Oligopoly Power, Cross-Market Effects and Demand Relatedness: An Empirical Analysis

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Abstract

The goal of the paper is to develop a conceptual framework that can be used to examine market competitiveness and assess cross-market effects in a multi-product oligopoly consisting of firms producing and selling various demand-related products. The econometric model which consists of two inverse demand functions and two price-margin equations is applied to the US catfish processing industry. Focusing on fresh catfish filet and whole fresh catfish, the empirical results rule out the existence of cross-market effects, but give support to the existence of some degree of market power. In that setting, the oligopoly power indices are, respectively, 18.2% and 13.3% for fresh catfish filet and whole fresh catfish thereby indicating that the price distortion is more pronounced in the market for fresh catfish filet than it is in the market for whole fresh catfish.

Keywords: Oligopoly power, Cross-market Effects, Multi-product firms.

JEL Classification: C51, D24, D40

1. Introduction

The aim of this paper is to empirically evaluate the degree of market power and assess cross-market effects in the US catfish processing industry. Towards this end, the paper uses and estimates a conjectural variation model that takes into account both the oligopoly power and cross-market effects.

The analysis of market power in the US catfish industry has been the focus of a large body of literature. For instance, Kinnucan and Sullivan (1986) applied Houck's method (1985) to analyze the degree of market power in the catfish industry in West Alabama. Using Appelbaum's model (1982), Kouka (1995) tested for market power and estimated the oligopoly power index in the US catfish processing industry. Bouras and Engle (2007) investigated the oligopoly and oligoposony power in the US catfish industry based on a statistic conjectural variation model. In a subsequent paper, Bouras et *al*., (2010) examined the oligopsony power in the US catfish industry using a dynamic conjectural variation model. Recently, Bouras et *al*., (2017b) used data from the US catfish industry to test the effectiveness of the New Empirical Industrial Organization (NEIO) technique in measuring the degree of market power. These papers relied, however, on the assumption that catfish processors produce and sell a single product. In reality, catfish processors produce and sell a variety of processed catfish products. These include, among others, fillet, shank fillet, nuggets, and steaks. As such the US catfish processing industry should be treated as a multi-product oligopoly predominantly producing and selling demand-related products. It is, therefore, important to take into consideration not only multimarket contacts but also cross-market effects when addressing the issue of market power in multi-product oligopolies.

The existing papers concerning the analysis of market power in multi-product oligopolies are scant. For example, Gelland and Spiller (1987), while focusing on the markets for credit denominated in the local currency and foreign currency, analyzed the degree of market power and the effect of barriers to entry on the degree of competitiveness in the Uruguayan banking sector. In another example, Schroeter and Azzam (1990) tested for both the oligopoly power and oligopsony power in the US meat industry with a special focus on the markets for beef and pork.

With a four-firm concentration ratio oscillating between 60% and 70% (Dillard, 1995), the US catfish processing industry is among the moderately concentrated industries in the United States. Such a concentrated structure has led economists and policy-makers to voice concerns about the exercise of market power by catfish processors. In that setting, previous empirical papers either supported or ruled out the existence of some degree of market power in the US catfish processing industry. For the intended analysis, we focus utterly on fresh catfish fillet and whole fresh catfish. These two processed products account for over 75% of total fresh catfish processed (USDA, 2012).

The remainder of this paper proceeds as follows: the next section presents the theoretical model and the empirical application; the third section contains data, the empirical estimation of the econometric models and statistical tests; the fourth section provides the estimation of the Lerner indices; the last section concludes the paper.

2. Theoretical Model and Empirical Application

2.1. Theoretical Model

The starting point of our model is a multi-product firm producing and selling two demand-related products: q_1 and q_2. The multi-product firm purchases a material input in competitive markets. After converting the material input into different processed products, the multi-product firm sells its final products in non-completive markets. The profit maximization's problem for the j^{th} multi-product firm can be formulated as

(1) $$\underset{q_1^j, q_2^j}{\text{Max}}\, \pi^j = \underset{q_1^j, q_2^j}{\text{Max}} \left[\sum_{i=1}^{2} \left[\left(P_i\left(Q_1, Q_2\right) - k_i \times w \right) \times q_i^j - TPC_i \right] \right].$$

Where P_i is the price of the i^{th} final product; Q_1 and Q_2 are the industry's total quantities sold of product 1 and product 2, respectively; k_i is the conversion factor associated with the i^{th} final product;[1] TPC_i is the total cost of processing the material input into the i^{th} final product; and

[1] The conversion factor, k_i, refers to the amount of the material input needed to obtain one pound of the i^{th} final product.

w is the price of the material input. Differentiation of Equation 1 with respect to q_1^j and q_2^j yields the following first-order conditions

(2)

$$\frac{\partial \pi^j}{\partial q_1^j} = 0 \;==>\; P_1 + q_1^j \frac{\partial P_1}{\partial Q_1}\frac{\partial Q_1}{\partial q_1^j} + q_1^j \frac{\partial P_1}{\partial Q_2}\frac{\partial Q_2}{\partial q_1^j} + q_2^j \frac{\partial P_2}{\partial Q_1}\frac{\partial Q_1}{\partial q_1^j} + q_2^j \frac{\partial P_2}{\partial Q_2}\frac{\partial Q_2}{\partial q_1^j} - k_1 w - mpc_1 = 0$$

,

(3)

$$\frac{\partial \pi^j}{\partial q_2^j} = 0 \;==>\; P_2 + q_2^j \frac{\partial P_2}{\partial Q_2}\frac{\partial Q_2}{\partial q_2^j} + q_2^j \frac{\partial P_2}{\partial Q_1}\frac{\partial Q_1}{\partial q_2^j} + q_1^j \frac{\partial P_1}{\partial Q_2}\frac{\partial Q_2}{\partial q_2^j} + q_1^j \frac{\partial P_1}{\partial Q_1}\frac{\partial Q_1}{\partial q_2^j} - k_2 w - mpc_2 = 0$$

Where mpc_1 and mpc_2 are the marginal processing costs of converting the material input into product 1 and product 2, respectively. Equations (2) and (3) can be expressed in terms of elasticities as

(4) $$P_1 + P_1\eta_{11}\theta_{11} + P_1\eta_{12}\theta_{21} + P_2\left[\frac{q_2^j}{q_1^j}\right]\eta_{21}\theta_{11} + P_2\left[\frac{q_2^j}{q_1^j}\right]\eta_{22}\theta_{21} - k_1 w - mpc_1 = 0$$

(5) $$P_2 + P_2\eta_{22}\theta_{22} + P_2\eta_{21}\theta_{12} + P_1\left[\frac{q_1^j}{q_2^j}\right]\eta_{12}\theta_{22} + P_1\left[\frac{q_1^j}{q_2^j}\right]\eta_{11}\theta_{12} - k_2 w - mpc_2 = 0.$$

Where:

$\eta_{11} = \left[\frac{\partial P_1}{\partial Q_1}\frac{Q_1}{P_1}\right]$: own price elasticity of the inverse demand for product 1;

$\theta_{11} = \left[\frac{\partial Q_1}{\partial q_1^j}\frac{q_1^j}{Q_1}\right]$: own conjectural elasticity for product 1;

$\eta_{12} = \left[\frac{\partial P_1}{\partial Q_2}\frac{Q_2}{P_1}\right]$: cross price elasticity of the inverse demand for product 1 with respect to product 2;

$\theta_{21} = \left[\frac{\partial Q_2}{\partial q_1^j}\frac{q_1^j}{Q_2}\right]$: cross conjectural elasticity for product 2 with respect to product 1;

$\eta_{21} = \left[\frac{\partial P_2}{\partial Q_1} \frac{Q_1}{P_2} \right]$: cross price elasticity of the inverse demand for product 2 with respect to product 1;

$\eta_{22} = \left[\frac{\partial P_2}{\partial Q_2} \frac{Q_2}{P_2} \right]$: own price elasticity of the inverse demand for product 2;

$\theta_{12} = \left[\frac{\partial Q_1}{\partial q_2^j} \frac{q_2^j}{Q_1} \right]$: cross conjectural elasticity for product 1 with respect to product 2;

$\theta_{22} = \left[\frac{\partial Q_2}{\partial q_2^j} \frac{q_2^j}{Q_2} \right]$: own conjectural elasticity for product 2.

In order to use aggregate data, multiply Equation (4) by q_1^j and Equation (5) by q_2^j, assume constant conjectural variations and constant marginal processing costs, and sum over catfish processing plants yields

(6) $$P_1Q_1 + P_1\eta_{11}\theta_{11}Q_1 + P_1\eta_{12}\theta_{21}Q_1 + P_2\eta_{21}\theta_{11}Q_2 + P_2\eta_{22}\theta_{21}Q_2 - k_1wQ_1 - mpc_1Q_1 = 0$$

(7)

$$P_2Q_2 + P_2\eta_{22}\theta_{22}Q_2 + P_2\eta_{21}\theta_{12}Q_2 + P_1\eta_{12}\theta_{22}Q_1 + P_1\eta_{11}\theta_{12}Q_1 - k_2wQ_2 - mpc_2Q_2 = 0.$$

After a few algebraic manipulations, Equations (6) and (7) become

(8) $$M_1 = -(\eta_{11}\theta_{11} + \eta_{12}\theta_{21}) - (\eta_{21}\theta_{11} + \eta_{22}\theta_{21})\left[\frac{P_2Q_2}{P_1Q_1} \right] + \frac{mpc_1}{P_1}$$

(9) $$M_2 = -(\eta_{22}\theta_{22} + \eta_{21}\theta_{12}) - (\eta_{12}\theta_{22} + \eta_{11}\theta_{12})\left[\frac{P_1Q_1}{P_2Q_2} \right] + \frac{mpc_2}{P_2}.$$

where $Q_1 = \sum_{j=1}^{N} q_1^j$ and $Q_2 = \sum_{j=1}^{N} q_2^j$ are the industry's total quantities sold of product 1 and product 2, respectively; $M_1 = \left[\frac{P_1 - k_1w}{P_1} \right]$ and $M_2 = \left[\frac{P_2 - k_2w}{P_2} \right]$ are the price margins for product 1 and product 2, respectively.

2.2. Empirical Application

The theoretical model presented in the previous section is used to assess the degree of oligopoly power and cross-market effects in the US catfish processing industry. The US catfish processing industry is comprised of multi-product processing plants producing and selling various demand-related products. Each catfish processing plant purchases live catfish in competitive markets. After converting live catfish into processed catfish, the catfish processing plant sells its final products in non-completive markets. For simplicity and application purposes, we focus exclusively on fresh catfish fillet, denoted by q_1, and whole fresh catfish, denoted by q_2. The basis for our econometric model, therefore, is the margin equations (8) and (9). To estimate the parameters of the econometric model and following prior literature (e.g., Bouras and Engle, 2007; Bouras *et al*., 2017a), we assume that catfish processing plants use three inputs, namely, labor, capital and energy denoted respectively by L, K and E. Assuming linear marginal processing costs, the econometric model in its final form is given by:

(10)

$$M_1 = -\left(\eta_{11}\theta_{11} + \eta_{12}\theta_{21}\right) - \left(\eta_{21}\theta_{11} + \eta_{22}\theta_{21}\right)\left[\frac{P_2 Q_2}{P_1 Q_1}\right] + \delta_1\left(\frac{P_K}{P_1}\right) + \delta_2\left(\frac{P_E}{P_1}\right) + \delta_3\left(\frac{P_L}{P_1}\right) + \varepsilon_1$$

(11)

$$M_2 = -\left(\eta_{22}\theta_{22} + \eta_{21}\theta_{12}\right) - \left(\eta_{12}\theta_{22} + \eta_{11}\theta_{12}\right)\left[\frac{P_1 Q_1}{P_2 Q_2}\right] + \gamma_1\left(\frac{P_K}{P_2}\right) + \gamma_2\left(\frac{P_E}{P_2}\right) + \gamma_3\left(\frac{P_L}{P_2}\right) + \varepsilon_2$$

.

Where δ's and γ's are parameters to be estimated; P_K, P_E and P_L are the prices of capital, energy and labor, respectively; ε_1 and ε_2 are the error terms; and all the remaining variables and parameters are as previously defined. To overcome the identification problem, we use a two-step procedure. In the first step, we obtain the estimates for the own and cross price elasticities by estimating the inverse demand functions for fresh catfish fillet and whole fresh catfish. These estimates, in turn, are used in the second step to estimate the price margin equations. Towards this end, we estimate the following log-linear models

(12) $$\log(P_1) = \alpha_0 + \eta_{11}\log(Q_1) + \eta_{12}\log(Q_2) + \alpha_1\log(t) + u_1$$

(13) $$\log(P_2) = \beta_0 + \eta_{22}\log(Q_2) + \eta_{21}\log(Q_1) + \beta_1\log(t) + u_2.$$

Where P_1 and P_2 are the prices of fresh catfish fillet and whole fresh catfish, respectively; Q_1 and Q_2 are the industry's total quantities sold of fresh catfish fillet and whole fresh catfish, respectively; and t is a time trend variable.

3. Data and Empirical Estimation

3.1. Data

In order to evaluate the degree of market power and assess cross-market effects in the US catfish processing industry, we use monthly data ranging from 01/1991 to 12/2012. The data were compiled from a variety of sources. The bank prime loan rate, which is used as a proxy for the price of capital, was taken from the Federal Reserve of St. Louis; live catfish, whole fresh catfish and fresh catfish fillet prices, quantity sold of whole fresh catfish, and quantity sold of fresh catfish fillet were collected from the US Department of Agriculture. The price of electricity, which is used as a proxy for the price of energy, was collected from the US Department of Energy; and hourly minimum wage, which is used as a proxy for the price of labor, was obtained from the US Department of Labor. The descriptive statistical analysis is provided in Table 1.

Table 1: Descriptive Statistical Analysis

Variable	Min	Max	Mean	Standard Deviation
Bank Prime Loan Rate (%)	3.3	9.5	6.3	2.1
Price of live catfish ($/Lb)	0.5	1.3	0.8	0.1
Price of whole fresh catfish ($/Lb)	1.2	2.7	1.6	0.2
Quantity sold of whole fresh catfish (1,000 Lbs)	1484.0	4928.0	3136.2	587.0
Price of fresh catfish fillet ($/Lb)	2.4	4.9	3.0	0.5
Quantity sold of fresh catfish fillet (1,000 Lbs)	1877.0	6815.0	4050.9	1073.0
Electricity price (¢/kilowatt hour)	4.2	7.7	5.4	0.9
Hourly minimum wage ($/Hour)	3.8	7.3	5.3	1.0

3.2. Empirical Estimation

The empirical assessment of the degree of market power and market-cross effects is carried out using a two-step procedure. In the first step, we estimate the inverse demand functions for fresh catfish fillet and whole fresh catfish. Table 2 contains own and cross price elasticities of the inverse demand along with other log-linear models' parameter estimates.

Table 2: Parameter Estimates for the inverse demand for fresh catfish fillet and whole fresh catfish.

Parameter	Estimate	Standard Error
Fresh Catfish Fillet		
α_0	4.709*	0.564
η_{11}	-0.314*	0.052
η_{12}	-0.173**	0.080
α_1	0.077*	0.019
R^2	79.41%	
Log-Likelihood	336.14	
Akaike Info Criterion	-2.52	
F-Statistic	334.19*	
Whole Fresh Catfish		
β_0	4.151*	0.596
η_{22}	-0.280*	0.079
η_{21}	-0.191*	0.058
β_1	0.034**	0.014

R^2	59.42%
Log-Likelihood	268.51
Akaike Info Criterion	-2.00
F-Statistic	126.90*

Note: * and ** represent 1%, and 5% significance level, respectively.

Having obtained the estimates for own and cross-price elasticities of the inverse demand functions, these estimates are used in the second step to estimate the margin equations for fresh catfish fillet and whole fresh catfish. The margin equations are estimated jointly using Three-Stage Least Squares method (3SLS) with correction for autocorrelation and heteroscedasticity using Newey and West's approach (1987). Table 3 provides parameter estimates for the margin equations for both fresh catfish fillet and whole fresh catfish.

Table 3: Parameter Estimates of the Margin Equations for fresh catfish fillet and Whole Fresh Catfish

Parameter	Estimate	Standard Error
Fresh Catfish Fillet		
θ_{11}	0.315	0.270
θ_{21}	0.204	0.277
δ_1	-0.007**	0.004
δ_2	-0.004	0.019
δ_3	0.143*	0.025
Whole Fresh Catfish		
θ_{22}	0.338***	0.182
θ_{12}	-0.105	0.108
γ_1	0.024*	0.003
γ_2	-0.022	0.014
γ_3	0.031***	0.017

Note: *, **, and *** represent 1%, 5%, and 10% significance level, respectively.

Of particular relevance are the own and cross conjectural elasticities: θ_{11}, θ_{22}, θ_{12} and θ_{21}. These parameters are used to test statistically the hypotheses of market power and cross-market effects. These statistical tests are summarized in Table 4. The first hypothesis is the inexistence of cross market effects. This test amounts to testing whether θ_{12} and θ_{21} are jointly equal to zero. With a Chi-square statistic of 1.66, the hypothesis of no cross-market effects cannot be rejected. The second hypothesis is the inexistence of market power. This test is equivalent to testing whether θ_{11}, θ_{22}, θ_{12} and θ_{21} are jointly equal to zero. With a Chi-square statistic of 206.34, the hypothesis of the inexistence of marker power can be rejected at the 1% significance level.

Table 4: Chi-squared Statistical Tests

Null Hypothesis	Chi-square Statistic
No Cross Effects:	
$H_0 : \theta_{12} = \theta_{21} = 0$	1.66
No Market Power:	
$H_0 : \theta_{11} = \theta_{22} = \theta_{12} = \theta_{21} = 0$	206.34*

Note: * represents 1% significance level.

4. Lerner Indices

To further analyze the degree of market power in the US catfish processing industry we compute the Lerner indices, commonly known as the oligopoly power indices, at the industry level for both fresh catfish fillet and whole fresh catfish. Using Equations (8) and (9), the Lerner indices at the industry level for both fresh fillet and whole fresh catfish .are, respectively, given by

(14) $$L_1 = \left(-\left(\eta_{11}\theta_{11} + \eta_{12}\theta_{21}\right) - \left(\eta_{21}\theta_{11} + \eta_{22}\theta_{21}\right)\left[\frac{P_2 Q_2}{P_1 Q_1}\right]\right)$$

(15) $$L_2 = \left(-\left(\eta_{22}\theta_{22} + \eta_{21}\theta_{12}\right) - \left(\eta_{12}\theta_{22} + \eta_{11}\theta_{12}\right)\left[\frac{P_1 Q_1}{P_2 Q_2}\right]\right).$$

The estimates of the Lerner indices at the industry level for both fresh catfish fillet and whole fresh catfish for various years are reported in Table 5 and Figure 1. According to the results, the Lerner index for fresh catfish fillet ranges from nearly 17% to nearly 21% while that for whole fresh catfish ranges from over 11% to over 15%. Evaluated at the mean values of the variables, the estimates of the Lerner indices for fresh catfish fillet and whole fresh catfish are 18.2% and 13.3%, respectively. These estimates are statistically significant at the 1% level. As shown in Table 5, the Lerner index for fresh catfish fillet is higher than that for whole fresh catfish, implying that the price distortion is more pronounced in the market for fresh catfish fillet than it is in the market for whole fresh catfish. Although prior literature regarding the estimation of the oligopoly power index in the US catfish processing industry is scant, using aggregate data from 1977 to 1993, Kouka (1995) reported an average oligopoly power index of 44%.

Table 5: Lerner Indices for Fresh Catfish Fillet and Whole Fresh Catfish for Selected Years

	Lerner Index	
Year	Fresh Catfish Fillet	Whole Fresh Catfish
1992	0.2088	0.1125
1994	0.2035	0.1154
1996	0.1935	0.1221
1998	0.1843	0.1304
2000	0.1799	0.1354
2002	0.1725	0.1466
2004	0.1695	0.1528
2006	0.1722	0.1474
2008	0.1746	0.1434
2010	0.1772	0.1393
2012	0.1910	0.1242
Average	**0.1820***	**0.1330***

Note: * represents 1% significance level.

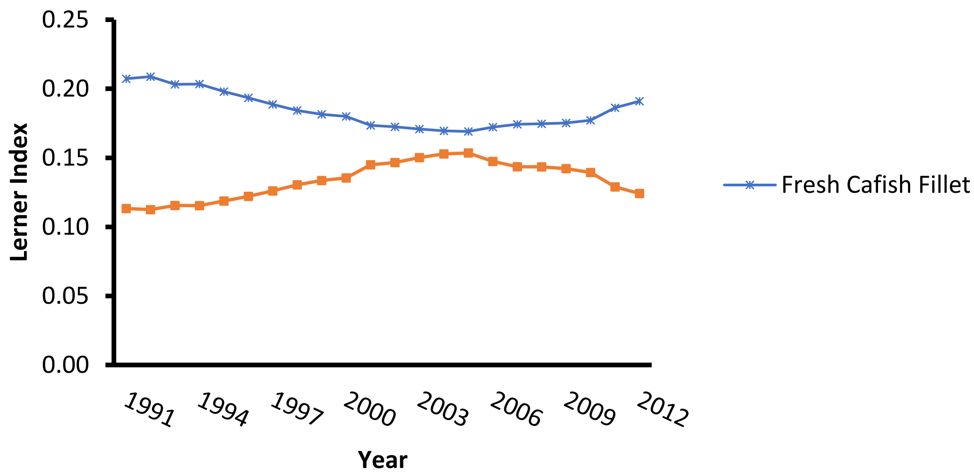

Figure 1: Yearly Lerner Indices for Fresh Catfish Fillet and Whole Fresh Catfish.

5. Concluding Remarks

The objective of this paper is to empirically evaluate the degree of market power and assess cross-market effects in the US catfish processing industry. To this end, the paper uses and estimates a conjectural variation model that takes into account both the oligopoly power and cross-market effects. Using monthly data from the US catfish processing industry while focusing exclusively on the market for whole fresh catfish and fresh catfish fillet, Chi-square statistical tests show that while the hypothesis of cross-market effects can be rejected, the existence of some degree of market power cannot be ruled out. In addition, the estimates of the oligopoly power index for fresh catfish fillet is higher than that for whole fresh catfish, implying that the price distortion is more pronounced in the market for fresh catfish fillet than it is in the market for whole fresh catfish.

References

[1] Appelbaum, E. (1982). "The estimation of the degree of oligopoly power." Journal of Econometrics 19:2/3, 287-299.

[2] Houck, J. P. (1985). "The link between supply response and production elasticities." Central Journal of Agricultural Economics 7:1, 11–17.

[3] Kinnucan, H., and G. Sullivan (1986). "Monopsonistic food processing and farm prices: The case of the West Alabama catfish industry." Journal of Agricultural and Applied Economics 18:2, 15-24.

[4] Bouras D., and C. Engle (2007). "Assessing oligopoly and oligopsony power in the U.S. catfish industry." Agribusiness Journal 25:1, 47-57.

[5] Bouras, D. Kaliba, A., Bouras, A., and A. Dutta (2010). "Testing for market power in the U.S. catfish industry: A dynamic error correction approach." Journal of Applied Economics and Policy 29: (Spring), 15-33.

[6] Bouras, D., Anunoby, O., and O. Saitakhunov (2017a). "Output price risk, material input price risk, and price margins: Evidence from the US catfish industry." Journal of Economics & Management 29: 23-36.

[7] Bouras, D., Frank, T., and E. Burgess (2017b). "Functional forms and oligopolistic models: An empirical analysis." International Journal of Economics and Financial Issues 7: 4, 1-5.

[8] Dillard, J. G. (1995). Organization of the catfish industry: Market structure-conduct-performance *Catfish Farmers of America*, Annual Meetings, Memphis, Tennessee.

[9] Federal Reserve Bank of St. Louis, (1992-2012). Economic Data: Bank Prime Loan Rate.

[10] Gelfand, M. D. and P.T. Spiller (1987). "Entry barriers and multiproduct oligopolies: do they forbear or spoil?" International Journal of Industrial Organization 5:1, 101–113.

[11] Kouka, P. (1995). "An empirical model of pricing in the catfish industry." Marine Resource Economics 10:2, 161-169.

[12] Newey, W., and K. West (1987). "A simple, positive semi-definite, heteroscedastic and autocorrelation consistent covariance matrix." Econometric 55:3, 703-708.

[13] Schroeter, J., and A. Azzam (1991) "Measuring market power in multi-product oligopolies: the US meat industry." Applied Economics 22:10, 1365-1376

[14] U.S. Department of Agriculture. (1992-2012). Catfish and trout production. *National Agricultural Statistics Service*.

[15] U.S. Department of Energy, (1992-2012). Energy information administration. *Monthly Energy Review*.

[16] U.S. Department of Labor, (1992-2012). Bureau of labor statistics, employment and earnings.