates, and on a few manors they dominated the arable land. However, over the entire Winchester estate fodder crops and mixed grains only made up an average of 14.08 per cent of arable land planted each year on the 31-manor sample from 1325-70.[50] Considering the low percentages of arable land sown with mixed grains and the fact that leguminous fodder crops were rarely marketed, it seems reasonable to focus on wheat, barley and oats in this paper.[51] Titow and Farmer recorded the acreage of wheat, barley and oats sown on each of the Winchester manors.[52] The average acreage in seed (1349-70) ranged from 43 acres on Bitterne manor in southern Hampshire to 489 acres on East Mean manor also is southern Hampshire with a median across all manors of 134 acres. In order to compare acreages sown across manors in the regressions, it was necessary to standardize the acreages: the acreage of each crop sown in a given year was divided by the average acreage of that crop sown on the manor over the period or sub-period studied.

Farmer also recorded many local and regional price series along with a national price series for wheat, barley, and oats. Unfortunately, manor-specific wheat prices were not available for all years, so manor specific prices were interpolated with Farmer's regional price series. The interpolated prices made up less than 10 per cent of the data. Barley and oats prices were either not available on a manor specific level

[49] University of Saskatchewan Archives, The Papers of David Farmer, Series III, Boxes 11, 12, and 14; Hampshire Record Office, Titow Research Papers, 97M97/B1, 97M97/B5.

[50] Corroborated by Titow, *English*, 42; Hare, 'Bishop', 194-6, 202.

[51] Campbell, 'Measuring', 157.

[52] University of Saskatchewan Archives, The Papers of David Farmer, Series III, Box 10, Folder 1, parts 1-4.

or had too many missing values to be used at the manor level. Therefore, Farmer's regional price series, the arithmetic mean of the prices on manors in each region, were used in the regressions. These regional series were interpolated using Farmer's national series.[53] As a robustness check, the regional wheat price series was also used in the regressions, but there was no change in the results. Farmer's national wage series was not available in disaggregated form among the scanned copies of his notes, so the national reaping wage series was used in the regressions.[54]

II

Previous studies of price responsiveness in medieval England solely used correlation coefficients to measure whether the acreage sown with a particular grain varied in relation to the price. Pearson correlations measure whether there is a relationship between two variables. However, they cannot reveal the causality between the two variables, and they do not measure the size of the response, i.e. the amount of extra land planted when the price of a certain grain increases.

In order to determine causality, one must form a theoretical model that links the prices and supply. Dodds, Stone, and Biddick had implicit models even though they did not elaborate them in detail. Stone argued that the acreage planted with a particular grain at the beginning of the year was determined (in part) by the price of the grain throughout the same year.[55] Thus, he assumes that reeves were able to predict the wheat price in the twelve months after they planted their wheat crop in the late autumn and adjusted the acreage sown with wheat accordingly. This seems a rather heroic assertion given that prices fluctuated substantially throughout the year and reeves could not have been privy to all of the information needed to perfectly predict the price in the year after they planted their crops.[56] Biddick and Dodds, on the other hand, follow the traditional agricultural supply response literature in arguing that acreage decisions made at the beginning of the harvest year were based on reeve's understanding of past prices. Thus, Dodds uses an average of prices in the previous two years and Biddick uses a number of lagged prices before settling on the price in the previous year.[57]

However, even with an implicit theoretical model, correlations between prices and acreages planted are not robust enough to measure price responsiveness because they do not measure the size of the effect of one variable on the other. For example, imagine a hypothetical manor where the reeve sows one hundred acres with wheat on average, and the average wheat price is 8 shillings/quarter. Now suppose the reeve increases or decreases the acreage sown by one acre in the current year for every two shillings/quarter change in the wheat price in the previous year: thus, the reeve plants 102 acres of wheat when the wheat price was 12 shillings/quarter in the previous year

[53] Farmer, 'Prices', (1991), 501-25; Farmer, 'Prices', (1988), 787-817; University of Saskatchewan Archives, The Papers of David Farmer, Series III: Box 10, Folder 30; Box 12, Folder 50; Box 14, Folders 1, 2, and 5.

[54] Farmer, 'Prices', (1991), 501-25.

[55] Stone, *Decision-Making*, 206-12; Stone, 'Medieval', 619-23.

[56] McCloskey and Nash, 'Corn', 177-8.

[57] Biddick, 'Agrarian Productivity', 106-9; Dodds, *Peasants*, 161.

and 98 acres of wheat when the wheat price was 4 shillings/quarter in the previous year. A Pearson correlation coefficient would show a strong relationship between the acreage planted with wheat and the wheat price in the previous year, but this does not mean that the price had any influence on overall supply. Assuming constant yields, the total output would only increase by 2 per cent even though the price increased by 50 per cent. This scenario would yield a very low price elasticity of supply of 0.034.

Thus, in order to measure the size of the influence of prices on acreage planted, it is necessary to use regression analysis. In order to compare price responsiveness across manors, elasticities of supply must be estimated. A price elasticity of supply is simply the percentage change in output that is caused by a one per cent increase in the price. Generally, elasticities greater than or equal to one are considered to be elastic or highly responsive to prices because a one percentage increase in the price leads to a larger than one per cent increase in the supply. Elasticities less than one are considered inelastic or not particularly responsive to prices. However, agricultural price elasticities of supply are rarely as high as 1 because farmers in all time periods had less flexibility to adjust their output than firms in other sectors of the economy. Therefore, later in the paper the medieval price elasticities estimated will be compared with price elasticities of supply for agricultural production in the nineteenth and twentieth centuries to gauge whether medieval price elasticities of supply were low relative to others.

This paper employs a partial adjustment model to estimate price elasticities of supply. The exact formulation of the model along with the methods of estimation are provided in Appendix A for those apt in modelling and econometric techniques. Put simply, the partial adjustment model assumes that there is an equilibrium or desired acreage that farmers will want to plant with a certain crop based on expected prices. However, farmers may not be able to immediately adjust their production to the equilibrium level and the model accounts for this by allowing the equilibrium level to be reached over a period longer than one year.

The reeve's expected price is held to be the price of each grain in the previous year.[58] This may seem an unrealistic assumption, but the correlation between the wheat price in the current year and previous year is higher than the correlation between the wheat prices in the current year and any other lags and moving averages of lagged prices. Thus, the price in the previous year may be the best indicator of price fluctuations in the subsequent year anyway. As Askari and Cummings have argued, it is necessary to represent the price in different ways in the model in order to capture the various incentives that farmers faced.[59] Three price measures were used in the regressions in order to understand more precisely what triggered reeves to shift their production: the price of each grain, the relative cost of a grain and its closest substitute, and the labour input costs measured as the price of the grain divided by the reaping wage. As mentioned above, manor specific wheat prices were available for all manors, but regional prices were used for barley and oats in the regressions. Reaping

[58] Unfortunately, it is not possible to use a more complex notion of expected prices in the partial adjustment model without controls that were unavailable for the medieval period. See note 95 in the appendix.

[59] Askari and Cummings, 'Estimating', 259.

wages were highly correlated with ploughing, mowing, and threshing wages, and therefore can be used as a proxy for all labour input costs.[60]

The main indicator produced by the partial adjustment model is the short-run price elasticity of supply. The short-run price elasticity of supply is the percentage change in acreage caused by a one per cent increase in the price in one year. There are three possible interpretations of the short-run price elasticity. If the short-run elasticity is statistically significant and positive, then reeves planted larger acreages with a crop when its price was higher and, therefore, attempted to maximize profit from that crop. If the short-run price elasticity of supply is negative, then reeves planted larger acreages with a crop when its expected price was low. Finally, if the short-run price elasticity of supply is not significantly different than zero, then reeves did not respond to prices in their planting decisions.[61]

The model was estimated first for the panels of 31 and 49 manors for the periods 1325-48, 1349-70, and 1325-70. These panel estimators produce an aggregate measure of price responsiveness on the Winchester estate. In addition, price elasticities of supply were estimated for each manor as a time series for the 49 manors for which data exist from 1349-70 in order to understand what factors influenced supply responsiveness on different manors across the estate.

III

The aggregate price elasticities of supply estimated using the entire Winchester panel dataset suggest a pessimistic interpretation of price responsiveness in medieval England. Price elasticities of supply for wheat were either not statistically significant or were negative across all time periods (Table 1). Barley price elasticities varied across time periods from negative elasticities for the period before the Black Death to positive, yet small elasticities after the Black Death. This change may reflect reeves' response to growing demand for barley after the Black Death. Oats elasticities of supply were positive and significant before the Black Death but became insignificant after the Black Death. These positive elasticities for oats are surprising considering that oats were marketed less than barley or wheat. Perhaps the demand for oats as food before the Black Death and the greater flexibility of planting in the spring field led to some price responsiveness.[62] It is also surprising that many of the price elasticities for the price relative to the wage were significant, suggesting that the Winchester estates were not immune to labour cost pressures despite their large supply of coerced labour. In conclusion, aggregate price elasticities of supply for wheat were zero, and the price elasticities of supply for barley and oats were very low even if they were statistically significant.

[60] Farmer, 'Prices', (1991), 501-25.

[61] Yotopoulos and Nugent, *Economics*, 135-7.

[62] Campbell, *English*, 245-7.

Table 1: Price elasticities of supply for wheat, barley and oats on the Winchester manors 1325-70.

	Wheat				Barley				Oats			
Price Elasticities	1325-48	1349-70	1325-70	1349-70*	1325-48	1349-70	1325-70	1349-70*	1325-48	1349-70	1325-70	1349-70*
Grain Price	-0.018	-0.024*	-0.039***	-0.009	-0.040**	0.031*	0.001	0.028	0.092***	-0.022	-0.024	-0.017
Grain Price Relative to Substitute	-0.048	-0.049***	-0.073***	-0.066***	-0.052*	0.028	-0.032	0.045*	0.015	-0.039	0.017	-0.032
Grain Price Relative to Labour Costs	-0.022	-0.008	-0.014	0.007	-0.037*	0.034**	-0.028**	0.035**	0.090***	-0.003	0.042***	-0.002

Notes: Short-run price elasticities estimated using equation 3 in appendix I for each grain, time period and price type are reported. The fourth starred column (1349-70) includes all 49 manors while the unstarred periods only include the smaller panel of 31 manors. Stars denote significance in the following manner: * significant at the 10 per cent level, ** significant at the 5 per cent level, *** significant at the 1 per cent level.

Sources: see text.

At the disaggregated level for the 49 manors available from 1349-70, the supply response to changes in wheat prices was generally quite low across the Winchester manors. Only fourteen manors had significant short-run price elasticities of wheat supply in the regressions: five positive elasticities and nine negative elasticities (Tables 2 and 3). These price elasticities, estimated in time series regressions with first differenced variables, are not directly comparable with the aggregate elasticities presented above, so they have not been reported here. Overall, ignoring statistical significance, there were 20 manors with positive average price elasticities across the three price types (41 per cent).

Table 2: Summary of time series results for supply response on individual manors.

	Wheat	Barley	Oats
Total Manors	49	42	48
Positive, Significant Elasticities	5	9	5
Negative, Significant Elasticities	9	4	12
Insignficant Elasticities	35	29	31
Mean Short-run Positive, Sig. Elasticities	0.236	0.501	0.424
Min Short-run Positive, Sig. Elasticities	0.148	0.213	0.168
Max Short-run Positive, Sig. Elasticities	0.370	1.096	0.863
Positive Elasticities	20	23	14
Negative Elasticities	29	19	34
Percentage Positive Elasticities	40.82%	54.76%	29.17%

Sources: see text.

Positive and significant price elasticities of barley supply were much more prevalent for the Winchester manors than positive price elasticities of wheat supply: nine manors had significant, positive elasticities; four manors had significant, negative elasticities; and twenty-nine manors did not significantly adjust planting strategies based on the price. Again setting aside statistical significance, of the 42 Winchester manors where barley was sown, 23 had positive average price elasticities, or 55 per cent. The response for barley was therefore different than the response for wheat in the period after the Black Death in three key ways: there were more positive

and significant price elasticities on individual manors; ignoring statistical significance, there were more manors with positive price elasticities; and the aggregate elasticities were statistically significant, though low. These differences are expected because the acreage of barley could be changed more easily without disrupting long-term cropping strategies by decreasing the acreage planted with oats in the spring-sown field. Thus, one would expect more responsiveness between the spring-sown crops than wheat, which was more often sown in its own field or with small amounts of rye and mixed grains. Barley may have also been more responsive because increasing demand for barley following the Black Death made it a highly marketable crop, perhaps providing incentives for price responsiveness in barley planting decisions.[63]

The supply response to oats was much more prevalent than expected. Five manors had positive and significant short-run price elasticities of supply for oats, and twelve manors had significant and negative price elasticities of supply for oats. The fact that seventeen manors in total were price responsive in their oats planting is puzzling: oats were both heavy and bulky to transport; they were used predominantly as a fodder crop, especially following the Black Death; and they were rarely marketed.[64] Ignoring statistical significance, there were very few manors that had positive price elasticities: 14 manors had positive average price elasticities (29 per cent) while 34 had negative average price elasticities.

This strongly negative price response in oats planting decisions after the Black Death may be explained as a counterpoint to the positive price response in barley planting decisions discussed above. Because all grain prices were highly correlated and oats production was constrained within the spring-sown fields, an increase in barley sown would require oats sown to diminish in response. This response was not statistically significant at the aggregate level, but it could help explain the large number of manors with negative price elasticities of oats supply.

In summary, there were reeves on a number of manors that responded to different price variables in determining the acreage sown with wheat, barley, and oats. Positive and significant price elasticities were higher and more prevalent for barley than for wheat or oats because barley was easily substitutable with oats within the spring-sown field and because barley was highly marketable as a brewing grain following the Black Death.[65] Wheat elasticities were understandably lower because wheat was the primary winter-sown grain, which meant that in the absence of other winter sown grains, a substantial change in the acreage planted with wheat would require altering existing crop rotations. However, in aggregate the price elasticities were low if not insignificant or negative; reeves were not price responsive when making planting decisions.

[63] Campbell, *English*, 243-5.

[64] Campbell, *English*, 245-7.

[65] Campbell, *English*, 243-5.

Table 3: Summary of price elasticities of supply on 49 Winchester manors, 1349-70

Manor Name	Wheat Elasticities	Barley Elasticities	Oat Elasticities
Adderbury	0		0
Alresford	0	0	0
Ashmansworth	+	0	–
Beauworth	–	0	0
Bentley	0	–	0
Bishop`s Stoke	0	0	0
Bishop`s Waltham	0	–	–
Bitterne	0	+	0
Brightwell	0	0	0
Brockhampton	+	0	0
Burghclere	0	0	–
Cheriton	0	0	+
Crawley	0	0	0
Culham	0	+	+
Downton	0	0	–
Droxford	0	0	–
East Meon	0	0	0
East Meon Church	–	0	0
Eblesbourne (Bishopstone)	0	0	0
Ecchinswell	–	0	–
Fareham	0	–	+
Farnham	–	+	0
Fonthill	–	+	0
Hambledon	–	0	0
Harwell	0	0	+
High Clere	–	0	–
Ivinghoe	0	+	0
Knoyle	0	0	0
Mardon	0	+	0
Marwell	0	0	0
Morton	0		0
North Waltham	0	+	–
Overton	–	0	–
Rimpton	0	0	0
Sutton	0	+	0
Taunton Holway	0		0
Taunton Hull	0		0
Taunton Nailsbourne	0		0
Taunton Poundisford	0		+
Taunton Staplegrove	0		0
Twyford	0	+	–
Upton	+	–	–
Waltham St Lawrence	0	0	0
Wargrave	0	0	0
West Wycombe	+	0	0
Wield	–	0	0
Witney	0	0	0
Wolvesey	0	0	
Woodhay	+	0	–

Notes: + denotes at least one positive and significant price elasticity of supply; – denotes at least one negative and significant price elasticity of supply; 0 denotes no statistically significant price elasticities of supply; manors without a symbol did not produce that type of grain.

Sources: see text.

IV

After presenting aggregate and manor-level price elasticities of supply for the acreage sown with wheat, barley, and oats, we can now place this responsiveness in its long-term historical context by comparing it with other countries in the nineteenth and twentieth centuries. Comparing supply response across countries and centuries is complicated. Because prior studies of price responsiveness used the total acreage planted with a certain crop in a region, only the price elasticities of supply estimated as a panel are comparable with the later price elasticities, and even these regressions are not completely similar because the panel better accounts for variation on individual manors than the regional aggregate data for later periods.[66]

Table 4: Comparison of medieval price elasticities of supply with price elasticities of supply calculated for other periods and countries.

Crop	Short-run Price Elasticities	Period	Place	Source
Wheat	insig	1325-48	Southern England	author
	-.066	1349-70	Southern England	author
	0.09	Late 19th c.	Hungary	(Eddie, 1971)
	0.42	Late 19th c.	Germany	(Eddie, 1971)
	0.0278	Late 19th c.	Missouri, USA	(Fisher and Temin, 1970)
	0.3053	Late 19th c.	Wisconsin, USA	(Fisher and Temin, 1970)
	0.00 - 0.08	Early 20th c.	Punjab	(Krishna, 1963)
Barley	-0.043	1325-48	Southern England	author
	0.04	1349-70	Southern England	author
	0.19	Late 19th c.	Hungary	(Eddie, 1971)
	0.27	Late 19th c.	Germany	(Eddie, 1971)
	0.39	Early 20th c.	Punjab	(Krishna, 1963)
Oats	.091	1325-48	Southern England	author
	insig	1349-70	Southern England	author
	0.11	Late 19th c.	Hungary	(Eddie, 1971)
	0.05	Late 19th c.	Germany	(Eddie, 1971)

The short-run price elasticities of wheat supply in the aggregate Winchester panel were either not significantly different than zero or significantly negative. These are far below elasticities found in later periods (Table 4). Fisher and Temin found that the short-run price elasticity of supply for wheat in the United States in the late nineteenth and early twentieth centuries was between 0.0278 in Missouri and 0.3053 in Wisconsin.[67] Krishna found short-run price elasticities of wheat supply in early twentieth century Punjab to be between zero and 0.08 depending on the irrigation method employed, while Eddie found short-run price elasticities of wheat supply to be 0.09 in Hungary and 0.42 in Germany in the late nineteenth century.[68] Therefore, it

[66] Rao, 'Agricultural', 3.

[67] Fisher and Temin, 'Regional', 142-43; Askari and Cummings, *Agricultural*, 131-6.

[68] Krishna, 'Farm', 485; Eddie, 'Farmers', 576; Askari and Cummings, *Agricultural*, 392-93.

appears that price elasticities of wheat supply were lower in medieval England than they were in the less-developed parts of Europe such as Hungary in the late nineteenth century, and the gap increased when compared to the more technologically advanced countries like Germany.

Price elasticities for barley and oats were available for fewer modern countries. The short-run price elasticities of barley supply on the Winchester manors before the Black Death were negative, but after the Black Death, the elasticity was positive and significant at an average of 0.04. Oats elasticities were significantly positive before the Black Death at 0.091 but not significantly different than zero thereafter. These elasticities were somewhat lower than elasticities in Hungary, Punjab, and Argentina in later periods. Eddie estimated short-run price elasticities of barley and oats supply to be 0.19 and 0.11 respectively in late-nineteenth-century Hungary and 0.27 and 0.05 respectively in Germany.[69] Krishna observed a short-run price elasticity of 0.39 for barley in Punjab before World War II.[70] Finally, Reca found the short-run price elasticity of oats supply to be 0.08 in Argentina before World War II.[71] Thus, although the barley elasticities were statistically significant and positive, they were still considerably lower than price elasticities of supply in both the modern and less developed parts of the world in the nineteenth and twentieth centuries. Oats elasticities seem to have been fairly low throughout time, but the medieval English elasticities were at about the same level. These comparisons with price responsiveness in other periods and countries suggest that reeves were not particularly responsive in medieval England and that there was an increase in price responsiveness between the fourteenth and nineteenth centuries, which could have potentially played a role in the transformation of agriculture during the early modern period.

V

As seen above, select Winchester manors were responding to changing economic conditions when making their planting decisions, but why reeves on some manors were responsive and others were not is still puzzling. This puzzle can be tested using regression analysis with the price elasticities of supply estimated for each manor serving as the dependent variable and seven important contributors to price responsiveness serving as the independent variables. Again, these elasticities were only estimated for the post-Black Death period (1349-70) when all 49 manors could be included in the regression so that the sample size would be large enough to produce robust results. Four price elasticities of supply were input into the regressions for each grain regardless of statistical significance, one for each price type described above (price, price relative to substitute grain, and price relative to wage) and another for the mean of the previous three elasticities. Logistic regressions were also attempted assigning one to manors with positive significant price elasticities and zero to all other manors, but these regressions were not robust or particularly helpful in displaying the relationships, so I have excluded them from the paper.

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[69] Eddie, 'Farmers', 576; Askari and Cummings, *Agricultural*, 394-95.

[70] Krishna, 'Farm', 485.

[71] Schuh and Brandão, 'Theory', 662.

The first independent variable included in the regression was the coefficient of variation (standard deviation divided by the mean) of each grain's yield per seed over the period. Askari and Cummings found that when yield coefficients of variation were larger, it was more difficult for farmers to make useful predictions about the future, and they were less likely to be price responsive.[72] Second, the average percentage of arable land sown with the grain over the period 1349-70 served as a measure of the importance of a crop on the manor. This variable was excluded for wheat because it was highly correlated with another important variable, the percentage of the winter field sown with rye or mixed grains such as bere and maslin. When rye and mixed grains were planted in the winter field, the wheat acreage could be expanded or contracted at the expense of these other grains within existing rotations rather than the acreage planted with wheat being determined by the size of the winter field. Thus, manors planting higher percentages of the winter field with rye and mixed grains should have had more flexibility to be price responsive. Third, the number of fields planted on the manor tested whether having more fields allowed more flexibility in crop rotation.[73]

Fourth, the average percentage of the year that Bishop Eddington spent at each manor during his episcopate (1345-1366) was included as a measure of the bishop's influence on production and the requirements of the manor to provide for the bishop's household. This variable was calculated from Bishop Eddington's register, where the bishop's location when making decrees and conducting business was recorded.[74] In addition, the distance to the closest manor house, palace, or castle held by the bishop of Winchester was also included since manors in close proximity to the bishop also had to provide for his household.[75] Sixth, the number of markets in a 16 km radius of the manor measures the influence of market density on price responsiveness.[76] 16 km is consistent with the normal marketing range for two manors in Wiltshire.[77] Finally, a dummy variable was included to represent London's economic sphere where manors within London's trading zone were set equal to unity and all other manors were given a zero.[78] Only these seven important variables were included in the regressions because the sample sizes were too small to support a great number of variables.

The regressions were estimated for the price elasticity of each price type and each crop separately using OLS methods. These regressions are tentative estimations

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[72] Askari and Cummings, *Agricultural*, 394-95.

[73] Both the number of fields variable and the percentage of the winter field sown with rye and mixed grains are the average for the years 1362-4 when these variables were recorded by Farmer. University of Saskatchewan Archives, The Papers of David Farmer, Series III, Box 10, Folder 10 part 1.

[74] *Register*, xxiii-xxvi. Other measures of the time spent by the bishop on the manors were also input into the regressions with similar results.

[75] Map, Wolvesey Castle, Winchester.

[76] Keene and Letters, *Markets and Fairs*. A large number of market density measures were tried such as manors within a 10, 16, and 25 km radius of the manor. These values did not lead to significantly different relationships.

[77] Farmer, 'Two', 6; Farmer, 'Marketing', 360-4.

[78] Campbell, *et al.*, *Medieval Capital*.

of the relationships at best because of the low sample sizes used to predict the price elasticities on each manor, but they provide a first look at the kinds of factors that might have been driving price responsiveness in southern England after the Black Death.

For price elasticities of wheat supply (Table 5), manors that sowed a larger percentage of the winter field with rye or other mixed grains had consistently and significantly higher price elasticities of supply. Therefore, when the acreage planted with wheat could be adjusted within existing rotations by expanding or contracting the acreage planted with rye and other mixtures, reeves were more likely to be price responsive. The other variables did not have a significant effect on price elasticities. Therefore, local or regional markets did not seem to strongly influence price responsiveness for wheat. Again, these regressions are tentative because of the small sample size in estimating the individual manor price elasticities of supply and because the R-squares are low varying between 0.23 and 0.34.

Table 5: Regressions explaining the variation in estimated price elasticities of wheat supply on 49 manors held by the bishop of Winchester, 1349-70.

Price Elasticity of Acreage Planted Dep	1	2	3	4
Model	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust
Grain Type	Wheat	Wheat	Wheat	Wheat
Price Type	Grain	Relative Grain	Grain Wage	Mean Elasticity
N	48	48	48	48
Constant	-0.047	0.129	-0.030	0.017
	(-0.37)	(1.15)	(-0.27)	(0.17)
Coefficient of Variation of Wheat Yield	-0.396	-0.780*	-0.242	-0.473
	(-0.95)	(-1.84)	(-0.71)	(-1.36)
% of Winter Field Sown with Rye or Mixed Grains	0.341**	0.279*	0.452***	0.358***
	(2.69)	(1.88)	(3.29)	(3.28)
Number of Fields	0.001	-0.002	0.004	0.001
	(0.22)	(-0.22)	(0.75)	(0.22)
Days per Year Manor Visited by Bishop Eddington	-4.002	0.238	-3.726	-2.497
	(-1.00)	(0.08)	(-1.08)	(-0.80)
Distance to Manor House	0.001	0.001	-0.000	0.000
	(0.44)	(0.35)	(-0.27)	(0.25)
Markets in 16km Radius	0.004	0.004	0.001	0.003
	(1.39)	(0.99)	(0.60)	(1.33)
Access to London Market	-0.022	0.090	-0.039	0.010
	(-0.28)	(0.81)	(-0.57)	(0.15)
R-square	0.26	0.33	0.36	0.37
F-statistic	4.71	4.20	3.36	4.63

Notes: Unstandardized coefficients with t-statistics in parentheses: * denotes significance on the 10 per cent level; ** denotes significance on the 5 per cent level; *** denotes significance on the 1 per cent level.

Sources: see text.

When estimating the regression for the price elasticities of barley supply, none of the coefficients were statistically significant (Table 6). This is puzzling because barley was the most price responsive of the three grains in aggregate and also had the most manors with positive price elasticities. The regression was slightly more powerful in predicting the variation in price elasticities of oats yields (Table 7), but many of the coefficients were only significant at the 10 per cent level and were only significant in one or two of the regressions, limiting their interpretive strength. The most robust variable was the market saturation variable. The number of markets in a 16 km radius had a positive effect on the price elasticity of oats supply, suggesting that market saturation could also influence price elasticities of oats despite the fact that oats were marketed less frequently than wheat and barley.[79]

Table 6: Regressions explaining the variation in estimated price elasticities of barley supply on 49 manors held by the bishop of Winchester, 1349-70.

Price Elasticity of Acreage Planted Dep	1	2	3	4
Model	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust
Grain Type	Barley	Barley	Barley	Barley
Price Type	Grain	Relative Grain	Grain Wage	Mean Elasticity
N	41	41	41	41
Constant	-0.348	0.099	0.354	0.035
	(-0.58)	(0.22)	(0.84)	(0.12)
Coefficient of Variation of Barley Yield	-0.109	0.889	-0.119	0.220
	(-0.15)	(1.02)	(-0.19)	(0.40)
Percentage of Arable Sown with Barley	1.270	-0.295	-0.173	0.268
	(1.34)	(-0.49)	(-0.27)	(0.66)
Number of Fields	0.013	-0.026	0.005	-0.003
	(1.23)	(-1.08)	(0.45)	(-0.23)
Days per Year Manor Visited by Bishop Eddington	-0.695	8.158	-0.218	2.415
	(-0.08)	(0.96)	(-0.02)	(0.38)
Distance to Manor House	-0.001	0.007	-0.001	0.001
	(-0.27)	(1.00)	(-0.44)	(0.49)
Markets in 16km Radius	-0.001	-0.007	-0.020	-0.009
	(-0.04)	(-0.47)	(-1.54)	(-1.09)
Access to London Market	-0.028	0.034	-0.163	-0.052
	(-0.19)	(0.15)	(-1.24)	(-0.55)
R-square	0.20	0.22	0.24	0.12
F-statistic	2.37	0.77	2.50	1.07

Notes: Unstandardized coefficients with t-statistics in parentheses: * denotes significance on the 10 per cent level; ** denotes significance on the 5 per cent level; *** denotes significance on the 1 per cent level.

Sources: see text.

[79] Campbell, 'Measuring', 157.

In conclusion, it is difficult to explain why some manors had higher price elasticities of supply than others. The concentration of markets around each manor had a positive effect on the price elasticity of oats supply, but this effect was not significant in explaining variations in price elasticities of wheat and barley supply. However, the existence of more than one crop in both the spring and winter fields significantly increased the reeve's production flexibility and was also correlated with higher elasticities of wheat supply. This may suggest that more sophisticated rotations that utilized a wider variety of crops may have increased the production flexibility of the reeve.[80] Despite these few significant variables, the regressions explaining the spatial variation in price elasticities had relatively low explanatory power with r-squares ranging from 0.12 to 0.51. The difficulty in explaining the spatial variation in price elasticities is puzzling and perhaps corroborates Stone's finding that some reeves were good managers and others were not.[81]

Table 7: Regressions explaining the variation in estimated price elasticities of oat supply on 49 manors held by the bishop of Winchester, 1349-70.

Price Elasticity of Acreage Planted Dep	1	2	3	4
Model	OLS	OLS	OLS	OLS
Heteroskedasticity	Robust	Robust	Robust	Robust
Grain Type	Oats	Oats	Oats	Oats
Price Type	Grain	Relative Grain	Grain Wage	Mean Elasticity
N	47	45	47	47
Constant	-0.561	-0.237	-0.626	-0.465
	(-1.68)	(-0.81)	(-1.59)	(-1.49)
Coefficient of Variation of Oat Yield	2.113*	0.326	2.826*	1.734
	(1.87)	(0.48)	(1.90)	(1.62)
Percentage of Arable Sown with Oats	-0.721	-0.902	-0.957	-0.884
	(-1.17)	(-1.46)	(-1.37)	(-1.47)
Number of Fields	-0.000	0.009	-0.004	0.003
	(-0.01)	(0.68)	(-0.19)	(0.17)
Days per Year Manor Visited by Bishop Eddington	-2.099	10.541	-5.383	0.915
	(-0.17)	(0.76)	(-0.45)	(0.07)
Distance to Manor House	-0.006*	-0.006	-0.006	-0.006*
	(-1.77)	(-1.40)	(-1.29)	(-1.71)
Markets in 16km Radius	0.008	0.020***	0.005	0.011*
	(1.22)	(2.82)	(0.66)	(1.77)
Access to London Market	0.351*	0.242	0.279	0.290
	(1.72)	(0.89)	(1.20)	(1.36)
R-square	0.47	0.24	0.51	0.42
F-statistic	1.81	2.14	1.27	1.76

Notes: Unstandardized coefficients with t-statistics in parentheses: * denotes significance on the 10 per cent level; ** denotes significance on the 5 per cent level; *** denotes significance on the 1 per cent level.

Sources: see text.

[80] Campbell, *English*, 291-301.

[81] Stone, *Decision-Making*, 205-12.

VI

Stone's more qualitative findings of price responsiveness on select manors throughout southern England in the late Middle Ages are corroborated by the minority of manors held by the bishop of Winchester that were significantly price responsive in their planting decisions. In fact, as he suggests different manors were price responsive in different ways (Table 3).[82] In the end, however, aggregate price elasticities of supply were very low if they were significantly different than zero. Reeves on the Winchester estate did not adjust the acreage sown with various crops based on prices. These claims must be weakened slightly when extending them to the rest of England because the Winchester sample was not representative of England as a whole. If manors from the more developed eastern regions such as East Anglia and Kent were included in the sample, supply response might be marginally higher. However, even considering the seigniorial sector as a whole, it seems unlikely that reeves would have been price responsive relative to later time periods.

Projecting this inference from the seigniorial sector to the agricultural sector as a whole is more difficult because very little is understood about supply response in peasant agriculture. As mentioned above, Dodds found some evidence that peasants were price responsive, but Sapoznik found the opposite when looking at good tithe data at the local level.[83] Hypothetically, the addition of the peasant sector could increase or decrease overall price responsiveness in the agricultural sector. It is possible that because peasants often farmed small strips of land in larger common fields, they had less production flexibility than the seigniorial sector and thus were even less price-responsive than reeves managing demesnes. On the other hand, if peasants held land in closes where they had considerable control over their production, they may have been more price responsive than reeves managing demesnes. If forced to speculate, I would suggest a pessimistic view of peasant price responsiveness for several reasons. First, the traditional risk-aversion of subsistence farmers should not be underestimated. Second, even when peasants had considerable control over their own land, it would have been very difficult for them to abruptly switch from one crop to another because they would have had to purchase seed at considerable cost. Third, as Sapoznik has argued, peasants may have been forced to devote a larger proportion of their production to non-market fodder crops than the seigniorial sector because peasants did not have the same access to pasture and grassland.[84] Finally, because peasants fed their families from their fields, a smaller proportion of their total output was marketed. Thus, although the peasant sector may have produced two-thirds to four-fifths of agricultural output, the peasant share of total marketed output was likely substantially lower than their share of total output.[85] Therefore, it seems reasonable to tentatively assume that price responsiveness was low across the agricultural sector of medieval England.

Low price elasticities of supply in agriculture should not be dismissed as a narrow measure of commercialization in the economy for several reasons. Low

[82] Stone, *Decision-Making*, 205-12.

[83] Dodds, *Peasants*, 161; Sapoznik, 'Productivity', 18.

[84] Sapoznik, 'Productivity', 23.

[85] Dodds, 'Demesne', 124.

agricultural supply response would have negatively affected living standards by prolonging and accentuating periods of famine and dearth. If reeves and peasants were not price responsive, then they would not have expanded their grain production when prices were higher. Thus, it would have taken longer for supply shortfalls to be overcome. Low supply response also contributed to higher price variation for similar reasons, making it more difficult for farmers to predict price conditions in the future. Finally, low supply response meant that changes in prices were unlikely to drive changes in grain output or the efficiency of production on manors. For instance, a sharp, sustained rise in the wheat price relative to the oats price would not necessarily lead to an increase in wheat production relative to oats production. Therefore, structural changes in the economy such as the disappearance of villeinage, the leasing of manors, and the growth of the wage labour market later in the fourteenth century may have been more important drivers of economic change in the post-Black Death period than prices.

From a long-run perspective, the evidence presented here challenges the assumption held by economists that farmers have always been price responsive.[86] This could affect the long-run development literature in two ways. First, a shift from low supply response to higher supply response could have been an important part of the capitalist transformation of English agriculture in the early modern and modern periods, and thus, might explain differing development trajectories across Europe. Second, low price responsiveness in medieval agriculture poses methodological problems for the market integration literature. Economists have measured market integration using the price volatility of grain prices at specific locations. They assume that if markets were more integrated, price volatility would be lower because high prices would be mediated by grain transported in from regions with a surplus.[87] However, as mentioned above, price volatility would also be influenced by whether or not producers were price responsive. Thus, if farmers became more price responsive over the early modern period, grain price volatility would decline in the absence of greater market integration.

Insignificant or low price elasticities of supply in medieval England suggest that reeves on the Winchester estates were not strictly behaving according to neoclassical economic principles, but determining why their behaviour differed is more difficult. One possible explanation would be that reeves simply were economically irrational. Although commercialization had increased over twelfth and thirteenth centuries, Postan's dictum that medieval farmers could not be expected 'to sow more or to work harder in response to the stimuli of prices or under the influence of a pessimistic or optimistic view of future business prospects' was largely true.[88]

Another possible explanation for low or insignificant price elasticities of supply would be that the agricultural technology of the period limited reeves' flexibility to adjust their output from existing crop rotations year-to-year. The threat of declining soil fertility forced reeves to maintain strict two- or three-field rotations with regular fallows and prevented them from expanding the acreage planted with a certain crop in response to price changes. Thus, it was only with the invention of

[86] Allen, *British*, 7-8.

[87] Bateman, 'Evolution', 455.

[88] Postan, 'Note', 79.

more complex crop rotations beginning with the 'Norfolk System' in the late medieval period and continuing during the early modern Agricultural Revolution that farmers gained the ability to vary their output in response to prices.[89]

Manorial customs and institutions could have also misaligned reeves' incentives making it against their interest to be price responsive. It certainly did not help that reeves received no financial incentives for profit maximizing behaviour and that the estates did not seem to measure profit in a useful way.[90] However, the reeves incentives could be misaligned in other ways. For instance, on the bishop's manor of Taunton customary tenants could be required to purchase grain from the estate at rates slightly above market prices. These purchases made up 28 per cent of wheat sales and 86 per cent of oats sales from 1283 to 1348. Thus, if the reeve expanded wheat production with higher prices, he and his fellow customary tenants might be forced to purchase more grain at higher prices whether they needed the grain or not. This custom clearly disrupted normal links between production, demand and prices.[91] Likewise, production decisions could have also been primarily driven by the lord's consumption requirements rather than by profit maximizing calculations. This would have been especially true for lords with smaller estates than the bishop of Winchester, who could not possibly have consumed the majority of the output of their estates.

A final possibility is that prices were so volatile in medieval England that it did not make sense to try to predict future price movements.[92] Past price movements were completely disconnected from future price movements because exogenous weather variation had such a strong influence on grain output and prices. Thus, it was only with improving agricultural technology, decreasing weather volatility, and increasing market integration that prices became stable enough for farmers to adjust the acreage planted with crops in accordance to prices.

Distinguishing between these four possible explanations of low supply response in the medieval period will require further research. Unfortunately, detailed information on farm production like that available in medieval manorial accounts does not exist for the early modern period, so it will be difficult to extend the current methodology. However, the same methodology could be applied to manors in the more advanced regions of England such as East Anglia in the medieval period to see whether the more complex and intensive cropping systems employed there increased reeves' flexibility to adjust their production year-to-year. The importance of the bishop's consumption could be tested more rigorously in two ways: first, by attempting to understand what factors affected the amount of grain transferred to the lord from each manor and second, by testing whether variables related to the lord's consumption such as distance to a manor house or the average time spent at a manor affected the acreage planted with certain grains. This kind of analysis would help resolve lingering doubts about the roles of central estate planners versus semi-autonomous reeves. Reeves' rationality can also be tested in other spheres where technology was perhaps less of a limitation. For instance, did reeves sell a higher

[89] Campbell, *English*, 291-301; Allen, *Enclosure*.

[90] Stern, *Hertforshire*, 64-6; Harvey, *Manorial*, 28-9; Drew, 'Manorial', 16.

[91] Thornton, 'Level', 132-3.

[92] Campbell and Ó Gráda, 'Harvest'.

proportion of their output when the price was higher or horde their grain in times of dearth? New economic models and robust econometric techniques will be required to test these new hypotheses, but they will be necessary in order to determine the full extent of commercialization in the medieval economy.

In conclusion, the evidence presented in this paper does not refute the wave of commercialization that other authors have discovered in the two centuries before the Black Death, nor does it prove that the medieval English economy was a natural economy in the way that Postan argued.[93] Instead, it suggests that despite the increased urbanization, monetization, and marketization, there were real limitations in the commercial development of the economy.

[93] Postan, 'Note', 79.

Appendix I: Partial Adjustment Model of Supply Response

This paper tests the acreage supply response of reeves in a partial adjustment model framework. The partial adjustment model is made up of two structural equations. First, the equilibrium (desired) acreage planted is taken to be a function of expected prices

$$X_t^* = a + bP_t^e + u_t \tag{1}$$

where X_t^* is the equilibrium acreage planted at time *t* and P_t^e is the expected price in the current year. Essentially, the equation states that reeves planted their fields based on the grain price that they expected for the succeeding year. For the sake of simplicity in estimation, expected prices are taken to be the price in the previous year.

$$P_t^e = P_{t-1} \tag{2}$$

The second structural equation holds that the actual change in acreage planted from one period to the next is proportional to the difference between the equilibrium (desired) acreage planted and the acreage planted in the last period

$$X_t - X_{t-1} = \gamma(X_t^* - X_{t-1}) \tag{3}$$

where X_t is the acreage planted in year *t* and γ is the speed of adjustment from one year to the next. This equation allows for various constraints that might prevent farmers from adjusting their production to the equilibrium (desired) acreage every year. If γ is equal to unity, then the farmers are adjusting to the equilibrium level every year: i.e. they are actually planting the desired equilibrium acreage. However, if γ is less than unity, then farmers took more than one year to adjust to the equilibrium (desired) acreage. When equation 1 is substituted into equation 3 to remove the unknown equilibrium acreage planted, the following equation is obtained

$$X_t = a\gamma + b\gamma P_{t-1} + (1-\gamma)X_{t-1} + \gamma u_t \tag{4}$$

Thus, the acreage planted is a function of the lagged price and the acreage planted in the previous year.[94]

The expected price in this model is taken to be the price in the previous year. This simplification is common in agricultural supply response literature and was necessary because including a price expectation other than the price in the previous year makes the model unidentifiable.[95] The short-run elasticity, the response of

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[94] Yotopoulos and Nugent, *Economics*, 138-40; Nerlove, *Dynamics*, 45-65; Askari and Cummings, *Agricultural Supply Response*, 25-37; Askari and Cummings, 'Estimating', 257-8.

[95] Nerlove did develop the adaptive expectations model to account for more complexity in expected prices where the expected price was held to be a weighted average of past prices:

$$P_t^e = \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda} P_{\lambda-1}$$

However, in order to combine the partial adjustment and adaptive expectations models, either the coefficient of adjustment, γ, in the partial adjustment model or the coefficient of expectation, β, in

acreage to price in one year, is the coefficient on the lagged price in equation 4 ($b\gamma$) when both the acreage sown and the prices are logged. The long-run elasticity 'is defined as the elasticity over the time period necessary for complete adaptation', and when acreages sown and prices are logged, it is equal to b in equation 4.[96]

In order to estimate price elasticities of supply that would be comparable with the aggregate estimations available for the nineteenth and twentieth centuries, equation 3 was first estimated using each panel. Fixed-effects regressions were not possible because there was serial correlation in the idiosyncratic errors for all models, so Generalized Least Squares regressions were employed. Acreages planted were standardized based on the mean acreage planted with each crop over the period so that the indexed value was the percentage change from the mean from year to year.

In order to pinpoint which manors were price responsive and which were not, standard time series OLS regressions were used to estimate equation 4 on each individual manor. Because some of the series were stationary and others were not, first differences of the acreage sown, lagged acreage sown and lagged price variables were used in all regressions. The regressions were also checked for serial correlation, and where serial correlation was present, Prais-Winsten regressions were used to correct the parameters and standard errors.[97]

in the adaptive expectations model must be equal to unity. Otherwise the model is unidentifiable in the absence of further restrictions, which were not possible with medieval data.

[96] Yotopoulos and Nugent, *Economics*, 139.

[97] The Prais-Winsten regression performs a generalized least-squares regression on the data assuming first-order autoregressive serial correlation of the errors.

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