Aggregate and Farm-level Productivity Growth in Tobacco: Before and After the Quota Buyout *

by
Barrett E. Kirwan†
T. Kirk White‡
Shinsuke Uchida§

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 6-9, 2010

January 11, 2010

†University of Maryland. Contact: bkirwan@erec.umd.edu

‡Economic Research Service, U.S. Department of Agriculture. Contact: kwhite@ers.usda.gov. Phone: 202-694-5415. Fax: 202-694-5756.

§University of Maryland and USDA/ERS. Contact: suchida@arec.umd.edu

Aggregate and Farm-level Productivity Growth in Tobacco: Before and After the Quota Buyout [*]

by

Barrett E. Kirwan

University of Maryland

T. Kirk White

Economic Research Service, U.S. Department of Agriculture

Shinsuke Uchida

University of Maryland and USDA-ERS

PRELIMINARY AND INCOMPLETE

January 11, 2010

[*]Research results and conclusions expressed are those of the authors and do not necessarily reflect the views of the U.S. Department of Agriculture. The results in this paper have been screened to insure that no confidential information is revealed. We thank Erik Dohlman, Keith Fuglie, Jim MacDonald and other participants in the ERS/RRED lunch seminar series for comments on the paper. We also thank Eldon Ball, Tom Capehart, Michelle Da Pra, Linda Foreman, Rich Nehring, Bob Pearce, Randy Rucker, Will Snell, Wally Thurman, and Sun Ling Wang.

Correspondence to: T. Kirk White, Economic Research Service, U.S. Department of Agriculture, 1800 M St., NW, Washington, D.C. 20036. email: kwhite@ers.usda.gov. Phone: (202) 694-5415. Fax: (202) 694-5756.

Abstract

We examine the distortionary effects of agricultural policy on farm productivity by examining the response of U.S. tobacco farmers productivity to the quota buyout of 2004. We isolate the impact of distortionary policy, i.e., the tobacco quota, by decomposing aggregate productivity growth into the contribution of farm-level productivity growth and the contribution of reallocation of resources among tobacco growers. Reallocation of resources includes entry into and exit from tobacco farming, as well as growth or decline of the resources allocated to existing tobacco farms. We find that aggregate productivity of Kentucky tobacco farms grew 37% between 2002 and 2007. Reallocation of resources among continuing tobacco farms contributed 22 percentage points to productivity growth. Reallocation through entry and exit contributed 10 percentage points, and the elimination of quota rental costs directly contributed 5 percentage points.

JEL codes: E32, L6, O47

Key words: Tobacco; Quotas; Aggregate Productivity Growth; Reallocation.

1 Introduction

The Tobacco Transition Act of 2004 was a "black swan" in the modern history of U.S. farm policy: the Act ended a 66-year-old federal farm program and replaced it with...nothing. The Transition Act, also known as the tobacco quota buyout, was a rapid and complete market liberalization: from one growing season to the next, U.S. tobacco production went from a policy environment of severe restrictions on production to a free market regime. Such a large and seemingly permanent policy change provides a rare opportunity to study the full effects of distortionary economic policy. In this paper we seize this opportunity by analyzing the effects of the buyout on aggregate productivity growth in tobacco production. We focus on a single major tobacco-producing state: Kentucky.

Under the federal tobacco program, the USDA annually set an aggregate limit on virtually all domestic tobacco production and supported the prices received by U.S. tobacco growers. In addition, in most states, tobacco quota could not be sold or leased across county lines. These and other restrictions of the quota program severely limited growers' ability to efficiently allocate land and other resources for tobacco production. The quotas were a source of economic rents for quota owners, but they were also a major expense for growers, many of whom had to lease some if not all of their quota. Economic theory predicts that removing the restrictions imposed by the quota program frees farmers to allocate resources to tobacco production more efficiently. To what extent has reallocation occurred? To what extent did reallocation of resources contribute to productivity growth in tobacco production after the buyout?

Previous research has examined different aspects of the quota buyout. Brown, Rucker, and Thurman (2007) used county-level data and simulations to predict the effects of the quota buyouts on production and welfare under various assumptions. They declined to make a normative statement about the welfare effects of the buyout, but they predicted that in the medium run tobacco production would increase. In fact, domestic tobacco production declined after the buyout and has yet to fully recover to pre-buyout levels.

Using the farm-level Agricultural Resource Management Survey (ARMS), Dohlman, Foreman, and Da Pra (2009) find that after the 2004 buyout, many farms exited tobacco production, and, on average, the remaining farms consolidated and grew. The use of marketing contracts–unusual before 2001–increased substantially. Production became more concentrated in North Carolina and Kentucky, and by 2008, yields had increased slightly compared to 2004. Tobacco prices and acreage fell, but export demand grew.

In this paper we focus on the total factor productivity of tobacco growers before and after the buyout at both the aggregate and farm levels. We use data from the 1997, 2002, and 2007 Censuses of Agriculture, linked longitudinally at the farm level and supplemented with farm-level data from the ARMS. In contrast to previous research, the panel we construct allows us to decompose the effects of the buyout into the contributions of continuing farms and the contributions of entry into and exit from tobacco production.

We find that the aggregate productivity of Kentucky tobacco farms decreased by 38% between 1997 and 2002, but grew by 37% between 2002 and 2007. Between 1997 and 2002, technical efficiency growth of continuing tobacco farms contributed almost nothing to aggregate productivity growth (APG), while reallocation of resources across continuing tobacco farms contributed -25 percentage points, and net entry contributed -13 percentage points. Between 2002 and 2007, technical efficiency growth continued to contribute almost nothing. However, reallocation among continuers contributed 22 percentage points, net entry contributed 10, and the direct effect of the elimination of quota rental costs contributed 5 percentage points to APG.

Our finding that resource reallocation makes a large contribution to aggregate productivity growth is in contrast to, but not necessarily inconsistent with, previous research on aggregate productivity growth in U.S. agriculture. Using aggregate state-level data Ball, Gollop, Kelly-Hawke, and Swinand (1999) finds that resource reallocation across states had little effect on aggregate productivity growth in agriculture. To the extent that resource reallocation is occuring within states more than across states, our results highlight the importance of using highly disaggregated data to study the sources of aggregate productivity growth.

Our results on reallocation also emphasize the importance of allowing for adjustment costs, imperfect competition, quotas, taxes, subsidies, or other distortions when measuring aggregate productivity growth. Hulten (1978) shows that in a perfectly competitive economy with no distortions, aggregate productivity growth is equal to the weighted sum of enterprise-level technical efficiency growth rates, i.e., aggregate technical efficiency growth. As emphasized by Petrin and Levinsohn (2008, P-L hereafter), in this type of economy, further reallocation of resources does not contribute to aggregate productivity growth. However, both P-L and Basu and Fernald (2003) point out that when there are adjustment costs or markups over marginal cost or other distortions (such as taxes, subsidies or quotas), (i) aggregate productivity growth is generally not equal to aggregate technical efficiency growth and (ii) reallocation of resources can contribute to aggregate productivity growth. To the extent that U.S. agricultural production (or any other sector of the economy) can be characterized as a sector in which subsidies, quotas and other distortions are important, our results have important implications for measuring aggregate productivity growth in this sector.

Although our results are generally consistent with economic theory, we interpret our results on entry and exit with some caution. We have the best farm-level longitudinal links currently available to researchers. However, we find a surprising amount of entry into tobacco farming during a period in which the market share of U.S. tobacco growers was in decline. Further research on the entry and exit of tobacco farms (and farm entry and exit more generally) is needed.

2 The U.S. Tobacco Quota Program and the Quota Buyout

Under the federal tobacco program, growers had to own or lease marketing quota in order to sell tobacco. Allocated by the federal government when the program started in 1938, quota was an asset with its own market, but it was not completely freely tradable. The program applied to the two major types of tobacco, burley and flue-cured. In this paper we focus on Kentucky, where the vast majority of the value of tobacco production is burley. So here we discuss the burley program, although many of the rules were similar for flue-cured tobacco. Womach (2003) provides an overview of the program for both burley and flue-cured tobacco.

Starting in 1991, burley growers could buy or lease quota separately from the land on which the tobacco was grown. However, except in Tennessee, burley quota could not be sold or leased across county lines. Because of increasing foreign competition and decreasing domestic demand, U.S. tobacco production declined steeply between 1997 and 2002, and the number of tobacco farms decreased from 93,000 in 1997 to 57,000 in 2002. Kentucky followed the national trend, with the number of farms with tobacco sales decreasing from 46,792 in 1997 to 29,253 in 2002.[1] Quota could only be sold or leased to active growers. However, it could be inherited, and it could be retained by inactive growers. In the final years of the program, most quota was not owned by active growers (Womach (2004)). Quota had to be used by the owner or leased to another grower in 2 out of 3 years or be forfeited. Thus the quota program placed both geographic and temporal restrictions on the allocation of land and other resources to tobacco production.

The design of the quota buyout also probably affected production decisions. Quota owners received \$7 per pound of quota. Importantly, growers who produced tobacco between 2002 and 2004 received an additional \$3 per pound of quota–the so-called "grower benefit." Various proposed versions of the quota buyout were discussed in policy circles and tobacco communities years in advance of the Transition Act. In light of these facts, it seems likely that some quota owners continued or even entered tobacco production instead of renting out their quota in 2002 so that they could capture the grower benefit. Our empirical results are consistent with this hypothesis.

[1]See the NASS Quickstats website: http://quickstats.nass.usda.gov.

3 A Brief Review of the Theory of Aggregate Productivity Growth

There are large theoretical and empirical literatures devoted to measuring aggregate productivity growth. Petrin, White, and Reiter (2009) provides an overview of those literatures, and we will not repeat it here. Petrin and Levinsohn (2008, P-L hereafter) shows how to aggregate changes in firm-level technical efficiency and changes in resource allocations across firms to changes in aggregate final demand. P-L also shows how to decompose aggregate productivity growth into the separate contributions of firm-level technical efficiency growth and the reallocation of each factor of production across firms. We apply the P-L methodology and adapt it to the environment of U.S. tobacco production before and after the quota buyouts. In particular, we add a term to the P-L decomposition which measures the direct effect of the elimination of quota rental costs on aggregate productivity growth.

We follow the discussion of the theory in P-L and Petrin, White, and Reiter (2009), except that here we focus on a single industry. For the purpose of explaining the theory, we assume that all tobacco farms only produce tobacco.[2] Each farm i's production technology can be represented as

$$Q_i = F(X_i, M_i, \omega_i). \tag{1}$$

where $X_i = (X_{i1}, \ldots, X_{iK})$ is a vector of primary input usage (land, labor, buildings and machinery) on farm i and $M_i = (M_{i1}, \ldots, M_{iJ})$ is the vector of intermediate inputs. Finally, ω_i is the level of farm i's technical efficiency.

P_i is the price of farm i's output. The sum $\sum_i P_i dQ_i$ is the instantaneous change in industry aggregate output. In the context of a single industry, assuming market clearing, the change in industry output equals the change in industry aggregate demand.[3]

[2] In the data most tobacco farms also produce other crops. We discuss how we deal with this issue in section 6 below.

[3] If we were aggregating across more than one industry, then in order to compute aggregate productivity, we would compute the change in *final* demand. In this case we would subtract from Q_i any of farm i's output that was used as intermediate input in

P-L defines instantaneous aggregate productivity change as the change in aggregate demand holding prices constant and subtracting the change in aggregate costs. If we focus on a single industry (and ignore this industry's effects on the productivity of industries that use its output as an intermediate input), we can write this industry's aggregate productivity change as:

$$AP_{LEVEL} \equiv \sum_i P_i dQ_i - \sum_i \sum_k W_{ik} dX_{ik} - \sum_i \sum_j P_{ij} dM_{ij} - \sum_i R_{iq} dQ_i, \tag{2}$$

where W_{ik} is the marginal cost of the kth primary input, dX_{ik} is the instantaneous change in the use of that primary input at farm i. P_{ij} is the price paid by farm i for intermediate input j, and dM_{ij} is the change in the use of intermediate input j on farm i. The last term on the right side of equation (2) captures the direct cost of renting quota, where R_{iq} is the rental rate of quota for farm i. For farms that own quota for all of the tobacco that they sell, R_{iq} captures the opportunity cost at the margin of not renting out their quota. If we divide equation (2) by the initial aggregate value-added of the industry, we get the following equation for aggregate productivity growth (APG):

$$APG = \sum_i D_i dlnQ_i - \sum_k \sum_i D_i c_{ik} dlnX_{ik} - \sum_i \sum_j D_i c_{ij} dlnM_{ij} \sum_i D_i c_{iq} dQ_i, \tag{3}$$

where $D_i = \frac{P_i Q_i}{\sum_{i=1}^N P_i Y_i}$ is the Domar (1961) weight,

$$c_{ik} = \frac{W_{ik} X_{ik}}{P_i Q_i} \tag{4}$$

is the revenue share of primary input k,

$$c_{ik} = \frac{P_{ij} M_{ij}}{P_i Q_i} \tag{5}$$

other industries (e.g., tobacco used in cigarette production). See Petrin, White, and Reiter (2009) for further discussion.

is the revenue share of intermediate input j, and

$$c_{iq} = \frac{R_{iq}Q_i}{P_iQ_i} \tag{6}$$

is the revenue share of quota rental costs. The Domar weight takes into account the fact that some of farm i's output will contribute to aggregate productivity growth because it will be used as intermediate input in other industries (e.g., higher quality tobacco may make cigarette manufacturers more productive). So, for example, if we multiply our APG estimates for tobacco by the share of tobacco valued-added in aggregate value-added for an entire economy, the result with tell us how much productivity growth in tobacco contributes to aggregate productivity growth for the entire economy.

P-L shows that if the production function F is differentiable, then aggregate productivity growth in equation (3) can be decomposed as:

$$\begin{aligned} APG \;=\; & \textstyle\sum_i D_i \sum_k (\varepsilon_{ik} - c_{ik}) dlnX_{ik} + \sum_i D_i \sum_j (\varepsilon_{ij} - c_{ij}) dlnM_{ij} \\ & - \textstyle\sum_i D_i c_{iq} dlnQ_i + \sum_i D_i dln\omega_i, \end{aligned} \tag{7}$$

where D_i is the Domar weight, ε_{ik} and ε_{ij} are the elasticities of output with respect to primary and intermediate inputs, $c_{ik} = \frac{W_{ik}X_{ik}}{P_iQ_i}$ and $c_{ij} = \frac{P_jM_{ij}}{P_iQ_i}$ are the respective farm-specific revenue shares for primary and intermediate inputs, and $dln\omega_i$ is the growth rate of farm i's technical efficiency, defined as:

$$dln\omega_i = dlnQ_i - (\sum_k \varepsilon_{ik} dlnX_{ik} + \sum_j \varepsilon_{ij} dlnM_{ij}), \tag{8}$$

Equation (7) shows that if every farm's output elasticity for every input is equal to its revenue share for those inputs, then reallocation of inputs does not contribute to aggregate productivity growth. In this case, in the absence of quota rental costs, aggregate productivity growth is just the weighted sum of the farm-level technical efficiency growth rates from equation (8). However, if there are gaps between these output elasticities and revenue shares, perhaps because of quota programs that restrict the reallocation of land and other resources, then reallocation can increase aggregate productivity growth. The first two terms on the right side of equation (7) measure the effect of this reallocation on aggregate productivity growth.

Next we describe our data and our sample.

4 Brief Overview of the Data and Sample Selection

We use the confidential farm-level Censuses of Agriculture for 1997, 2002, and 2007 matched at the farm level to the 2008 Agricultural Resource Management Survey (ARMS). We also use Will Snell's county-level estimates of burley tobacco quota rental rates in Kentucky, ERS price indexes for farm inputs, capital rental rates for farm machinery from the Bureau of Labor Statistics (BLS), and weather data from the National Oceanic and Atmospheric Administration (NOAA). In the Ag Censuses, we observe individual farms, and we use a numeric farm-level identifier to link these farms longitudinally across censuses. For each farm, in each census year we observe tobacco revenue and pounds and acres of tobacco harvested. On the input side, we observe farm-level total expenditures on chemicals, fertilizer, utilities, fuel, contract labor, hired labor, seeds/transplants, machinery, and the total value of land and buildings. We also use data from the 2008 ARMS to impute allocations of inputs to tobacco production. We discuss this imputation and other aspects of our measures in detail in section 6 below.

From the set of farms in the 1997, 2002, and 2007 Ag Census data, we select farms that have both positive acres and positive quantities of tobacco harvested in a given Ag Census year. We further restrict the sample to farms that received the Ag Census long-form questionnaire, since only the long form asks about production costs. We estimate aggregate productivity growth of tobacco industry from 1997 to 2002 and from 2002 to 2007. For each time period, we classify farms into three categories: entrants, exits, and continuers. For example, farms which are in the data in 1997 but disappear from the sample (or change numerical identifiers) or don't produce tobacco in 2002 are considered exits for this period; tobacco farms which are in our sample in 2002 but not in 1997 are entrants; and those with positive tobacco production in both 1997 and 2002 are continuers. Because the long-form sample is randomly chosen within each Census year, we cannot count as continuers farms that received the long form in only one of two Census years. We thus represent the population of continuing tobacco farms by using the product of the Census sampling weights in 1997 and 2002. To represent the population of farms that exited tobacco production between 1997 and 2002 we weight exits by their 1997 long form sampling weight; and to represent the population of entrants in 2002, we weight them by their 2002 long-form sampling weight. Using these weights, we have a weighted count of 48,271 tobacco farms in Kentucky in 1997. A weighted count of 27,023 of these farms exited between 1997 and 2002 and 8,267 farms entered between 1997 and 2002. 21,719 farms exited tobacco production between 2002 and 2007, 5,854 continued to 2007, and 2,798 entered between 2002 and 2007.

5 Discrete Time Approximation

The Petrin and Levinsohn (2008) theory is developed in continuous time. Our data data are collected at 5-year intervals. We use Tornqvist-Divisia indexes to approximate the growth rates described by the theory. For the 1997 to 2002 period (when the quota program was in operation), we approximate aggregate productivity growth, equation (3), by the following:

$$\begin{aligned}\widehat{APG}_t \;=\; & \textstyle\sum_{i\in C}(\overline{D}_{it}(1-\overline{c}_{iqt})\Delta lnQ_{it} - \sum_k \overline{s}_{ikt}\Delta lnX_{ikt} - \sum_j \overline{s}_{ijt}\Delta lnM_{ijt}) \\ & + \textstyle\sum_{i\in eN}(D_{it}(1-c_{iqt}) - \sum_k s_{ikt} - \sum_j s_{ijt}) \\ & - \textstyle\sum_{i\in eX}(D_{i,t-5}(1-c_{iq,t-5}) - \sum_k s_{ik,t-5} - \sum_j s_{ij,t-5})\end{aligned} \tag{9}$$

where $\overline{D}_{it} = \frac{D_{it}+D_{i,t-5}}{2}$ is the average of farm i's Domar weights in 1997 and 2002, $\overline{s}_{ikt} = \frac{s_{ikt}+s_{ik,t-5}}{2}$ is the average of farm's i's expenditures for the kth primary input as a share of industry *aggregate* value-added, and $\overline{s}_{ijt}$ is the analogous measure for intermediate inputs. Δ is the first difference operator, i.e., $\Delta lnQ_{it} = lnQ_{it} - lnQ_{i,t-5}$ is the difference between the log of farm i's tobacco output 2002 and the log in 1997. X_{ikt} and M_{ijt} are our measures of farm-level primary and intermediate inputs. In the summation terms, C denotes the set of continuing tobacco farms. The set of entering tobacco farms are denoted by eN, and the set of exiters are denoted by eX. Thus the first row on the right side of equation (9) approximates the APG contribution of continuing farms, and the sum of the second and third rows approximates the total contribution of entry and exit.

Starting in 2005, tobacco farmers no longer needed to rent quota to sell tobacco. Thus one major cost of production was eliminated. Taking this into account, for the 2002 to 2007 period, we approximate aggregate productivity growth by:

$$\begin{aligned}\widehat{APG}_t \;=\; & \textstyle\sum_{i\in C}(\overline{D}_{it}\Delta lnQ_{it} - \sum_k \overline{s}_{ikt}\Delta lnX_{ikt} - \sum_j \overline{s}_{ijt}\Delta lnM_{ijt}) \\ & + \textstyle\sum_{i\in eN}(D_{it} - \sum_k s_{ikt} - \sum_j s_{ijt}) \\ & - \textstyle\sum_{i\in eX}(D_{i,t-5} - \sum_k s_{ik,t-5} - \sum_j s_{ij,t-5}) \\ & + \textstyle\sum_{All\,i} s_{iq,t-5},\end{aligned} \tag{10}$$

where $s_{iqt} = \frac{R_{iqt}Q_{it}}{\sum_{i=1}^{N} P_{it}Y_{it}}$ is the share of farm i's quota rental costs in the industry's aggregate value-added in year t. Note that this last term is summed across *all* Kentucky tobacco farms in 2002. The sum approximates the direct contribution to APG between 2002 and 2007 from eliminating quota rental costs.

Under the quota program (1997 to 2002 in our data), the decomposition of APG into reallocation and technical efficiency growth can be approximated by:

$$\begin{aligned}\widehat{APG}_t \;=\; & \textstyle\sum_{i\in C}(\overline{D}_{it}\sum_k(\overline{\varepsilon}_{ik} - \overline{c}_{ikt})\Delta lnX_{ikt} + \overline{D}_{it}\sum_j(\overline{\varepsilon}_{ij} - \overline{c}_{ijt})\Delta lnM_{ijt} \\ & - \overline{s}_{iqt}\Delta lnQ_{it} + \overline{D}_{it}\Delta ln\omega_{it}) \\ & + \textstyle\sum_{i\in eN}(D_{it} - \sum_k s_{ikt} - \sum_j s_{ijt} - s_{iqt}) \\ & - \textstyle\sum_{i\in eX}(D_{i,t-5} - \sum_k s_{ik,t-5} - \sum_j s_{ij,t-5} - s_{iq,t-5})\end{aligned} \tag{11}$$

The first row on the right side of equation (11) approximates the APG contributions of reallocation of primary and intermediate inputs among continuing tobacco farms. We estimate Cobb-Douglas production functions in logs and use the parameter estimates for the output elasticities ε_{ik} and ε_{ij}. Note that we estimate production functions separately for each year, but we assume that all tobacco farms in Kentucky in a given year use the same production technology. We calculate revenue shares, c_{ikt} and c_{ijt}, for each farm in each year. The second row give the approximate contributions of reallocation of quota and technical efficiency growth, both among continuing farms. To measure the growth rate of farm-level technical efficiency, we take the first difference of the residuals from our production function estimation. We discuss estimation of the production function in the next section. The final three rows approximate the total contribution of entry and exit. Note that we cannot decompose the contribution of entrants and exits into reallocation versus technical efficiency growth. One way to interpret this fact is that entry and exit are a form of reallocation.

After the quota buyout, the quota rental cost terms in the second and third lines of equation equation (11) disappear. For the 2002-2007 our APG decomposition becomes

$$
\begin{aligned}
\widehat{APG}_t \quad = \quad & \textstyle\sum_{i\in C}(\overline{D}_{it}\sum_k(\overline{\varepsilon}_{ik}-\overline{c}_{ikt})\Delta lnX_{ikt}+\overline{D}_{it}\sum_j(\overline{\varepsilon}_{ij}-\overline{c}_{ijt})\Delta lnM_{ijt} \\
& +\overline{D}_{it}\Delta ln\omega_{it}) \\
& +\textstyle\sum_{i\in eN}(D_{it}-\sum_{i\in eN}\sum_k s_{ikt}-\sum_j s_{ijt}) \\
& -\textstyle\sum_{i\in eX}(D_{i,t-5}-\sum_k s_{ik,t-5}-\sum_j s_{ij,t-5}) \\
& +\textstyle\sum_{All\, i} s_{iq,t-5}
\end{aligned}
\tag{12}
$$

6 Measurement and Estimation

For the aggregate productivity growth estimates and their decompositions, we need two types of measures: (i) farm-level tobacco revenues and expenditures and (ii) farm-level real tobacco output and real inputs. For real inputs, we use measures of three primary inputs (land, machinery and equipment, and the sum of contract and hired labor) and five intermediate inputs (fertilizer, chemicals, seeds/transplants, fuel, and utilities). We explain each measure below.

Our measure of tobacco revenue, $P_{it}Q_{it}$–the numerator in the Domar weight in equations (9), (11) and (12)–is the value of tobacco sales on farm i in year t. When aggregating productivity across farms, we want to take account of differences in the quality of the farms' output. Thus, in one way, the value of tobacco sales is an ideal measure for our purposes, because the price presumably captures any between-farm differences in tobacco quality.[4] On the other hand, it is possible that some tobacco sold in year t was produced in a previous year, adding measurement error to our Domar weight. This is unlikely to be a problem during the years of the tobacco quota program, because tobacco not sold at auction was purchased at the support price by the Commodity Credit Corporation. We are investigating the extent to which this is an important measurement issue in the post-buyout years.

Our measure of the farm-level quantity of tobacco output Q_{it}, is pounds of tobacco harvested in year t. Unfortunately, we do not have direct measures of the quality of tobacco harvested. Thus any *changes* in the quality of tobacco harvested will not be captured in our measure of the growth of farm-level output, ΔlnQ_{it}, and will show up in the growth rate of farm-level technical efficiency, $\Delta ln\omega_{it}$.

Our measure of land is acres of tobacco harvested. Ideally, we would like to know the number of acres planted and the quality of the land, but these are not available in the Ag Census. To the extent that acres planted are different from acres harvested, this introduces measurement error. We discuss the issue of land quality in the results section below. To obtain a measure of the farm-level cost of land used in tobacco production, we multiply the farm's acres of tobacco harvested by the farm-specific rental rate for land, which we also observe in the Ag Census. If the farm does not rent any land, then we multiply the acres of tobacco harvested by the average rental rate for all tobacco farms in the county.

For other inputs, in the Ag Censuses we observe farm-level total expenditures for each input, not tobacco-specific allocations of these inputs.

[4] Differences in prices received by tobacco farmers could also reflect different *types* of tobacco sold. However, differences in types of tobacco are unlikely to be a big factor in our sample. Although other types of tobacco are produced in Kentucky, the vast majority of the value of production comes from burley tobacco.

Most tobacco farms also produce other crops. Since our focus is on tobacco-specific productivity growth, except for land we need to impute the allocation of these inputs to tobacco production. Fortunately the 2008 ARMS includes a tobacco-specific questionnaire which asks for total farm-level expenses for labor and intermediate inputs.[5] For each of these expenses it also asks "How much of this expense was for the tobacco enterprise?" We use the tobacco-specific expenses in the ARMS data and the total farm-level expenses in the Ag Censuses to impute for the missing tobacco-specific expenses for all farms in the Ag Census years. For example, in the Ag Census, we have a measure of the total farm-level production expenses paid for hired farm labor. In 2008 the ARMS tobacco questionnaire asks how much of the farm operation's total wage expenses for hired farm labor was for the tobacco enterprise. We use a farm-level numeric identifier to match tobacco farms in the 2008 ARMS survey to tobacco farms in the 2007 Ag Census. Then we run the following regression:

$$HIREDTOBSH_i = \beta_1 TOTHIREDEXP_{it} + \gamma Z_i + \mu_i, \qquad (13)$$

where $HIREDTOBSH_i$ is farm i's tobacco-specific hired farm labor expenses as a share of the farm's total hired labor expenses in the 2008 ARMS, $TOTHIREDEXP_{it}$ is the same farm's total hired labor expenses from the 2007 Ag Census, Z_i is a vector of other farm-level variables from the 2007 Ag Census, γ is vector of parameters, and μ_i is an error term. Z_i includes total sales of agricultural products, total farmland size, total production costs, the number of operators of the farm, pounds of tobacco harvested, acres of all crops harvested, sales shares of tobacco products, livestock products, and hay products, and harvested acreage shares of tobacco, alfalfa, hay, corn, and soybeans. We estimate the parameter β_1 and the parameter vector γ on the set of tobacco farms in the 2007 Ag Census that match to the

[5] The ARMS is a large annual survey, and tobacco farms appear in every ARMS. Commodity-specific versions of the ARMS include larger samples, sampling weights designed to reflect production of that commodity, and detailed questions about the commodity enterprise. Prior to 2008, the most recent tobacco-specific ARMS version was conducted in 1996 and was specific to flue-cured tobacco.

tobacco-specific sample in the 2008 ARMS. Using the regression coefficient estimates from this model and the set of right-hand-side variables from the Ag Censuses, we predict the tobacco-specific hired labor expenses for each tobacco farm in the 1997, 2002, and 2007 Ag Censuses. Finally, we multiply this share by the observed total hired labor expenditures for that farm in that year to impute tobacco-specific hired labor expenses for each farm. We follow the same procedure for our other variable expense measures in the Ag Census: contract labor, fertilizer purchased, chemicals purchased, fuel, utilities, and seeds or transplants purchased.

For each type of input, we need two types of variables: nominal expenditures, which are needed for the APG calculations in equation (9), and quantities, which are needed in both equation (9) and equation (16). Except for land, we have to substitute real expenses for quantities. The lack of availability of price indexes also dictates that we combine some real expenditure variables. To be consistent, we combine the corresponding nominal expenditures as well.

We combine our imputed tobacco-specific contract and hired labor expenditure variables into one labor expenditures variable. To compute real labor input, we deflate tobacco-specific labor expenditures by the region-specific farm labor wage rate available from the USDA's National Agricultural Statistics Service (NASS).

For real agricultural chemicals and seeds/transplants, we deflate (imputed) nominal tobacco-specific expenditures by state-specific price indexes for these inputs.[6] For real fuel and utilities expenditures, we deflate the imputed nominal tobacco-specific expenditures by the state-specific price indexes for gas and electricity, also available from NASS.[7]

[6] The price indexes, used to construct the USDA state-level productivity accounts, were provided by Eldon Ball and Sun Ling Wang of USDA's Economic Research Service. For more information about the construction of these price indexes and the USDA productivity accounts, see http://www.ers.usda.gov/Data/AgProductivity/.

[7] We obtained per gallon prices paid for gasoline, diesel, and LP gas from NASS's Agricultural Prices Survey, conducted annually in April in each NASS-defined farm production region (see http://www.nass.usda.gov). The price of fuel is then computed as the average of these three prices. For electricity, we extracted annual average retail

For fertilizer, we gathered region-specific prices paid by farmers from NASS's Agricultural Prices Survey. Since per-ton prices for burley tobacco fertilizers were similar except for lime, we aggregated the per-acre application amounts for all non-lime fertilizers recommended in the 2008 University of Kentucky Burley Tobacco Per Acre Costs and Returns Budget. Then using NASS survey prices for each type of fertilizer, we computed the average of fertilizer price for Kentucky burley weighted by the per-acre quantities of each type of fertilizer.

Our final measured input to production is farm machinery and equipment. To compute the real input, we divide the total value of farm machinery and equipment (observed in the Ag Census) by the state-specific price index for farm machinery and equipment from the USDA productivity accounts. To compute the cost of this type of capital, we multiply the farm-level real value by the Bureau of Labor Statistics' annual rental rates for farm tractors and for agricultural machinery (excluding tractors) for NAICS industries 111 and 112 (crop and animal production). Unfortunately, since the 2008 ARMS tobacco-specific questionnaire does not ask about tobacco-specific capital expenditures, we cannot use the ARMS data to allocate farm-level expenditures on machinery and equipment to tobacco production. We also do not have an estimate of utilization of these types of capital. To the extent that larger farms can make more use of their equipment without having to buy more equipment than smaller farms, our estimates of the returns to scale will be biased. However, our results indicate that the input with far and away the largest output elasticity is land, a capital type for which we do have a tobacco-specific measure.

Although quota is not an input to production, leasing quota (or the opportunity cost of not leasing it out) is a cost of production. To measure farm-level quota rental costs, we multiply the farm's pounds of tobacco harvested by Will Snell's estimates of the county- and year-specific quota rental rates for burley tobacco in Kentucky.

prices from the EIA-826 Database's Monthly Electric Utility Sales and Revenues Data (see http://www.eia.doe.gov/cneaf/electricity/page/eia826.html).

6.1 Sample Weights

Because we use the long-form sample in the Ag Census to estimate aggregate changes in the population of tobacco farms, we multiply the Domar weight by the interacted sampling weights for the two Census years. The modified Domar weights for tobacco farms that continue from year t-5 to year t are are given by

$$\widehat{D}_{i,t-5} = \frac{w_{i,t} w_{i,t-5} P_{i,t-5} Q_{i,t-5}}{\sum_{i=1}^{N} w_{i,t-5} w_{it} P_{i,t-5} Y_{i,t-5}}, \tag{14}$$

and

$$\widehat{D}_{it} = \frac{w_{i,t-5} w_{it} P_{it} Q_{it}}{\sum_{i=1}^{N} w_{i,t-5} w_{it} P_{it} Y_{it}}, \tag{15}$$

where $w_{i,t-5}$ and w_{it} represent the Census sampling weights in year t-5 and t, respectively. For entering or exiting farms the Domar weight is multiplied by the farm's long-form sampling weight in the year in which it enters or exits.

7 Estimation

We assume Kentucky tobacco farms' technology can be approximated by a Cobb-Douglas production function. We estimate log specifications of the production function separately for each year of our data. As a robustness check, we compare results across several different production function estimators, including Ordinary Least Squares, OLS with county fixed effects, the Levinsohn and Petrin (2003, LP hereafter) proxy method, and the Wooldridge (2009) modification of the LP estimator. In order to take account of differences in weather that might affect productivity, we also estimated specifications in which we included sub-state region-level measures of rainfall and degree-days. Although the production function parameter estimates differed somewhat across estimators and specifications, the main results are all robust to these differences.

Given a set of production function parameter estimates, our estimate of farm-level log technical efficiency is

$$ln\widehat{\omega}_{it} = lnQ_{it} \quad - \quad (\textstyle\sum_k \varepsilon_{kt} lnX_{ik} + \sum_j \varepsilon_{jt} lnM_{ij}). \tag{16}$$

where $\widehat{\epsilon}_{kt}$ and $\widehat{\epsilon}_{jt}$ are the estimated elasticities of tobacco output with respect to, respectively, primary input k and intermediate input j.

8 Results

Table 1 shows our estimates of APG and its decomposition for Kentucky tobacco farms. The first row shows the decomposition for 1997 to 2002 using equations (9) and (11). We find that the aggregate productivity of Kentucky tobacco farms decreased by 38% between 1997 and 2002. Almost all of this decrease was due to reallocation of one sort or another. Column 2 shows the total contribution of reallocation of primary and intermediate inputs and quota among continuing farms. We find that this reallocation contributed -25 percentage points to the decline in aggregate productivity. Aggregate technical efficiency growth of continuing farms contributed almost nothing to the decline in aggregate productivity. When we use OLS to estimate the farm-level production functions, we find that technical efficiency growth contributed -1 percentage point to the decline. When we use other estimators, the contribution of technical efficiency growth is sometimes negative and sometimes positive, but always close to zero. Column 4 shows the contribution of farms entering and exiting tobacco production. From 1997 to 2002 we find that net entry contributed -13 percentage points to aggregate productivity growth.

The second row of table 1 shows APG and its decomposition for 2002 to 2007 using equations (10) and (12). In stark contrast to the earlier period, we find that the aggregate productivity of Kentucky tobacco farms grew by 37% between 2002 and 2007. As expected, after the quota buyout, reallocation among continuing tobacco farms contributed positively, adding 22 percentage points to aggregate productivity growth in Kentucy tobacco.

As in the earlier period, the contribution of aggregate technical efficiency growth was negligible. In the post-buyout period, net entry contributed 10 percentage points to aggregate productivity growth as less productive farms exited tobacco production. The final column of table 2 shows our estimate of the direct APG contribution of eliminating the quota rental costs, the final summation term in equation (12): we find that this added 5 percentage points to aggregate productivity growth in Kentucky tobacco between 2002 and 2007. Since all tobacco farms faced the same policy change simultaneously, econometrically we cannot identify the effect of quota elimination on net entry and reallocation of resources (other than quota). However, we suspect that elimination of the quota program is responsible for much if not all of the aggregate productivity growth of Kentucky tobacco production over this period.

One may wonder why reallocation of resources had a *negative* effect on APG between 1997 and 2002. We suspect that the answer may lie in the quota buyout payments. As described above, the buyout payments created an incentive for tobacco quota owners to continue or enter production in 2002 so that they could receive the "grower benefit" of $3 per pound of quota in addition to the $7 per pound received by quota owners. At the margin, this may have led otherwise unprofitable (and less productive) tobacco farms to produce in 2002. Evidence on the exit rates of tobacco farmers is consistent with this hypothesis. Dohlman, Foreman, and Da Pra (2009) find that the number of tobacco farms declined by 51% from 2004 to 2005. Using the Census of Agriculture, we find that the net entry rate for tobacco farms was -39% between 1997 and 2002, but -69% between 2002 and 2007. Almost all of the difference in net entry was due to an increase in the exit rate.

9 Conclusions

We study the impact of the U.S. tobacco quota program and the quota buyout on aggregate productivity growth of tobacco farms in Kentucky. We find that aggregate productivity decreased in the years before the quota buyout and increased by 37% between 2002 and 2007. Almost all of the increase in aggregate productivity is due to reallocation of resources among continuing farms and through entry and exit. Our results highlight the importance of using highly disaggregated longitudinal data and taking into account the effect of distortionary economic policy when decomposing aggregate productivity growth.

References

Ball, V. E., F. M. Gollop, A. Kelly-Hawke, and G. P. Swinand (1999): "Patterns of State Productivity Growth in the U.S. Farm Sector: Linking State and Aggregate Models," *American Journal of Agricultural Economics*, 81(1), 164–179.

Basu, S., and J. Fernald (2003): "Aggregate Productivity and Aggregate Technology," *European Economic Review*.

Brown, A. B., R. R. Rucker, and W. N. Thurman (2007): "The End of the Federal Tobacco Program: Economic Impacts of the Deregulation of U.S. Tobacco Production," *Review of Agricultural Economics*, 29(4), 635–655.

Dohlman, E., L. Foreman, and M. Da Pra (2009): "Structural Change and Adjustment to Policy-reform: the Post-buyout Experience of Peanuts and Tobacco," Working Paper.

Hulten, C. (1978): "Growth Accounting with Intermediate Inputs," *The Review of Economic Studies*, 45, 511–518.

Levinsohn, and Petrin (2003): "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*.

Petrin, A., and J. Levinsohn (2008): "Measuring Aggregate Productivity Growth Using Plant-Level Data," Working Paper.

Petrin, A., T. K. White, and J. P. Reiter (2009): "The Impact of Plant-level Resource Reallocations and Technical Progress on U.S. Macroeconomic Growth," Working Paper.

Womach, J. (2003): "Tobacco Price Support: An Overview of the Program," Crs report for congress, Congressional Research Service.

——— (2004): "Tobacco Quota Buyout Proposal in the 108th Congress," Crs report for congress, Congressional Research Service.

Wooldridge, J. M. (2009): "On estimating firm-level production functions using proxy variables to control for unobservables," *Economics Letters*, 104(3), 112–114.

Table 1: Aggregate Productivity Growth, Reallocation, and Technical Efficiency
Kentucky Tobacco Farms, 1997-2007

	(1)	(2)	(3)	(4)	(5)
Year	Aggregate Productivity Growth	Reallocation, continuers	Technical Efficiency Growth, continuers	Entry & Exit	Elimination of Quota Rental Costs
1997-2002	-38%	-25%	-1%	-13%	
2002-2007	37%	22%	-1%	10%	5%

Sources: 1997, 2002, and 2007 Census of Agriculture and 2008 ARMS. See text for other data sources.