# Regional Changes in the Distribution of Net Value Added in U.S. Agriculture, 1960-2002

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***Abstract***

This paper examines the effects of structural changes on the distribution of net value added and the difference between net value added and agricultural income over time. We present and discuss the changes in the distribution of net value added (land, labor, capital, and farm income) over time. Net value added by U.S. agriculture grew significantly from $18 billion in 1960 to $95 billion in 1996. We examine regional differences in net value added using the Theil entropy measure. The inequality (dispersion) of net value added increased over time. The increased inequality in net value added represented both increases in regional dispersion in net value added and increases in the average inequality in net value added in each region. Thus, the net value added is becoming less alike across the United States. We also examine the inequality in the components of net value added. The greatest dispersion occurred in returns to land followed by returns to capital. Therefore, changes in the dispersion of net value added by agriculture are explained by differences in the payments to non-operator landlords and capital.



*Key words*: Theil entropy measure, net value added, farm structure, net farm income, land, labor, capital

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Production agriculture contributes income to farmers and ranchers and others (i.e., stakeholders) who participate in commodity production. Sweeping structural changes in production agriculture are affecting the distribution of returns to those stakeholders.

The economic contributions of agriculture are traditionally measured with the U.S. Department of Agriculture's statistical series on farm income. These estimates reflect the value-added to the economy by farmer-operator production factors (land, capital, labor, and operators' management). When these accounts were first established over 50 years ago, farm operators and their families owned most of the factors of production. Today many farms have multiple operators. Entities sharing in the risks of production include not only individual proprietors or operators, but also a myriad of individuals and legal entities that contribute at-risk capital in many forma (e.g., owners of animals placed in feedlots, passive investors, partners, and contractors). Net farm income includes the net returns to all these nonoperator equity holders, as well as to the returns to traditional farm operators. Also, the proportion of land, labor, and capital which is owned by non-equity holders and paid without contingencies for their services, has increased over time.

Policy makers and analysts are concerned about the financial well-being of the farm production sector, including both equity and non-equity holders. Therefore, the changing structure of U.S. agriculture requires new measures of the economic surplus created through production activities that also reflect the value-added by these non-equity holders. Examining the level and distribution of net value added by region and decomposing net value added by

components (land, labor, capital, and farm income) over time helps us to discern what forces are driving the changes in farm income and in the sector's value added.

This paper examines the effects of structural changes on the distribution of net value added (NVA) by the agricultural sector over time. First, we review the definition of net value added and the difference between net value added and agricultural income. Second, we develop the information inequality measure proposed by Theil (1967) to examine the distribution of net value added over time. Third, we describe the Theil inequality measure and the data used. Fourth, we present and discuss the changes in the distribution of net value added between and within regions, and in the distribution of the components of net value added (land, labor, capital, and farm income), over time. Finally, we summarize our results, discuss the implications, and suggest further research.

## Net Value Added by the Agricultural Sector

Today many farms, particularly larger operations, have multiple operators. Entities sharing in the risks of production include not only individual proprietors or operators, but also a myriad of individuals and legal entities that contribute at-risk capital in many forms. These include owners of animals placed in feedlots for finishing, passive investors contributing only capital in expectation of receiving dividends, partners, and contractors. Net value added includes the net returns to all these non-operator equity holders, as well as the returns to traditional operators. Also, the proportion of land, labor, and capital, which is owned by non-equity holders and paid without contingencies for their services, has increased over time. Therefore, the changing structure of U.S. farming requires new measures of the value created through production activities (Paul, 2000).

The concept of net value added originates in the System of National Accounts. Net value added disaggregates national income into various sectors. In the case of agriculture, net value added represents not only net farm income (income to farm operators), but also payments to non-operator labor and capital, and rental payments to non-operator landlords. Thus, net value added represents agriculture's contribution to the overall economic activity of the United States.

The economic contributions of agriculture are traditionally measured utilizing the U.S. Department of Agriculture's (USDA) statistical series on farm income. These estimates reflect the value-added to the economy by farmer-operator production factors (land, capital, labor, and management). When these accounts were first established over 50 years ago, farm operators and their families owned most of the factors of production. Farm operators obtained the services of some (usually off-farm) production factors by paying input suppliers who had little or no role in production decisions and did not share the "risks of production." Consequently, these payments were treated as production expenses in the farm income accounts. Thus, net farm income was legitimately viewed as a measure of the net income that farm families received from their operations and as an indicator of the net value of the farm sector's production of goods and services.

Currently value-added is a more accurate indicator of the farm sector's total output of goods and services since it is a broader measure reflecting the contribution of all factors of production regardless of the form of ownership. In addition to the more traditional measure of farm income, net value added includes the contributions of (1) farm real estate rented from individuals who were not equity-holders in the business, (2) returns on outside capital (borrowed capital from the perspective of a farm operator), and (3) hired labor provided by all equity-holders (i.e., land, capital, labor, and management of farm operators and others). The presence of

more disaggregated components under the value-added format provides transparency and insight into the forces driving the changes and trends in farm income. Changes in commodity production are the cause of most of the volatility in the income accounts, and much more detail is available to the reader in the value-added format. Net value added represents the total value of the farm sector's output of goods and services, less payments to other (nonfarm) sectors of the economy. It reflects production agriculture's contribution to national economic product. The value added approach to sector accounting is now the format accepted and used internationally.

Changes in the structure of agriculture alter the composition of net value added. The aggregation of production into fewer farms could imply more net value added by capital or non-operator labor. This reallocation from capital to labor may result from technology innovations (Schmitz and Seckler 1970). Further, differences in the structure of agriculture in different regions have implications for the composition of net valued added across regions in the United States. For example, increased scale in agriculture production in the Midwest may imply a relative increase in the value added by capital and non-operator landlords as the average farm size increases. Similarly, increasing specialization into fruit and vegetable production in the Pacific and Southeast regions may increase the relative share of net value added by non-operator labor.

## Measuring Dispersion (Inequality)

The history of economic thought recognizes two theories or research approaches on income distribution (Dagum, 1999). The first, the Ricardian, or functional distribution of income approach (Ricardo, 1817), addresses the income distribution among the owners of the factors of production and the price determination of each productive factor. It purports to account for factor price formation, such as rent, wages and profit, and the share that the corresponding factors of

have in national income. The second, the Pareto approach, is concerned with the size distribution of income among a set of economic units (Dagum, 1999). It studies the shape of the income distribution and their corresponding measure of inequality. The Pareto approach considers the total income received by each economic unit regardless of the factors of production. The informational measures applied in this study examine the distribution of economic rents from both Ricardian and Pareto perspectives. The inequality of overall income is consistent with the Pareto approach while the component inequality formulation follows the Ricardian emphasis on returns to factors of production.

We use the Theil (1967) measure of entropy, a statistical measure of dispersion or entropy, to examine changes in the distribution of net value added in relation to the number of farms, by states and regions, 1960-2002. Theil's measure of inequality is based on the entropy or information contained in a signal. As developed by Shannon (1949), the optimal measure of the amount of information contained is the entropy of the signal expressed as

$$J = -\sum_{i=1}^{N} p_i \ln\left(p_i\right) \tag{1}$$

where $J$ is the measure of entropy and $p_i$ is the probability that a given signal will occur. Following Theil's description of the entropy measure, a signal that is almost certain to occur contains no information $\left(p_i \to 1 \Rightarrow \ln\left(p_i\right) \to 0\right)$. The total amount of information in the signal is then the probability weighted average of each signal that could be received (as depicted in equation 1). Theil adapts the entropy approach by considering the possibility of a prior signal that event $i$ will occur. Theil's information inequality is then the probability weighted differences in two probabilities

$$I = \sum_{i=1}^{N} p_i \ln\left(\frac{p_i}{q_i}\right) \tag{2}$$

where $I$ is the information inequality and $q_i$ is the prior probability. If the prior event (or signal) is perfect then $p_i = q_i \Rightarrow \ln\left(p_i / q_i\right) = 0$ or there is no information (inequality) in the second signal. Further, given the concavity of the natural logarithm, the value of the information inequality is always positive and the greater the information in the signal the larger the information inequality.

Theil's measure of inequality has frequently been used to analyze income convergence (Theil 1979). In these applications, the prior signal is the share of the world's population that resides in a country or region and the posterior signal is the share of income earned by people in that region. In this application, as the share of world population approaches the share of income, income converges or income inequality declines. In our current application, we use a similar approach to analyze whether the farms' net value added are converging or diverging. Specifically, we define $p_i$ as the share of net value added in each state and $q_i$ as the number of farms in each state. As the net value added by each farm in different regions converges, the value of the information inequality presented in equation 2 declines. However, if farmers are becoming less alike in terms of net value added, the information inequality defined in equation 2 will increase.

In addition to its consistency with information theory, the information inequality also has the advantage of decomposability. Thus, the overall inequality can be broken down into inequality between regions and the average inequality within each region. Mathematically,

$$\begin{aligned} P_r &= \sum_{i \in r} p_i \\ Q_r &= \sum_{i \in r} q_i \end{aligned} \Rightarrow I_r = \sum_{i \in r} p_i / P_r \ln\left( \frac{p_i / P_r}{q_i / Q_r} \right) \tag{3}$$

where $P_r$ is the share of net value added in region $r$ (defining a state $i$ in region $r$ as $i \in r$), $Q_r$ is the share of farms in region $r$, and $I_r$ is the inequality of net value added in region $r$. The inequality across regions ($I_R$) can be derived from the regional shares in equation 3 as

$$I_R = \sum_r P_r \ln\left( \frac{P_r}{Q_r} \right). \tag{4}$$

Based on these two definitions, Theil (1967) demonstrates that the total inequality of a signal can be expressed as

$$I = I_R + \bar{I} \tag{5}$$

where the weighted average inequality is defined as $\bar{I} = \sum_r P_r I_r$ .

Theil and Moss (1999) extend Theil's original formulation to examine differences in the expenditures that result from different levels of income. Theil and Moss assume that $N$ consumers allocate their income across $n$ goods. The share of total income (income across all consumers) allocated by consumer $c$ to good $k$ is then denoted as $B_{ck}$. The inequality (or dispersion) of expenditures on each good based on the information inequality can then be defined as

$$J_k = -\ln(N) - \frac{1}{N} \ln\left( \frac{B_{ck}}{B_{.k}} \right) \tag{6}$$

where $J_k$ is the informational inequality for expenditures on good $k$ and $B_{.k}$ is the total share of expenditures on good $k$ by all consumers $\left( B_{.k} = \sum_{c=1}^{N} B_{ck} \right)$. Applying this expression across all goods yields the total inequality ( $J$ )

$$J = -\ln\left(N\right) - \frac{1}{N}\sum_{c=1}^{N} \ln\left(B_{.k}\right). \tag{7}$$

Extending the decomposition presented in equation 5, Theil and Moss conjecture that

$$J = \bar{J} - \bar{I} \tag{8}$$

where $\bar{J}$ is the average expenditure inequality across all goods $\left( \bar{J} = \sum_{k} B_{.k} J_k \right)$ and $\bar{I}$ is the income inequality (as defined in equation 2).

Theil and Moss (1999) analyzed the effect of income inequality on the allocation of income across consumption categories. They found that the share of income spent on necessities (e.g., food and clothing) was less disperse than expenditures on other factors (e.g., house furnishing). In this study, we use the component inequality approach to analyze differences in the composition of income (or net value added). Specifically, we use the component approach to decompose the overall inequality of value added into inequalities of value added from net farm income, rents to non-operator landlords, labor, and capital.

## Data

The U.S. Department of Agriculture's Economic Research Service's (ERS) farm sector national accounts include estimates of farm income, net value added, the farm business balance sheet, and farm sector financial ratios. For the farm income and balance sheet series, the farm sector is considered as a single entity, with no adjustment made for differences in ownership or business

arrangements among farms or other entities comprising the sector. Estimates generated by the farm sector national accounts program are also used to measure changes in farm sector performance and well-being. We use U.S.-level and state-level data from 1960-2002 U.S. Department of Agriculture, Economic Research Service for net value added and its components. We group the 48 conterminous States (excluding Alaska and Hawaii) into ten ERS farm production regions (Figure 1).

## Changes in the Level and Distribution of Net Value Added

Figure 2 depicts the overall change in the net value added by agriculture in the United States between 1960 and 2002. The overall net value added increased from $18 billion in 1960 to $95 billion in 1996, declining slightly to $90 billion in 2002 (nominal dollars). Decomposition of the source of net value added indicates that most of the net value added in agriculture comes from net farm income followed by labor, capital, and land. As depicted in Figure 2, the net value added by capital exceeded the net value added by labor from 1973 through 1991.

Turning to the regional distribution of net valued added, Figure 3 presents the inequality of net value added along with the inequality between regions and the average inequality in each region. In general, the overall dispersion of net value added increased steadily between 1960 and 2002. Further, both of the underlying inequalities (the inequality between regions and the average inequality in each region) have also increased. Thus, regions are becoming less alike in terms of net value added and states within each region are also becoming less alike.

Variations in net value added by states within regions, where states tend to be more homogeneous, tend to reflect microeconomic conditions. Variations in net value added between regions tend to reflect inherent macroeconomic conditions such as farm structural changes (changes in the size distribution of farms, changes in production methods, etc.) and government

price support and credit programs. Since (average) within-region variation in net value added and between-region variation in net value added contribute about equally to the total U.S. variation in net value added, we conclude that inherent macroeconomic conditions (changes in the size distribution of farms, changes in production methods, etc.) and government price support and credit programs and microeconomic conditions contribute about equally to the U.S. variation in net value added.

Figures 4 and 5 provide additional insight into both of these points. Specifically, while the inequality in the Lake States, Corn Belt, Northern Plains, and the Northeast has been bounded (generally less than 0.10), the inequality in the Appalachia grew eight-fold between 1960 and 2002. Thus, the growing inequality between regions and within regions can be attributed to specific regions (e.g., Appalachia). Although the inequality in the Southern Plains and Delta has also been bounded (generally less than 0.15), the inequality in the Southeast, Mountain States and Pacific has been considerably higher.

In order to further develop the implications of this divergence in net value added, we examine the inequality in the components of net value added, presented in Table 1. The average inequality in the components of value added have also increased over time reaching a maximum of 0.0597 or 43.7 percent of the inequality of net valued added in 1996-2002 (presented in Table 2). The dispersion in net value added is largely attributable to differences in the net value added by land. The inequality in net value added by farmland increased to 0.3989 in 1980-1986 or 55.3 percent of the inequality. The next largest share of the inequality in net value added is attributed to capital which increased to 0.2528 or 33.5 percent of the total inequality in 1996-2002.

## Summary and Implications

### *Summary*

This study examines the change in net value added in agriculture and the differences in the components of net value added over time. Net value added allows for the decomposition of the economic activity in the U.S. agricultural sector into net farm income, capital, labor and land rents paid to non-operator landlords. Thus, net value added represents the economic surplus created by agriculture over time.

First, we found that the net value added by agriculture grew significantly from $18 billion in 1960 to $95 billion in 1996. Focusing on the components of net value added, the largest component was net farm income followed by labor, capital, and land. Second, we examined the regional differences in net value added using the inequality approach pioneered by Theil (1967). The inequality (dispersion) of net value added increased over time. The increased inequality in net value added represented both increases in the regional dispersion in net value added and increases in the average inequality in net value added in each region. Thus, the net value added is becoming less alike across the United States. This means that the economic prospects for the agricultural sector in regions vary widely. In areas with high levels of inequality, continued consolidation is expected. That will involve a decline in farm numbers and an increasing average size of farm and ranch operations. Third, we then examined the inequality in the components of net valued added. Our results indicate that the greatest dispersion occurred in returns to farmland followed by non-operator capital. Therefore, changes in the dispersion of net value added by agriculture are largely explained by differences in the payments to non-operator landlords and capital.

***Explaining Changes in the Distribution of Net Value Added***

Changes in the structure of U.S. agriculture have occurred in the United States since the beginning of the twentieth century. Over this time, technological innovations have led to the

replacement of draft animals with farm machinery (capital) and, more recently, the replacement of labor with capital. As such, these innovations have caused reallocations of economic rents (Schmitz and Seckler 1970). Evenson and Huffman (1997) note that there has been a long history of structural change and total factor productivity change. They found that input prices, public and private research, public extension and government commodity programs directly and indirectly cause change in U.S. farm structure and in total factor productivity (TFP).

Their results suggest that changes in farm size have been dominated by input price changes rather than by technology or government programs.

Our results indicate that the largest component of the inequality in net value added can be attributed to regional differences in the net value added by land. However, this component is declining over time while the regional differences attributed to variations in net value added attributed to capital have been increasing. This suggests that changes in the structure of agriculture that affect the net value added by agriculture arise from emerging regional differences in capital structure. In order to monitor national and regional structural changes, our research concludes that additional research interest into the effect of vertical integration and agribusiness on the U.S. agricultural sector may be warranted.

In order to more fully interpret these results, we will need to more thoroughly examine relative factor price changes and changes in factor demand and supply at a more disaggregated level. Our finding, that generally most of the variation in net value added across regions is due to differences between regions rather than to differences in the components of net value added themselves, is consistent with the notion that differences in the quality and productivity of inputs across regions play a key role in the growth and distribution of income to land, labor, capital, and farm operators.

***Measurement Issues/Measuring Value Added at the Farm Level***

There are specific measurement issues associated with net value added and farm income that the U.S. Department of Agriculture, Economic Research Service are resolving using data from the Agricultural Resource Management Survey (ARMS). For example, both net value added and net farm income accrue to persons or entities other than the farm operator. Data collection steps have been taken through the ARMS to remedy this data shortcoming by accounting for multiple households and contract arrangements.

ERS has traditionally estimated income of the farm sector as a whole. However, ERS is now combining value-added measurement concepts with farm-level production and input acquisition information from the ARMS to develop a value-added account for each farm. Resulting estimates of value added generated by farm business establishments will be used to assess the relative distribution of farm business returns to suppliers of factors of production (http://www.ers.usda.gov/Briefing/FarmIncome/overview.htm).

Explanations for these changes in the level and distribution of net value added and in factor shares to rent, capital, labor, and farm operators will have to include an expanded view of farm structure and performance in order to better measure, analyze, and understand these changes. We believe that additional research interest into the effect of vertical integration and agribusiness on the agricultural sector in the United States may be warranted.

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**Table 1. Estimation of Net Value Added (NVA)**

| |
|---|
| Final crop output |
| + Final animal output |
| + Services and forestry |
| = Final agricultural sector output |
| - Intermediate consumption outlays |
| + Net government transactions |
| - Capital consumption |
| = Net value added |
| - Factor payments |
| - Employee compensation (total hired labor) |
| - Net rent received by non-operator landlords |
| - Real and non-real estate interest |
| = Net farm income |

**Table 2. Inequality of U.S. Net Value Added by Total NVA and by Components, selected years, 1960-2002**

| Years | Inequality of Total NVA $= J$ | Average inequality of NVA $= \overline{J}$ | Average inequality of components of NVA $= \overline{I}$ | Percent of inequality due to inequality of total NVA | Percent of inequality due to inequality of components of NVA |
|---|---|---|---|---|---|
| 1960-69 | 0.0979 | 0.0694 | 0.0285 | 70.9 | 29.1 |
| 1970-79 | 0.1119 | 0.0815 | 0.0304 | 72.8 | 27.2 |
| 1980-86 | 0.1401 | 0.0962 | 0.0439 | 68.7 | 31.3 |
| 1987-95 | 0.1087 | 0.0690 | 0.0397 | 63.5 | 36.5 |
| 1996-02 | 0.1363 | 0.0768 | 0.0596 | 56.3 | 43.7 |

Source: U.S. Department of Agriculture, Economic Research Service, farm business sector accounts.

"NVA" means "net value added."

**Table 3. Inequality of Net Value Added by Components: Land, Labor, Capital and Net Farm Income, selected years, 1960-2002**

| Years | Land | Labor | Capital | NFI 1/ | Percent of total inequality: land | Percent of total inequality: labor | Percent of total inequality: capital | Percent of total inequality: NFI 1/ |
|---|---|---|---|---|---|---|---|---|
| 1960-69 | 0.2656 | 0.0864 | 0.0849 | 0.0753 | 51.9 | 16.9 | 16.6 | 14.7 |
| 1970-79 | 0.3342 | 0.0820 | 0.1283 | 0.0785 | 53.6 | 13.2 | 20.6 | 12.6 |
| 1980-86 | 0.3989 | 0.0987 | 0.1206 | 0.1032 | 55.3 | 13.7 | 16.7 | 14.3 |
| 1987-95 | 0.3012 | 0.0862 | 0.1779 | 0.0548 | 48.6 | 13.9 | 28.7 | 8.8 |
| 1996-02 | 0.3288 | 0.1206 | 0.2528 | 0.0533 | 43.5 | 16.0 | 33.5 | 7.1 |

Source: U.S. Department of Agriculture, Economic Research Service, farm business sector accounts.
1/ "NFI" means "net farm income."

**Figure 1. USDA-ERS production regions**

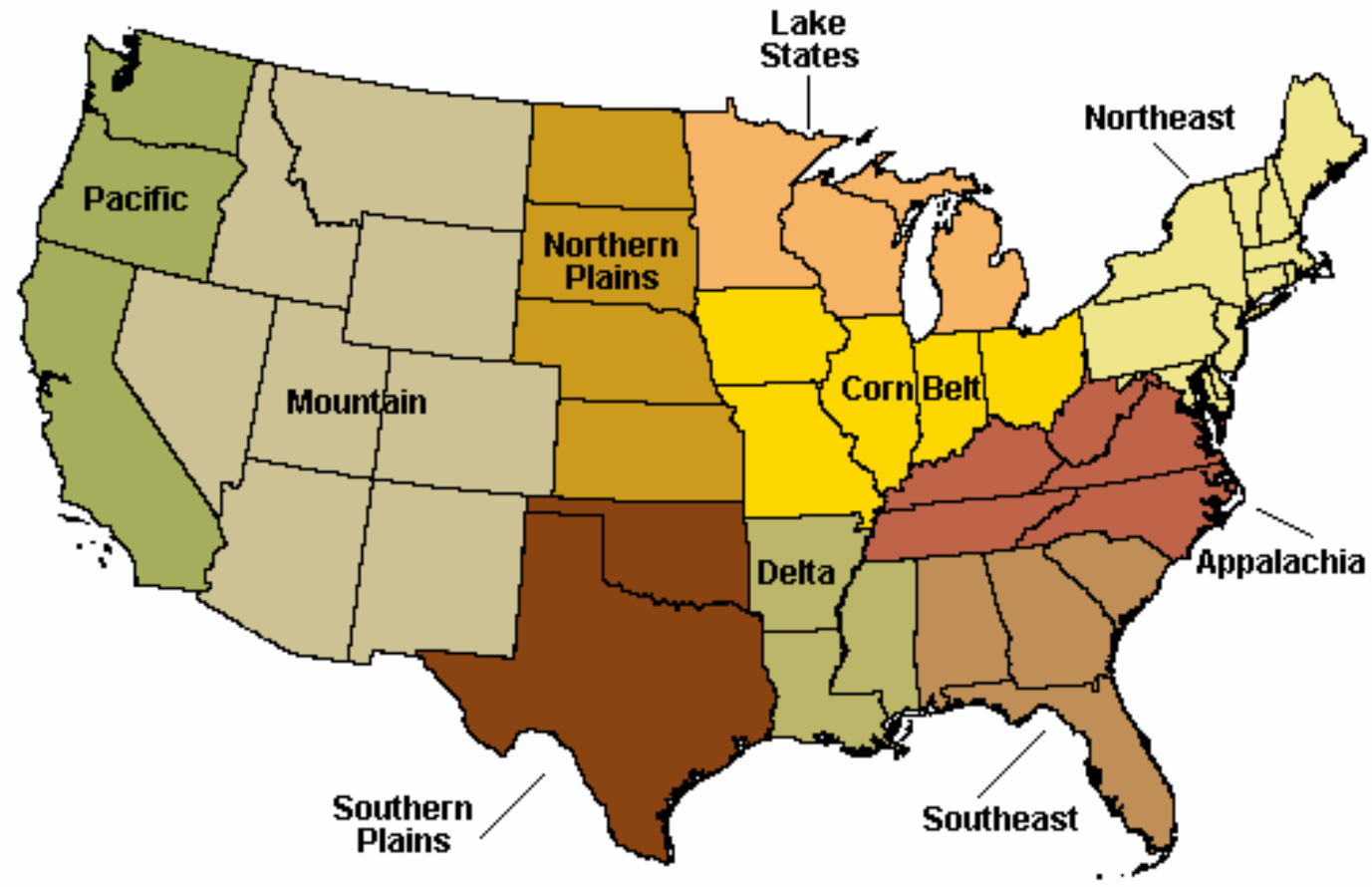
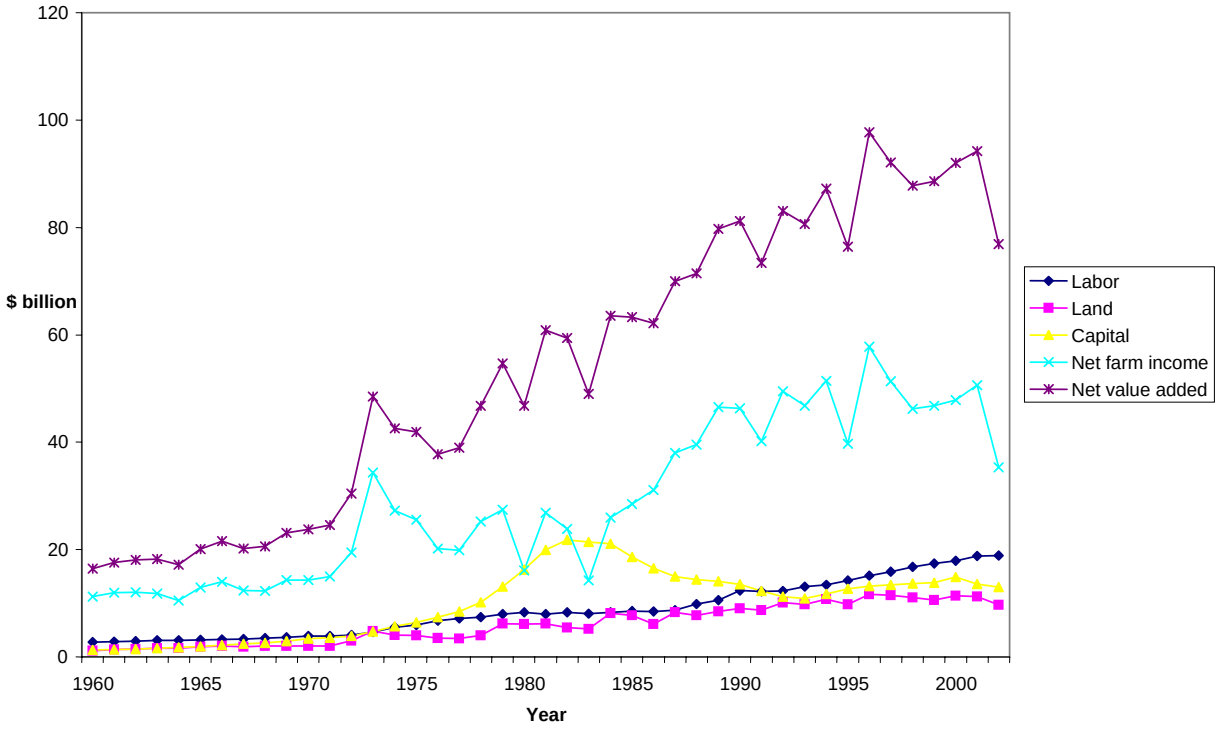
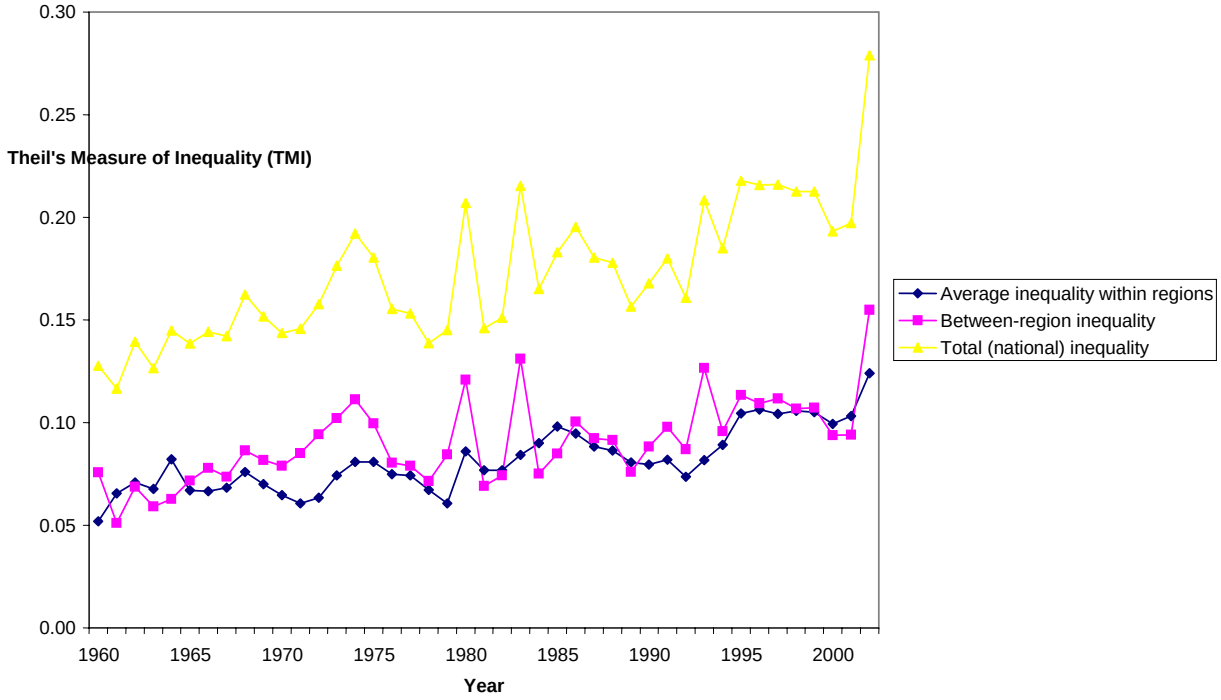


**Figure 2. Net value added and factor shares, 1960-2002**



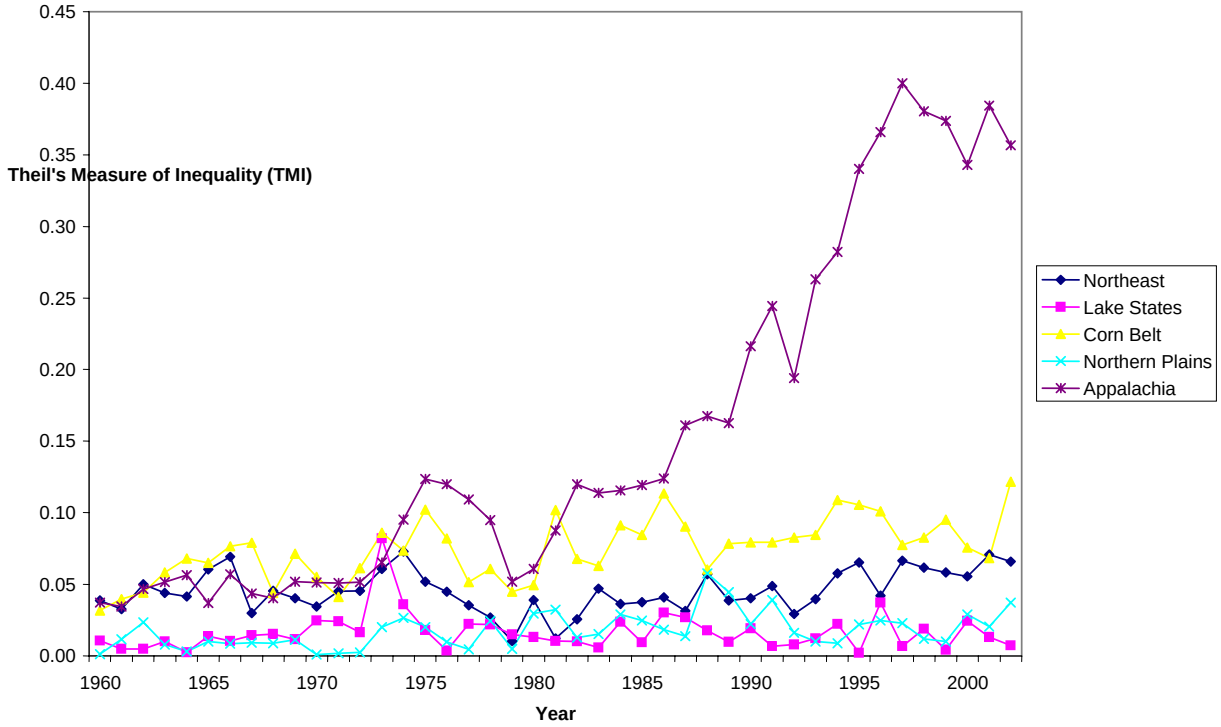

Source: USDA-ERS-RED-FSPW (farm sector accounts)

**Figure 3. (Average) within-region, between-region, and total inequality of net value added, 1960-2002**



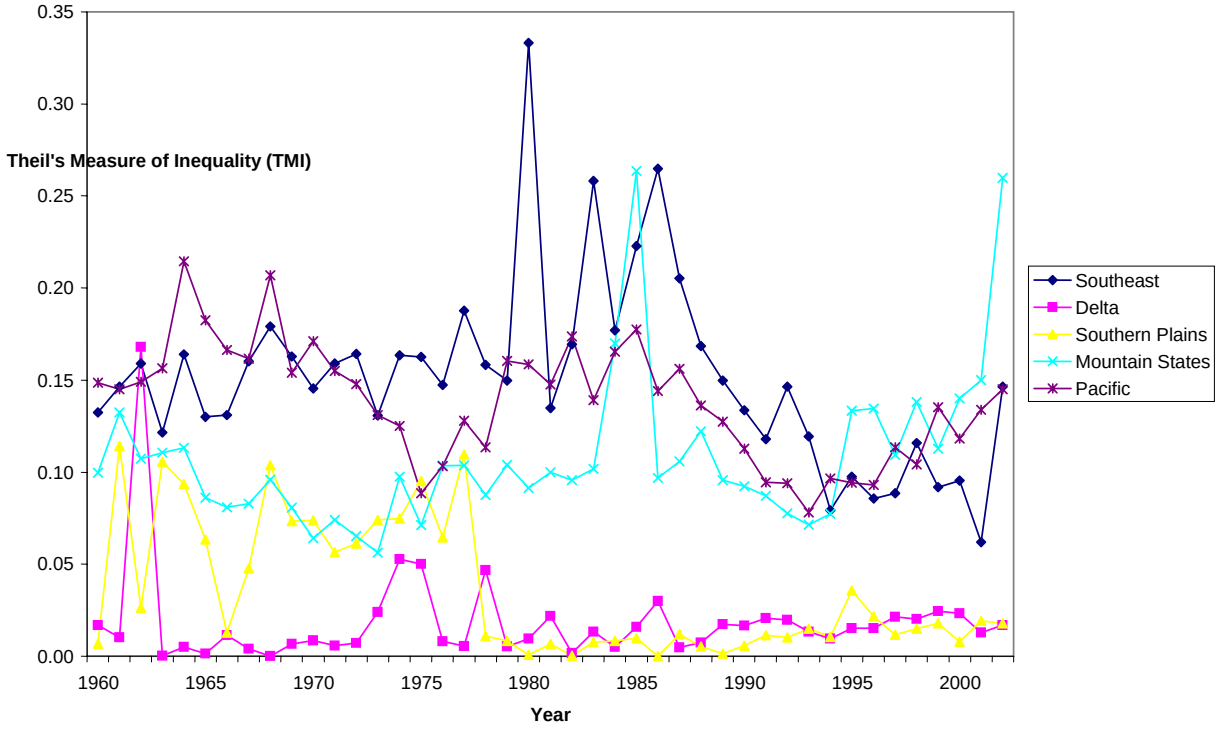

Source: USDA-ERS-RED-FSPW (farm sector accounts)

**Figure 4. Within-region inequality in net value added, selected regions, 1960-2002**




Source: USDA-ERS-RED-FSPW (farm sector accounts)

**Figure 5. Within-region inequality in net value added, selected regions, 1960-2002**




Source: USDA-ERS-RED-FSPW (farm sector accounts)