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Modeling technological bias and factor input behavior in China's wheat production sector

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ABSTRACT

Over the past three decades, China has implemented reforms in the agricultural sector in an attempt to increase efficiency and food security. However, China now faces a number of environmental degradation problems, in part, caused by her past agricultural reforms. In this paper we estimate, using a provincial-based panel dataset, a third-order translog cost function for China's grain production sector over the period 1990–2011. Results from the estimation, including estimated elasticities of demand for and substitution of factors, suggest that labor and capital are substitutes. This arises because the increasing cost of labor, induced by urbanization and the growth of the manufacturing sector, has lead to a substitution of machinery for labor in the production of wheat. The results are consistent with current government policies to encourage via subsidies and agricultural mechanization, which we show to be technically, a substitute for labor. We further conclude this will create an additional bonus of reducing the amount of fertilizer that is needed to efficiently and securely produce wheat in China, as the new capital is more efficient at fertilizer distribution.

1. Introduction

Over the last three decades, China has implemented a number of institutional reforms in the agricultural production sector, in an attempt to liberate the rural labor force and improve grain productivity. In 1978, China abandoned the Collective Grain Production System and introduced the Household Responsibility System. As a result, grain yields increased from 2.78 t per hectare in 1979 to 3.98 t per hectare in 1990 (CSY, 2013). From 1993, China also began to gradually allow the transfer of the Rural Contract Arable Land among rural households (Kong, 1993) and this particular institutional reform brought about the emergence of scale economies and stimulated households to increase investment in grain production (Du, 2013; Hao and Huang, 2011). In 2003, China abolished agricultural taxes and from 2004 introduced agricultural machinery and grain production subsidies (Hou and Liu, 2010; Ma et al., 2013). In 2004, the Ministry of Finance and the Ministry of Agriculture jointly launched, an agricultural machinery subsidy of 70 million RMB aimed at improving agricultural mechanization and stabilizing sown area. Since then, the central government has continuously invested approximately 15 billion RMB as a sown subsidy on wheat, corn and paddy rice (Sheng, 2013).

As might be expected, these subsidies have encouraged farmers to increase the sowing of high quality seeds and the purchase of agricultural machinery (Chen and Ting, 2011; Li and Wan, 2010; Wang and Xiao, 2007) and as a result, China has successfully fed 20% of the world's population using only 7% of the world's cultivated land.

Wheat is one of three most important grain crops in China, where in 2013, the sown area of wheat accounted for 22% and its output 21% of the national total, respectively (CSY, 2013). Wheat production is distributed across 10 provinces in northern China although it is mainly concentrated in five provinces in northern China; Henan, Shandong, Hebei, Jiangsu and Anhui (CSY, 2013)[4] where production has been increasing both in terms of output and sown area (from 58.6% and 51.7% in 1990 to 74.6% and 65.1% respectively). Of the five major wheat producing areas, Henan is the largest.

However, grain production in China still faces a set of challenges. Looking ahead, for example, total grain targets have to be strictly kept at a sown area of 105 million hectares, output of 550 mmt and a yield

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[4] Of national total, wheat output, Henan accounts for 26.3%, Shandong (18.0%), Hebei (11.1%), Anhui (10.7%) and Jiangsu (8.7%) in 2012.

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of 5.25 t per hectare by 2020 (GOSC, 2014). Unfortunately, the available land area is declining rapidly due to urbanization and industrialization and to stabilize grain output, China has been forced to increase factor inputs. As a result, China has become the largest consumer of fertilizer in the world, where use has reached 200 kg per hectare (Huang et al., 2008). Similarly, the use of pesticide continues to rise. From 1991 to 2012, the dosage per hectare doubled from 5.1 kg to 11.1 kg (CSY, 2013). Lindert (1999) found that in most areas in China, organic matter and nitrogen in the soil declined sharply between 1950s and 1980s. Similarly, SEPA (2006) reported a significant increase in heavy metals in the soil; Chang et al. (2003) found that by 2000, the area polluted by pesticide in China was over 16 million hectares which amounted to 13.2% of total farmland. Qu et al. (2011) believes that the pollution of irrigating water is the major cause of the problem. It seems that serious water shortages and rising labor costs have led to the country losing its comparative advantage in grain production (Qu et al., 2011).

As a consequence of these changes and reactions by the sector, the future of grain production in China hinges on how to alleviate crop plantation intensity and improve the production efficiency, while at the same time, protecting the agricultural environment and creating sustainable development.

In this paper we will investigate the extent to which these challenges are achievable by firstly constructing a third-order translog cost function, to empirically measure a number of important econometric hypotheses associated with for example, factor input bias and technological change. This allows us to investigate the recent behavior of the wheat production sector using the estimated elasticities of demand for and substitution of factors, and hence identify the key factors that are likely to determine the direction of future grain production and potential policy targets. Because of their size and importance, we pay particular attention to China's five major wheat producing areas.

The paper is organized as follows: Section 2 briefly reviews previous studies of China's grain production performance; Section 3 introduces the model to be estimated and hypotheses to be tested, followed by the data and variables used. Section 5 presents the results and discussion with the final Section providing some conclusions and policy implications.

2. Brief review of relevant literature

Productivity growth and technical efficiency are well documented for China's economy. Li and Liu (2011) decompose economic and productivity growth for post-reform China; Hang et al. (2015) measure energy inefficiency with undesirable outputs and technology heterogeneity for Chinese cities; Barros et al. (2011) measure the technical efficiency of the Chinese banking sector.

Other studies model the performance of agricultural production and measure productivity growth (Fan, 2000; Tian and Wan, 2000; Carter et al., 2003; Chen et al., 2009; Jin et al., 2010). Wei et al. (2010) and Ming and Li (2012) measure total factor productivity, technological change and technical efficiency. Wang and Lv (2006) investigate the performance of an individual grain crop, while Zhang (2008) and Wang et al. (2010) consider productivity growth, technological change and technical efficiency for China's paddy rice production. Huang et al. (2004) have investigated production efficiencies and regional variations for China's grain production, while Zhang et al. (2005) consider efficiencies for grain production in Henan province. Chen et al. (2013) model the dynamics of factor input adjustments for five major wheat producing provinces using a DEA approach.

Since 2003, many studies have focused on the effects of subsidies on grain production (Chen et al., 2014; Huang et al., 2011; Liu, 2010; Ma and Yang, 2005). Wang and Xiao (2007) investigate the effects of subsidies on the variety of seeds used, while Li and Wan (2010) and Chen and Ting (2011) consider the effects of subsidies on machinery purchases. Liu (2010) studies the effects of production subsidies on farmer decisions regarding grain planting and Xing and Hu (2013) analyze the effects of the new round of production policies. Most studies conclude that the subsidies favor grain production, for example, the increase of factor inputs and the stabilization of sown area.

From this set of papers and their brief review, we can conclude that i) the majority of studies have used a Data Envelopment Approach (DEA) and hence are unable to test many economic assumptions; ii) many studies use a parametric analysis and measure technological change and technical efficiency, but fail to identify the types of technological change; iii) many studies conclude that subsidies favor machinery purchase, but fail to identify the role that mechanization plays in the future grain production.

3. Methodology

The translog cost function is a convenient specification of duality theory that has attracted considerable attention in empirical studies (Berndt and Wood, 1979; Binswanger, 1974; Deaton and Muellbauer, 1980; Stevenson, 1980). As a second order approximation, its application allows one to avoid the need to specify a particular production function (Stratopoulos et al., 2000), nor is it necessary to assume constant or equal elasticities of substitution (Woodland, 1975). Furthermore, variables (prices and output) on the right hand side are exogenous in a translog cost function specification, which avoids the endogenous statistical problems.

This study uses a third-order Taylor expansion rather than the usual second-order format (Stevenson, 1980) as it allows more coefficients, estimated from cross-sectional data, to change from time period t to $t+n$, and also the truncated third-order form allows one to conduct particular tests that are not possible under a second-order formulation, for example price-induced technological bias.

Without having to estimate more parameters and serving particular tests, the truncated third-order Taylor series expansion in time and the logged input price and output can be stated as:

$$\begin{aligned}\ln C_{it}^{*} = {} & \beta_0 + \sum_{j=1}^{m}\beta_j \ln P_{ijt} + \beta_y \ln Y_{it} + \beta_T T + 0.5\sum_{j=1}^{m}\sum_{k=1}^{m}\beta_{jk} \ln P_{ijt} \ln P_{ikt} \\ & + \sum_{j=1}^{m}\beta_{jy} \ln P_{jt} \ln Y_{it} + \sum_{j=1}^{m}\beta_{jT} T \ln P_{ijt} + 0.5\beta_{yy}(\ln Y_{it})^2 \\ & + \beta_{yT} T \ln Y_{it} + 0.5\beta_{yyT} T(\ln Y_{it})^2 + 0.5\beta_{TT} T^2 \\ & + 0.5\sum_{j=1}^{m}\sum_{k=1}^{m}\beta_{jkT} T \ln P_{ijt} \ln P_{ikt} + \sum_{j=1}^{m}\beta_{jyT} T \ln Y_{it} \ln P_{jt}\end{aligned} \quad (1)$$

where ln denotes a natural logarithm; C_{it}^{*} is the equilibrium total cost of region i in period t; $j, k = L, F, M, O$(input factors); P_{jt} (P_{kt}) denotes the price of input j (k) at time t; Y_{it} is the level of output of region i in period t; T denotes a time trend reflecting biased technical change. Empirically, if $\beta_{jkT} \neq 0$ and $\beta_{jyT} \neq 0$, this third-order translog cost function specification should be used.

With the proper set of restrictions on its parameters, Eq. (1) can be used to approximate any of the unknown cost and production functions. The symmetry restrictions:

$$\beta_{jk} = \beta_{kj} \text{ and } \beta_{jkT} = \beta_{kjT} \text{ for all } j \neq k \quad (2)$$

implying equality of the cross-derivatives. Linear homogeneity in prices (when all factor prices double, the total cost has to double) implies:

$$\begin{aligned}&\sum_{j=1}^{m}\beta_j = 1, \sum_{j=1}^{m}\beta_{jk} = \sum_{j=1}^{m}\beta_{jy} = \sum_{j=1}^{m}\beta_{jT} = 0 \textit{ and} \\ &\sum_{j=1}^{m}\beta_{jkT} = \sum_{j=1}^{m}\beta_{kjT} = \sum_{j=1}^{m}\beta_{jyT} = 0, j, k = L, F, M, O.\end{aligned} \quad (3)$$

By Shephard's lemma, a firm's system of cost minimizing demand functions (the conditional factor demands) can be obtained by