A Structural Estimation of the Employment Effects of Offshoring in the U.S. Labor Market

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Abstract

This paper generalizes the Grossman and Rossi-Hansberg (2008) offshoring model to include numerous tasks/skill levels. This generalization allows a possible and direct linkage between the theoretical task offshoring model and occupational data that can be aggregated from the CPSMORG (Current Population Survey Merged Outgoing Rotation Groups) data from year 1983 to 2011. Empirical investigation of the effect of offshoirng on occupational employment for the ten major occupational groups (at 2-digit SOC level) in the U.S. labor market is conducted by estimating their offshoring cost functions using a non-parametric monotonic cubic spline interpolation method. Five relatively offshorable occupational groups are identified from the estimated offshoring cost functions.

The number of jobs offshored and the offshoring percentage for the five relatively offshorable occupational groups under three scenarios are calculated under NLS (non-linear least squares) method by attaching a cubic offshoring cost functional form to all five groups. Results show production occupations are the most offshorable while sales and related occupations are the least offshorable among all five groups under all three scenarios. Offshoring percentage for production occupations has been increasing in both pre- and post-2000 periods while the offshoring percentages for professional and related occupations, and management, business, and financial operations occupations have been decreasing over time.

Key words: Offshoring, Employment, Occupation, Monotonic Cubic Spline Interpolation, NLS, Offshoring Cost

JEL classification: F14, F16, C14

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1. Introduction

The debate over offshoring has intensified in the United States as offshoring has spread from the jobs of blue-collar workers in the manufacturing sector to those of white-collar workers in service sectors. The service sector comprises about 80 percent (U.S. Department of Commerce) of the U.S. employment and most white-collar workers are employed in the service sector. U.S. workers in all sectors have become more concerned about the security of their jobs due to increased offshoring activities as the global economy has continued to integrate. Given changes in technology (the internet), a well-educated radiologist and a low-skilled auto assembly line worker could both be susceptible to offshoring. These concerns are well reflected in results from Princeton University's telephone survey conducted in summer 2008.[1] Survey results indicate occupational offshorability reported by individual survey respondents are much higher than those predicted by economists.

The increase in offshoring along with a persistently high unemployment rate in recent years, has heightened policymaker concerns and has been the subject of increased economic research on the short- and long-run labor market implications of offshoring and in particular, the potential for U.S. job loss. The actual impact of offshoring is multi-dimensional and difficult to quantify. Existing empirical estimates (Bardhan and Kroll, 2003; Blinder, 2007; Blinder, 2009) provide a wide range of estimates for offshorable jobs in the U.S. labor market, varying from 11 to 47 percent. With relatively little theoretical guidance, the wide range in early empirical estimates provided limited information to policymakers facing tensions from a high national unemployment rate exceeding nine percent.

[1] For details, see Blinder and Krueger (2009).

Under such circumstances, an economic theory of offshoring has been exposited by Grossman and Rossi-Hansberg (2008). In their parsimonious framework, job tasks are defined as either low-skilled or high-skilled. Using comparative static analysis, they analyze the synergic action of *productivity effect*, *relative-price effect* and *labor supply effect* of offshoring on these two groups due to a change of offshoring costs. Their results show that offshoring might lead to wage gains for both low-skilled and high-skilled workers and create a win-win situation for all types of workers, but not necessarily reward one player by harming the others as stated in the traditional Stolper-Samuelson results. Motivated by these results, several papers empirically tested the effect of offshoring in the United States (Harrison and McMillan, 2010; Ebenstein et al., 2013; Crinò, 2010b) and in European countries (Goos et al., 2010; Crinò, 2010a; Criscuolo and Garicano, 2010).

Harrison and McMilan (2010) estimated a reduction of four million jobs in U.S. manufacturing employment due to offshoring over the period of 1982 to 1999. Ebenstein et al. (2013) found that the impact of offshoring on U.S. worker's wages has been underestimated by previous studies because offshoring has driven workers from high-wage manufacturing jobs to low-wage service jobs. In addition, workers performing routine tasks are most affected by offshoring and experience larger wage decline. On the other hand, studying the effects of service offshoring on white-collar employment in more than 100 U.S. occupations, Crinò (2010 b) concluded that (a) service offshoring increases employment in more skilled occupations relative to less skilled occupations; (b) at a given skill level, service offshoring penalizes offshorable occupations while benefiting less-offshorable occupations. However, evidence from European countries is mixed. Goos et al. (2010) found that offshoring was associated with reduced employment in offshorable occupations across 16 European countries as opposed to Crinò is (2010 a) finding that service offshoring has no effect on employment in Italian firms. Using occupational licensing as a shifter of offshoring costs, Criscuolo and Garicano (2010) found that an increase in service offshoring increased both wages and employment in less-offshorable service occupations (i.e., licensed occupations) in the UK.

Grossman and Rossi-Hansberg’s theoretical framework includes wage implications and may partially relieve policymaker concerns over increased wage inequality due to offshoring in the U.S. labor market, but it does not address the core question of to what extent offshoring will affect labor demand (i.e., number of jobs). Goos et al. (2010) did find offshoring to be an explanatory factor affecting the conditional demand for labor in different occupations in their theoretical model and estimation, but other existing studies simply extend their empirical investigation to the effects of offshoring on wage or employment and provide some empirical evidences.

In this paper, Grossman and Rossi-Hansberg’s (2008) offshoring model is generalized to include numerous tasks/skill levels (tasks correspond to specific occupations in this empirical framework) and investigate the effect of offshoring on occupational employment for ten major occupational groups (at 2-digit SOC level) in the U.S. labor market (see Table 2.1 and 2.2 for details of occupational groups). Using the CPSMORG (Current Population Survey Merged Outgoing Rotation Groups) data from year 1983 to 2011, analysis is conducted in two phases. First, the monotonic cubic spline interpolation method is used to estimate the offshoring cost functions for all ten occupational groups. The monotonic cubic spline interpolation method requires no specific functional form other than the assumption that offshoring costs are non-decreasing in the percentage of tasks being offshored. This nice property makes monotonic cubic spline interpolation method a perfect fit for this study because offshorability for one occupational group could largely differ from another. Next, a parametric method-nonlinear least squares (NLS)-is utilized for the five relatively offshorable occupational groups. Based on the monotonic cubic spline interpolation results, a cubic functional form is attached to the five relatively offshorable occupational groups to approximate their offshoring cost functions. Then, the number of jobs offshored and the offshoring percentage over the sample period for the five offshorable occupational groups are calculated.

Aside from a limited number of studies with primary information on offshoring activities (see for example, Crinò, 2010), researchers have used two alternative approaches to measure offshoring over time. The first approach is to approximate or infer offshoring activities using relevant information. For example, Ebenstein et al. (2013) use foreign affiliate employment of U.S. multinational firms as a measure capturing U.S. firms' offshoring activities. Criscuolo and Garicano (2010) use occupational licensing to infer the offshorability of an occupation in their study of offshoring of UK service sectors. Approximation of offshoring activities circumvents the issue of time-invariance of offshoring/offshorabilty index, but reliability of the approximation is unknown.

The second approach is to generate a time-invariant offshoring index based on firm offshoring activities. For example, Goos et al. (2010) construct an occupational offshorability index based on offshoring activities of 415 European firms between 2002 and 2008. Applying a time-invariant index assumes that the offshoring activities are either not influenced by the reduction of offshoring costs or that costs are constant over time. A time variant offshoring index is thus especially important when investigating the effect of offshoring over a relative long-time span. For example, the occupation of a radiologist would be considered as non-offshorable without the advancement in recent telecommunication technology which makes transformation of large image data a relatively costless task. An important contribution of this paper is to provide time-variant estimates of offshoring for more than 400 major U.S. occupations over the period of 1983 to 2011.

2. A Simple Structural Model of Offshoring

Inspired by empirical findings about the impact of characteristics of tasks on wage inequality and employment structure (e.g., Autor et al., 2003), Grossman and Rossi-Hansberg (2008) proposed a theoretical model of task offshoring to explain the impact of offshoring on the wage rates of different types of workers. In the Grossman and Rossi-Hansberg model, tasks are limited to only two types: low-skill and high- skill. Under a standard Heckscher-Ohlin set-up, Grossman and Rossi-Hansberg (2008) show how changing offshoring costs will affect the wage rates of low-skilled and high-skilled workers in the home country through static comparative analysis.

This research generalizes the analysis to include numerous tasks and link the concept of tasks to detailed occupations that are actually offshored. While the focal point of Grossman and Rossi-Hansberg (2008) is to decompose effects of offshoring on factor prices i.e., wage rates, this research focuses on exploring the effect of offshoring on employment levels in different occupations. To be consistent and comparable with Grossman and Rossi-Hansberg (2008), this research uses the term "task" instead of "occupation" in the structural model specification, but freely changes between these two in the remaining of this paper depending on the context. [2]

2.1 Model Specification

The production process requires many types of tasks and each type of task is denoted by o. Producing one unit of a specific good involves a continuum of each type of task. Without loss of generality, the measure of each type of task can be normalized to one.

[2] Each task corresponds to an occupation in our empirical framework.

Firms in the home country produce many goods. The number of goods produced in the home country is assumed to be larger than the number of types of tasks.[3] All tasks are involved in order to produce one unit of specific good,[4] i.e., a_{oj} is the total amount of domestic factor o that would be needed to produce a unit of good j in the absence of any offshoring. Firms can undertake an o-type task either at home or abroad depending on the offshoring costs and the relative wage of task o between home and foreign country. An o-type task is indexed by $i \in [0,\ 1]$ and ordered in a manner such that the offshoring cost of task o, denoted by $t(i)$, is non-decreasing in t.

2.2 Model Derivation

As some tasks are more difficult to offshore than others, offshoring costs are assumed to be varying across different tasks and changing over time. Denote offshoring costs shifter as $\beta_{o,s}$ with subscript o indicating task type and s indicating time period. Let $w_{o,s}$ and $w^*_{o,s}$ be respectively the home and foreign wage of task o. Then the relative wage between home and foreign country of each task o, denoted by $\omega_{o,s}$, satisfies $\omega_{o,s} = \frac{w_{o,s}}{w^*_{o,s}}$ for all periods s.

Following Grossman and Rossi-Hansberg (2008)'s formulation, $I_{o,s}$, the equilibrium marginal task o performed at home (or the cutoff point of task o at equilibrium) in period s in each industry is determined by the following condition such that wage savings exactly balance the offshoring cost of task o:

[3] This assumption is to guarantee a unique solution to the factor price of each type of task given the price and production technology of each good.

[4] If the cost-minimizing demand for factor o is zero, the o-type task will be missing in the production process.

$$w_{o,s} = w_{o,s}^{*}\beta_{o,s}t(I_{o,s})\,. \tag{1}$$

Then by my relative wage assumption $\omega_{o,s} = \frac{w_{o,s}}{w_{o,s}^{*}}$,

$$t(I_{o,s}) = \frac{\omega_{o,s}}{\beta_{o,s}} = \rho_{o,s}\,, \tag{2}$$

where $\rho_{o,s}$ denotes the equilibrium offshoring costs, which depends on the ratio of relative wage $\omega_{o,s}$ and the offshoring cost shifter $\beta_{o,s}$ at each period s. Given that $t(\cdot)$ is an increasing function in $I_{o,s}$, a higher proportion of task o will be moved offshore as $I_{o,s}$ increases. As $I_{o,s}$ is the cutoff point of the marginal task o performed at home country, $\rho_{o,s}$ precisely captures the offshoring decisions made by home firms.

Denote L_o the initial total employment of occupation o at home country without offshoring and $L_{o,s}$ the employment of occupation o in period s with offshoring, which is observed in data, then $L_{o,s}$, can be calculated as following:

$$L_{o,s} = (1 - I_{o,s}) \cdot L_o, \tag{3}$$

where $1 - I_{o,s}$ indicates the fraction of o-type tasks that are performed at home.

Under the perfect competitive assumption, the price of any good j is equal to the unit cost of production (if a positive quantity of the good is produced):

$$p_j = \sum_o w_{o,s}\Omega(\mathrm{I}_{o,s})a_{oj}(\cdot), \qquad (j > o) \tag{4}$$ [5]

where, the arguments in the function for the factor intensity a_{oj} are the relative costs of the

[5] Equivalent to Equation (3) in Section I, Grossman and Rossi-Hansberg (2008). For detailed derivation, please refer to Grossman and Rossi-Hansberg (2008).

various sets of tasks when they are located optimally with offshoring,

and $\Omega(\ \mathrm{I}_{\mathrm{o,s}}) = 1 - \ \mathrm{I}_{\mathrm{o,s}} + \frac{\int_0^{I_{o,s}} t(i)di}{t(I_{o,s})}$. (5)

In other words, $\Omega(\ \mathrm{I}_{\mathrm{o,s}})$ consists of two parts, $1 - \ \mathrm{I}_{\mathrm{o,s}}$ (the proportion of tasks that remains in home country) and $\frac{\int_0^{I_{o,s}} t(i)di}{t(I_{o,s})}$ (the proportion of tasks conducted in foreign country expressed in equivalent home-country factor employment).

As $I_{o,s} = \frac{L_o - L_{o,s}}{L_o} = 1 - \frac{L_{o,s}}{L_o}$ is a function of L_o, $\Omega(\ \mathrm{I}_{\mathrm{o,s}})$ is a function of L_o.

Since the number of the goods is larger than the number of factors $(j > o)$, factor prices$\left(w_{o,s}\Omega(\ \mathrm{I}_{\mathrm{o,s}})\right)$ can be uniquely determined and solved from the systems of equations (4). That is,

$w_{o,s}\Omega(\ \mathrm{I}_{\mathrm{o,s}}) = c_o$, (6)

where C_O depends on the prices p_j and all production technologies of all goods produced in home country. Identity (6) is the key equation in identifying the equilibrium cutoff point of offshoring percentage $(\mathrm{I}_{\mathrm{o,s}})$ of task o, offshoring cost $t(i)$ as well as constant C_O. Section 2.3 explains estimation of Equation (6).

2.3 Model Interpretation

Although the Grossman and Rossi-Hansberg (2008) model is static, it can be interpreted with some dynamics within each period. Given the wage differential between the home and foreign country, the equilibrium cutoff point of offshoring $I_{o,s}$ is determined by Equation (1) at the beginning of period s, which automatically determines the domestic labor demand for task o (in Equation (3)). By the zero-profit condition under perfect competition, the new wage $w_{o,s}$ for task o at the end of period s in the home country is obtained by solving Equation (4) (or equivalently Equation (6)). If the new wage $w_{o,s}$ is higher (or lower) than the starting wage in period s, the firm in the home country increases (or decreases) offshoring until it reaches its new equilibrium cutoff point at the end of period s that we observe in the data. The same process repeats in all periods.

By this interpretation, it is explicitly assumed the wage and employment observed in our data set are equilibrium wage and employment at the end of each period, which are both driven by offshoring. Then by estimating Equation (6), we can identify the offshroing cost function $t(i)$[6] and the initial employment without offshoring for each task o.

3. Estimation Framework and Method

3.1 The Empirical Framework

To estimate Equation (6), take logarithm and reorder, which leads to,

$$ln w_{o,s} = -ln\Omega(\mathrm{I}_{o,s}) + ln c_o = ln c_o - ln\Omega(\mathrm{I}_{o,s}). \tag{7}$$

As $\Omega(\mathrm{I}_{o,s})$ is a function of the observed variable $L_{o,s}$, unobserved parameters L_o and the offshoring cost function $t(\cdot)$, standard linear estimation methods which can only estimate unknown parameters but not unknown functions are not applicable.

Further denote $y_{o,s} = ln w_{o,s}$, $x_{o,s} = L_{o,s}$. Then the conditional mean of $y_{o,s}$ can be specified as

$$E(y_{o,s}|x_{o,s}) = m(x_{o,s}, \boldsymbol{\theta_0}) = ln c_o - ln\Omega\left(\mathrm{I}_{o,s}(L_{o,s}, L_o, t(\cdot))\right) \tag{8}$$

Where $\boldsymbol{\theta_0} = (L_o, c_o, t(\cdot))$ consists of two parameters and one function to be identified. Since $\boldsymbol{\theta_0}$ contains the offshoring cost function that cannot be directly estimated, I need to

[6] However, the offshoring cost function $t(i)$ can only be identified up to a constant scale because multiplying a scalar to $t(i)$, Equation (6) still holds.

parameterize $t(\cdot)$ in order to proceed to estimate $t(\cdot)$ together with the other two parameters.

No specific structure except the monotonicity of $t(i)$ (i.e., $t(i)$ is non-decreasing in i) is assumed in the Grossman and Rossi-Hansberg (2008) framework. Hence, using a parametric estimation method and attaching any specific functional form to the offshoring cost function $t(i)$ for all ten occupational groups in empirical estimation will likely result in misspecification problems. Instead the non-parametric cubic spline method, in particular, the monotonic cubic spline interpolation method is adopted to approximate the offshoring cost function $t(i)$.

Once parameterization of $t(\cdot)$ is resolved, estimation of equation (8) becomes a standard non-linear estimation problem. The NLS estimators

$$\boldsymbol{\theta} = \min_{\theta \in \Theta} N^{-1} S^{-1} \sum_{o=1}^{N} \sum_{s=1}^{S} \left\{ y_{o,s} - m\left(\boldsymbol{x}_{o,s}, \boldsymbol{\theta}\right) \right\}^2 \tag{9}$$

minimize the sum of least squared residuals of the sample average and should solve the sample minimization problem if the true parameters $\boldsymbol{\theta_0} = argmin_{\theta \in \Theta} E\{[y - m(x, \boldsymbol{\theta})]^2\}$ solve the population minimization problem.

Ideally we would estimate Equation (3.8) occupation by occupation to identify the initial employment without offshoring L_o at home country, the constant parameter $\boldsymbol{C_O}$ and the set of parameters for each occupation o in the parameterized offshoring cost function $t(i)$. Due to data restrictions, [7] the individual occupations are grouped into ten broad

[7] See data description for details.

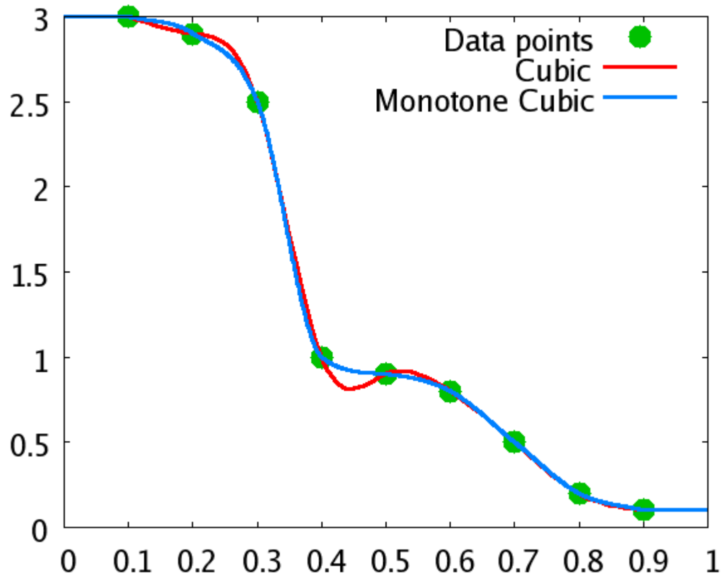
occupational groups for pre- and post-2000 periods respectively and these groups are used as the basis to estimate Equation (8). [8]

3.2 Application of Monotonic Cubic Spline Interpolation Method

A two-step monotonic cubic spline interpolation procedure is used to estimate $\widehat{\boldsymbol{\theta}} = \left(L_{\boldsymbol{o}}, c_{\boldsymbol{o}}, t(i)\right)$ for the ten occupational groups based on the algorithm of monotonic cubic spline interpolation developed by Wolberg and Alfy (1999, 2002). Figure 1 illustrates an example of monotonic cubic spline: the interpolating cubic spline passing through its control points is smooth and monotonic. While it is not yet often used in the field of economics, monotonic cubic spline interpolation is a well-developed method and widely used in numerical and statistical data analysis to solve engineering problems. The most compelling reason for the use of cubic polynomials is the property of twice differentiable continuity, which guarantees continuous first and second derivatives across all intervals. The goal of cubic spline interpolation is to determine the smoothest possible curve that passes through designated control points while simultaneously preserving the property of piecewise monotonicity within each interval.

[8] To distinguish, subscript $\boldsymbol{o}$ (bold *italic*) is used to represents an occupational group in the remaining of this paper.

Figure 1: An Example of Cubic Spline Interpolation



Source: Wikipedia (http://en.wikipedia.org/wiki/Monotone_cubic_interpolation).

The algorithm of Wolberg and Alfy (2002) is adopted in the first step. The algorithm itself consists of two parts designated WAA Step-1 (abbreviation of Wolberg and Alfy Algorithm) and WAA Step-2 to distinguish from the overall two-step interpolation procedure and avoid confusion. The WAA Step-1 attempts to find a twice continuously differentiable cubic spline which minimizes the modified second derivative discontinuity in the spline.[9] If a twice continuously differentiable cubic spline exists, the WAA Step-2 is then employed to obtain the optimal twice continuously differentiable cubic spline by computing the integral of the spline curvature. If not, the best first differentiable cubic spline is obtained in the WAA Step-1 and the WAA Step-2 is canceled.

[9] Definition of second derivative discontinuity: $\sum_i [f''(x_i^-) - f''(x_i^+)]^2$. Definition of modified second derivative discontinuity: summation of second derivative difference is non-negative, i.e., $\sum_i [f''(x_i^-) - f''(x_i^+) + K] \geq 0$, where K satisfies $f''(x_i^-) - f''(x_i^+) + K \geq 0$ for any arbitrary i. The reason to use modified second derivative discontinuity is to turn the objective function into a linear function so that linear programming can be applied. See Wolberg and Alfy (2002) for details.

To estimate $\boldsymbol{\theta}$, the offshoring percentage interval $i \in [0,\ 1]$ is partitioned into ten equal sub-intervals, representing the percentage increment of i being offshored. The WAA Step-1 and WAA Step-2 are applied to locally approximate the offshoring cost function $t(i)$ and obtain the monotonic cubic spline interpolation for each occupational group. The interpolated offshoring cost function is then used to calculate $\Omega\left(\ \mathrm{I}_{o,s}\left(L_{o,s}, L_{o,}t(\cdot)\right)\right)$ in Equation (3.9). Then the optimal estimators of $\widehat{\boldsymbol{\theta}}$ is obtained by minimizing the non-linear least square errors by iterations. $\widehat{\boldsymbol{\theta}}$ is a vector containing 13 estimators. They are estimator of the initial employment of occupation o at home country without offshoring $\hat{L}_{\boldsymbol{o}}$, estimator of the constant parameter $\hat{c}_{\boldsymbol{o}}$ and the set of estimators for parameterized offshoring cost function $t(i)$, which corresponds to 11 control points that portioned $i \in [0,\ 1]$ into ten equal sub-intervals.

3.3 Estimating Offshoring Cost Functions for the Ten Major Occupational Groups

Implementation of the monotonic cubic spline approximation to estimate offshoring cost functions for the ten major occupational groups requires updating the initial values of the cost function $t(i)$ at each control point of i. [10] Hence initial starting values for $t(\cdot)$ must be obtained. Blinder and Krueger (2009) provide values for offshorability in major occupational groups[11] as the starting point to differentiate relatively offshorable occupations from relatively non-offshorable occupations.[12] Based on their externally-coded estimates,

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[10] The 11 control points of i are 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8., 0.9, 1.

[11] See Table 2, Column 5, titled Externally-Coded Percent Offshorable in Blinder and Krueger (2009).

[12] There are sharp disagreements between self-classified and externally coded offshorability for some occupational groups. This research uses the externally-coded offshorability by professionals as the criterion to divide offshorable and non-offshorable groups.

the ten occupational groups are divided into two broad categories: Offshorable Groups and Non-offshorable Groups (Table 1).

Table 1: Offshorablility in Major Occupational Groups

Rank of Offshorablity	Occupational Group (Externally-coded Offshorable Percentage)
Offshorable Groups	
1	G9: Production occupations[13] (80.7%)
2	G5: Office and administrative support occupations (41.2%)
3	G2: Professional and related occupations (20.5%)
4	G4: Sales and related occupations (17.8%)
5	G1: Management, business, and financial operations occupations (16.4%)
Non-offshorable Groups	
6	G6: Farming, fishing, and forestry occupations (0.0%)
6	G7: Construction and extraction occupations (0.0%)
6	G10: Transportation and material moving occupations (0.0%)
7	G3: Service occupations (0.7%)
8	G8: Installation, maintenance, and repair occupations (1.3%)

Notes: Prepared by authors based on the externally-coded offshorable percentage (Column 2, Table 2) in Blinder and Krueger (2009).

Adjustment of employment size for each occupation within an occupational group is necessary before the monotonic cubic spline approximation is applied to estimate the offshoring cost functions for the ten major occupational groups. There are large between-occupation variations in employment within a same occupational group (Table 4). However, by estimating Equation (8) at the basis of occupational groups, the to-be-identified parameter L_o (i.e., the initial total employment without offshoring) is implicitly assumed to be same for all occupations within a group. This is a relatively strong assumption for the ten occupational groups with large between-occupation variations in employment within each

[13] For the purpose of simplicity and comparability with Blinder and Krueger (2009)'s results, only post-2000 occupation titles are used to indicate occupational groups in the main text unless otherwise specified.

occupational group. In order to identify $\boldsymbol{L_o}$ and obtain a meaningful $\widehat{\boldsymbol{L}}_{\boldsymbol{o}}$ for each occupational group, this study adjusts employment size to make employment size for each occupation relatively homogenous within an occupational group.[14]

As $\widehat{\boldsymbol{L}}_{\boldsymbol{o}}$ (i.e., estimated total employment without offshoring) is heavily dependent on the within-group variations of adjusted occupational employment $\tilde{L}_{o,s}$ between different occupations, offshoring percentage is restricted to not exceed 10% of the maximum $\tilde{L}_{o,s}$ (i.e., the maximum adjusted employment of all occupations across all years in the sample period) in each occupational group. In other words, the estimated $\widehat{\boldsymbol{L}}_{\boldsymbol{o}}$ is restricted to $\widehat{\boldsymbol{L}}_{\boldsymbol{o}} \leq 1.1 * max(\tilde{L}_{o,s})$. This restriction is also used as one stopping criterion for iterations when applying monotonic cubic spline interpolation to approximate the offshoring cost functions for the ten occupational groups.

3.4 Estimating Number of Jobs Offshored and Offshoring Percentage for the Five Relatively Offshorable Occupational Groups

After estimation of the offshoring cost functions for the ten major occupational groups, this analysis is focused on the five relatively offshorable occupational groups in Table 1. Nonlinear least squares (NLS) with a specific cubic functional form $t(i) = ai^3 + bi^2 + di + e$ is employed to re-estimate the offshoring cost functions for the five relatively offshorable occupational group. The number of jobs offshored and the offshoring percentage by detailed occupation in pre- and post-2000 sample period are calculated after estimation of the cubic offshoring cost function. There are a few reasons to focus on the relatively offshorable occupational groups. First, offshoring cost is relatively tractable because fluctuations of employment at offshorable occupations over time observed in data reflect the

[14] Detailed adjustment method of employment size is discussed in Section 4 after introducing the data set.

change of offshoring costs. Second, factors (e.g., technology, institutional restructuring) that could potentially affect the occupational employment except offshoring are not controlled in this study. In other words, changes of employment over time are assumed to be purely attributable to offshoring in this framework. While this is a strong assumption, it is more realistic for the relatively offshorable occupations which are primary focus of this study.

To calculate the number of jobs offshored and the offshoring percentage for the five offshorable occupational groups over the pre- and post-2000 sample period, this study uses $\hat{L}_{\boldsymbol{o}}$, which is estimated from the adjusted employment size $\tilde{L}_{o,s}$ of each occupation from the two-step cubic spline interpolation method, to recover $\tilde{L}_{\boldsymbol{o}}$, the unadjusted initial employment without offshoring for each occupational group by reversing the adjustment method.

Different scenarios are applied when re-estimating the cubic offshoring cost functions using NLS, calculating the number of jobs offshored and offshoring percentage for the five offshorable occupational groups. Based on Blinder and Krueger's (2009) estimates for offshorable occupational groups (re-organized in Table 3.1), the 20% scenario is chosen as a benchmark case for all five groups because the externally coded offshorability are relatively close to 20 percent (Group 1, Production occupations, 16.4%; Group 2, Professional and related occupations, 20.5%; Group 4, Sales and related occupations, 17.8%). In the 20% scenario, the offshoring percentage is assumed to not exceed 20 percent of the maximum $\tilde{L}_{o,s}$, i.e., the estimated $\hat{L}_{\boldsymbol{o}} \leq 1.2 * max(\tilde{L}_{o,s})$. The maximum offshoring percentage is then gradually relaxed to 40 percent (externally coded offshorable percentage is 41.2 percent for Group 5, Office and Administrative Support Occupations) and 80 percent (externally coded offshorable percentage is 80.7% for Group 9, Production Occupations) for all five offshorable groups.

4. Data Description and Adjustment

The CPSMORG (Current Population Survey Merged Outgoing Rotation Groups) data from years 1983 to 2011 are used to implement the two-step monotonic cubic spline interpolation procedure. The data are discontinuous due to a complete switch in the occupational and industrial classification system in CPS (Current Population Survey) in 2003.[15] This substantial change in the composition of detailed occupations between the 1980 and 2002 occupation codes makes linking data by occupation codes impossible. Hence, the sample is divided into two periods: pre-2000 (1983-1999) and post-2000 period (2000-2011) to conduct analysis at occupational level.

Observations for individuals with age less than 18 and or more than 65 are dropped from the sample to maintain focus on the labor force. Hourly wage series for each individual is created following Schmitt 2003 and inflated by 2000 CPI index to obtain the real hourly wage. Wage and employment are aggregated to occupation level based on 1980 census codes for the pre-2000 period and based on 2002 census codes for the post-2000 period. CPS earning weights are used to obtain occupational hourly wage while CPS final weights are used to obtain occupational employment during aggregation. To maintain balanced panels for both the pre- and post-2000 periods, occupations not present in all years of each analysis period were omitted from the data set. After aggregation, there are 486 occupations in the pre-2000 period and 460 occupations in the post-2000 period (Table 2.1 and 2.2).

As mentioned earlier, by estimating offshoring cost functions by occupational groups $\boldsymbol{L_o}$ is implicitly assumed to be same for all occupations within an occupational group. But the large between-occupation variations in employment within an occupational group is not

[15] Years 2000-2002 are dual-coded in both 1980 and 2002 census classifications systems.

in favor of this assumption. Several adjustments are made to reduce between-occupation variations and homogenize the employment size within each occupational group.

For both pre- and post-2000 sample period, mean employment for each occupation is calculated and a median employment for all occupations within an occupational group is obtained. Relative employment size for each occupation is mean employment of each occupation by this occupational group median employment.[16] Finally, the adjusted employment for each occupation in each year $\tilde{L}_{o,s}$ is observed employment $L_{o,s}$ divided by the relative employment size of each occupation. The adjusted employment for each occupation $\tilde{L}_{o,s}$ is used in the monotonic cubic spline interpolation to approximate the offshoring cost function.

The estimated $\hat{L}_{\boldsymbol{o}}$ largely depends on the maximum or minimum value of the adjusted employment $\tilde{L}_{o,s}$ within each occupational group. The estimated $\hat{L}_{\boldsymbol{o}}$ is likely to be misleadingly inflated if there are extreme values of $\tilde{L}_{o,s}$ within an occupational group. Hence, occupations with observations falling in the upper and lower five percentile of the adjusted employment are dropped to further homogenize the employment size of occupations within each occupational group. Table 4 summarizes the employment size variations for each occupational group before and after adjustment for pre- and post-2000 periods respectively. After adjustment, the mean and median employment size within each occupational group are quite close. The between-occupation employment variations within an occupational group are largely reduced.

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[16] If there are even-numbered groups within an occupational group, we use the larger of the two medians as the denominator.

5. Results and Discussion

5.1 Offshoring Costs for the Ten Major Occupational Groups

The 11 point estimates of the parameterized offshoring cost functions from the monotonic cubic spline interpolation method for the ten major occupational groups are summarized in Table 5. A corresponding interpolated offshoring cost function $t(i)$ for each occupational group are plotted in Figure 2.1 and Figure 2.2 for the pre- and post-2000 periods respectively. The estimated $\hat{c}_o$ and $\hat{L}_o$ are reported in Table 6.

One issue to be emphasized in front is that any direct comparison between pre- and post-2000 periods is not feasible although results for the pre- and post-2000 periods are sometimes displayed in parallel. As mentioned earlier, compositions of occupations within each occupational group for pre- and post-2000 periods are completely different. Consequently, the estimated $\hat{L}_o$ in pre-2000 period is not comparable with the estimated $\hat{L}_o$ in post-2000 period due to this occupational composition difference. Nonetheless, results from these two sample periods are consistent and some general patterns can be observed. Estimated offshoring cost functions indicate an effect of economies of scale in offshoring. The offshoring cost increases in the first ten percent of offshoring and then decreases as more jobs offshored.[17] Among the ten occupational groups, Group 1 (Management, business, and financial operations occupations), Group 2 (Professional and related occupations), Group 4 (Sales and related occupations), Group 5 (Office and administrative support occupations) and Group 9 (Production occupations) have relatively lower costs at any given level of offshoring percentage i in both the pre- and post-2000 periods. In

[17] The partition of 10 subintervals is arbitrary. But increasing the numbers of subintervals does not alter the result because the nice monotonic property of monotonic cubic spline interpolation within each interval.

particular, production occupations in Group 9, which are commonly regarded to contain the most impersonal and/or routine tasks and easiest to offshore, have the lowest offshoring costs when the offshoring percentage is below 40 percent (Table 4). The estimated offshoring cost for production occupations has a sharp increase when offshoring moves from the first 40 percent to 50 percent in the pre-2000 period, and from the first 30 percent to 40 percent in the post-2000 period. The remaining five occupational groups, Group 3 (Service occupations), Group 6 (Farming, fishing, and forestry occupations),[18] Group 7 (Construction and extraction occupations), Group 8 (Installation, maintenance, and repair occupations) and Group 10 (Transportation and material moving occupations), have relatively higher offshoring costs.

The rank of offshorability in this study based on estimated offshoring costs for both pre- and post-2000 periods is different from the externally coded offshorability of Blinder and Krueger (2009) based on individual telephone survey in 2008, but most results are consistent with them. Blinder and Krueger (2009) found Group 6 (Farming, fishing, and forestry occupations), Group 7 (Construction and extraction occupations) and Group 10 (Transportation and material moving occupations) to be the least offshorable. This study identified farming, fishing, and forestry occupations (Group 6), construction and extraction occupations (Group 7), and service occupations (Group 3) with the highest offshoring costs while transportation and material moving occupations in Group 10 with the second highest offshoring cost.

[18] Group 6 has low offshoring cost (small point estimates) in the first 30 percent of offshoring due to few observations between interval 0.0 and 0.3.

5.2 NLS Results for the Five Relatively Offshorable Occupational Groups

The estimated coefficients of the cubic offshoring cost function together with $\hat{c}_o$ and $\hat{L}_o$ by NLS method under three different scenarios are reported in Table 5. Corresponding offshoring cost functions $t(i)$ of the five relatively offshorable groups are displayed respectively in Figure 3.1 through Figure 3.5. Unlike the monotonic cubic spline interpolation method, it is difficult to directly compare the estimated cubic offshoring cost functions among different occupational groups within the same scenario, or the same occupational group among three different scenarios given the fact that the single cubic functional form attached to all five relatively occupational groups cannot be uniquely identified because there is only one moment condition (i.e., Eq. 6) available in the structural model.

The number of jobs offshored and the offshoring percentage are calculated based on the estimated $\hat{L}_o$ for the five relatively offshorable groups in pre- and post-2000 periods are summarized in Table 8.1 through Table 8.5. First, the initial total employment for each occupation o in each year s within an offshorable occupational group is recovered by multiplying the relative employment size of each occupation to its corresponding $\hat{L}_o$ estimated for each occupational group. The number of jobs offshored at each occupation o in each year s is then the difference between the recovered initial total employments of occupation o and $L_{o,s}$ observed in data. The offshoring percentage is then obtained using the number of jobs offshored divided by the initial total employment without offshoring.

Both the number of jobs offshored and offshoring percentage increase as the maximum offshoring capacity increases from 20% scenario to 80% scenario. Production occupations in Group 9 have been consistently increasing over time in both pre- and post-

2000 periods under all three scenarios. Under the 20% scenario that maximum 20 percent of production occupations are offshorable, the offshoring percentage for production occupations increases from 36.5 to 46.3 percent in the pre-2000 period and increases from 36.1 to 48.5 percent in the post-2000 period. Under the 40% scenario, offshoring percentage for production occupations increases from 45.6 to 54.0 percent in the pre-2000 period and increases from 45.2 to 55.9 percent in the post-2000 period. Under the 80% scenario, offshoring percentage for production occupations increases from 57.4 to 64.0 percent in the pre-2000 period and from 52.9 to 62.1 percent in the post-2000 period, which are less than the estimated 80.7 percent by Blinder and Krueger (2009).

Changes in the offshoring percentage for the five relatively offshorable occupational groups over the two sample periods are depicted in Figure 4.1 through Figure 4.5 additionally. Offshoring percentage for sales and related occupations in Group 4 and office and administrative support occupations in Group 5 have been gradually increasing over time in the post-2000 period. On the other hand, for management, business and financial operations occupations (Group 1) and professional and related occupations (Group 2), offshoring percentage actually has decreased over time.

In addition, using externally coded offshorability estimated for the five offshorable groups from Blinder and Krueger (2009) (reorganized in Table 3) as a criterion, results of the 20% scenario for Group 1, Group 2 and Group 4, the 40% scenario for Group 5, and the 80% scenario for Group 9 to are selected to make comparisons among groups. This comparison shows that occupations in sales and related occupations in Group 2 are the least offshorable among the five offshorable occupational groups followed by the management, business and financial operations occupations and professional and related occupations.

6. Conclusion

This research generalizes the Grossman and Rossi-Hansberg (2008) offshoring model to include numerous tasks/skill levels. This generalization allows a possible and direct linkage between the theoretical task offshoring model and occupational data that can be aggregated from the CPSMORG (Current Population Survey Merged Outgoing Rotation Groups) data from year 1983 to 2011. Empirical investigation of the effect of offshoring on occupational employment for ten major occupational groups (at 2-digit SOC level) in the U.S. labor market is conducted by estimating their offshoring cost functions using a non-parametric monotonic cubic spline interpolation method. Based on the estimated offshoring costs, five relatively offshorable occupational groups are identified including production occupations, office and administrative support occupations, sales and related occupations, professional and related occupations, and management, business, and financial operations occupations.

Motivated by the practical issue of difficulty in obtaining a time-variant offshoring/offshorability index faced by majority empirical studies interested in identifying the effect of offshoring, this study calculates the number of jobs offshored and the offshoring percentage under the NLS method for the five relatively offshorable occupational groups under different scenarios. Calculated offshoring percentage provides time-variant offshoring indices for more than 300 major detailed occupations in these five relatively offshorable groups that can be employed in other empirical studies.

The results of this research indicate that offshoring percentage for each occupational group may vary under different scenarios, but the evolution pattern is consistent. Production occupations are the most offshorable while sales and related occupations are the least offshorable among all five offshorable occupational groups under all three scenarios. The offshoring percentage for production occupations has been increasing in both pre- and post-2000 periods while the offshoring percentages for professional and related occupations, and management, business, and financial operations occupations have been decreasing over time.

APPENDIX

Table 2.1: Major Occupational Groups in Pre-2000 Period (1983-1999)

Group	1980 Census Codes	Occupation Title	Number of Occupations
1	003-037	Managerial and professional Specialty occupations	24
2	043-199 203-235	Professional specialty occupations Technical occupations	126
3	403-469	Service occupations	42
4	243-285	Sales occupations	23
5	303-389	Administrative support occupations	55
6	473-499	Farming, forestry, and fishing occupations	19
7	553-599 613-617	Construction trades Extractive occupations	35
8	503-549	Mechanics and Repairers	27
9	633-699 703-799	Precision Production Occupations Operators, fabricators, and laborers	99
10	803-889	Transportation and Material Moving Occupations	39
Total			486

*Notes: Occupational group information is obtained from (http://usa.ipums.org/usa/volii/98occup.shtml), but reorganized and reordered by author to be comparable with occupational groups in post-2000 period.

Table 2.2: Major Occupational Group in Post-2000 Period (2000-2011)

Group	2002 Census Codes	Occupation Title	Number of Occupations
1	0010-0950	Management, business, and financial operations occupations	42
2	1000-3540	Professional and related occupations	107
3	3600-4650	Service occupations	57
4	4700-4960	Sales and related occupations	17
5	5000-5930	Office and administrative support occupations	50
6	6000-6130	Farming, fishing, and forestry occupations	8
7	6200-6940	Construction and extraction occupations	36
8	7000-7620	Installation, maintenance, and repair occupations	34
9	7700-8960	Production occupations	75
10	9000-9750	Transportation and material moving occupations	34
Total			460

*Notes: Occupational groups are equivalent to those grouped at 2-digit SOC level.

Table 3: Occupational Employment Size[1] Variation

Pre-2000 Period: 1983-1999								
Group	Before Adjustment $\left(\overline{L_{o,s}}\right)$				After Adjustment[2] $\left(\overline{\tilde{L}_{o,s}}\right)$			
	Max	Min	Median	Mean	Max	Min	Median	Mean
1	5,179,799	10,103	234,885	509,254	336,438	168,371	257,054	255,055
2	1,829,530	2,439	60,309	155,601	85,892	35,756	60,110	60,309
3	2,463,471	11,309	218,522	433,122	295,584	147,323	224,454	222,077
4	3,470,040	16,358	239,788	624,399	296,549	197,353	247,542	245,897
5	4,064,116	4,676	186,986	368,996	260,335	117,224	188,326	186,986
6	1,173,238	1,894	39,952	154,177	61,434	22,577	40,062	39,952
7	1,103,129	3,192	42,083	135,112	55,790	27,795	42,113	42,083
8	746,818	3,043	101,811	161,553	131,050	76,843	101,989	101,811
9	1,409,946	2,775	42,481	121,924	59,714	25,258	42,741	42,689
10	2,780,569	3,098	87,280	289,827	54,206	120,427	87,752	7,280
Post-2000 Period: 2000-2011								
Group	Before Adjustment $\left(\overline{L_{o,s}}\right)$				After Adjustment $\left(\overline{\tilde{L}_{o,s}}\right)$			
	Max	Min	Median	Mean	Max	Min	Median	Mean
1	2,402,506	8,412	180,133	359,564	231,030	138,907	181,858	181,400
2	2,819,706	2,485	80,408	202,254	106,722	55,535	81,007	81,271
3	2,274,862	4,214	115,561	377,052	145,055	81,288	116,166	115,561
4	3,548,378	34,789	325,546	851,402	386,948	250,422	323,554	325,546
5	3,507,671	5,690	150,514	388,964	214,546	112,681	158,846	159,529
6	868,469	2,253	20,680	154,201	29,347	11,050	20,308	20,680
7	1,440,582	3,107	45,802	182,013	66,277	27,194	46,395	46,183
8	766,161	2,940	48,820	126,207	65,622	31,711	49,031	49,308
9	1,185,664	3,646	40,289	113,951	60,173	21,929	39,664	40,289
10	3,089,586	3,943	52,905	257,220	76,506	34,108	52,943	53,229

Notes: 1. For each occupation, employment is averaged across years within sample period.
2. Occupations with employment falling in the upper and lower five percentile are dropped after adjustment.

Table 4: Point Estimates of Parameterized Offshoring Cost Function $t(i)$ from Cubic Spline Interpolation Method for Ten Major Occupational Groups

Group	Value of $t(i)$ at Control Points i Pre-2000: 1983-1999									
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
1	5.33	3.38	11.5	25.8	38.4	49.6	70.3	77.7	95.6	137.3	202.1
2	1.12	2.65	10.3	15.4	32.5	71.9	111.5	137.7	130.7	124.4	108.8
3	14.8	6.05	6.04	22.2	49.3	173.7	252.7	372.5	297.8	452.8	259.4
4	0.01	6.60	12.6	20.8	40.5	56.1	87.8	120.5	185.8	167.5	144.5
5	10.2	1.18	5.36	24.5	41.2	45.8	55.2	83.1	107.3	136.5	145.7
6	7.44	12.0	19.6	40.0	51.1	101.8	119.0	170.5	249.8	369.4	505.1
7	4.19	9.27	17.4	25.2	75.4	52.3	92.7	136.0	193.1	307.4	448.7
8	0.40	0.20	16.4	16.3	73.5	110.6	128.8	162.2	265.8	356.5	551.8
9	8.24	0.14	1.07	7.34	18.9	53.8	103.5	132.0	151.5	182.6	166.0
10	11.7	9.35	19.1	42.8	74.3	182.2	279.1	424.0	551.8	766.9	1006.3
	Value of $t(i)$ at Control Points i Post-2000 Period: 2000-2011										
1	2.71	6.35	12.5	20.4	30.5	42.6	58.43	77.38	91.6	121.1	188.1
2	5.98	2.02	4.88	9.74	31.9	113.0	147.2	197.9	227.4	175.7	460.9
3	20.3	18.3	57.8	73.5	142.5	233.0	180.9	404.9	543.5	747.3	1076.9
4	0.00	0.38	13.0	29.3	29.6	53.2	61.3	86.4	104.5	120.1	184.9
5	3.18	1.04	0.88	38.3	35.5	47.0	64.4	85.4	101.7	133.4	168.8
6	20.4	23.5	25.4	35.8	53.7	77.8	109.2	168.0	247.8	222.3	262.3
7	2.21	27.8	26.6	40.8	23.2	82.2	116.5	203.8	264.8	363.0	543.6
8	5.67	7.27	2.13	18.2	34.6	40.9	52.5	92.0	144.7	182.2	269.8
9	0.54	0.09	0.90	41.1	20.7	69.8	103.4	95.5	85.6	117.3	134.2
10	17.9	11.1	9.83	53.7	80.0	99.9	132.7	170.6	121.8	195.2	241.1

Notes: 1. No other control variables are included in the model.
2. The upper bound is set that offshoring cannot exceed the 10% of the maximum employment of all occupations across all years within each group.
3. The maximum iterations is 500 times.
4. Initial value is adopted from the first-round cubic spline interpolation results without dropping any observations. See Table 3.A for details of initial value.

Table 5: Estimates of $\hat{L}_o$, $\hat{c}_o$ by Occupational Groups from Cubic Spline Interpolation Method for Major Ten Occupational Groups

Group	Pre-2000 Period (1983-1999)		Post Post-2000 Period (2000-2011)	
	$\hat{L}_o$	$\hat{c}_o$	$\hat{L}_o$	$\hat{c}_o$
1	370,034	5.86	245,310	7.00
2	89,912	6.69	110,980	6.51
3	323,423	2.72	152,963	3.82
4	314,449	3.74	425,643	5.05
5	284,791	3.27	225,284	3.77
6	67,578	1.85	29,860	3.43
7	61,369	4.21	69,592	4.98
8	137,680	5.05	69,206	5.50
9	62,628	3.40	66,190	3.13
10	367,550	5.95	84,049	4.20

Notes: 1. No other control variables are included in the model.
2. The upper bound is set that offshoring cannot exceed the 10% of the maximum employment of all occupations across all years within each group.
3. The maximum iterations is 500 times.
4. Initial value is adopted from the first-round cubic spline interpolation results without dropping any observations. See Appendix Table A for details of initial value.

Table 6: NLS Estimates of Cubic Offshoring Cost Function $\hat{L}_o$,$\hat{c}_o$ for the Five Relatively Offshorable Occupational Groups

Group	Pre-2000 (1983-1999)						Post-2000 (2000-2011)					
	Coefficients of Cubic $t(i)$				$\hat{L}_o$	$\hat{c}_o$	Coefficients of Cubic $t(i)$				$\hat{L}_o$	$\hat{c}_o$
	$\hat{a}$	$\hat{b}$	$\hat{d}$	$\hat{e}$			$\hat{a}$	$\hat{b}$	$\hat{d}$	$\hat{e}$		
	20% Scenario											
1	-3875	-4341	-1678	348.2	403,726	5.03	16397	19786	5933	-1380	277,236	5.63
2	-4062	-4267	-2823	549	103,070	4.94	-8.77	-9.30	-3.55	0.81	128,066	5.24
4	-2085	-2335	-896	195	355,858	2.88	-1733	-1916	-754	160	464,337	4.30
5	-16.91	-17.49	-7.04	1.54	312,402	2.85	2272	2582	972	-205	257,455	3.09
9	-5686	-6249	-2337	624	71,622	2.72	17.92	20.86	7.23	-1.63	72,208	3.00
	40% Scenario											
1	5136	5783	2149	-922.8	471,014	4.02	1578	5273	218	-407	323,442	4.46
2	2021	1801	966	-394	120,249	3.72	-1549	-1910	-723	338	149,410	3.99
4	-0.001	-0.001	-0.0003	0.0002	414,872	2.25	2511	2795	1042	-462	541,727	3.24
5	-460	-543	-403	145	364,469	2.18	-1922	-2181	-809	344	300,364	2.50
9	3392	3706	1421	-685	83,600	2.16	4024	5176	1581	-779	84,242	2.42
	80% Scenario											
1	4639	5217	1813	-1037	543,488	3.61	-4753	-5446	-1848	1115	390,700	4.01
2	-6880	-7702	-2649	1658	141,377	3.73	378	917	63	-117	181,275	3.84
4	2.09	2.45	0.79	-0.59	533,774	2.06	-2316	-2570	-819	547	650,472	3.04
5	133	334	284	-110	449,143	2.11	3589	4001	1382	-801.8	366,463	2.24
9	5430	6137	2205	-1330	106,827	2.10	2338	2662	917	-540.2	98,066	2.29

Notes:

1. No other control variables are included in the model.
2. Occupations with employment falling in the upper and lower five percentile are dropped after adjustment.
3. The maximum iterations is500 times.
4. Initial value is adopted from the first-round cubic spline interpolation results without dropping any observations. See Table 3.A for details of initial value.

Table 7.1: Calculated Number of Jobs Offshored and Offshoring Percentage for Group 1 (Management, Business and Financial Operations Occupations) from NLS Method

	Year	20% Scenario		40% Scenario		80% Scenario	
		No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage
Pre-2000	1983	7,771,465	47.6%	10,400,000	55.1%	13,200,000	61.1%
	1984	7,085,993	45.8%	9,713,385	53.5%	12,500,000	59.7%
	1985	6,707,947	46.1%	9,335,339	53.8%	12,200,000	60.0%
	1986	6,292,123	42.1%	8,919,514	50.3%	11,700,000	57.0%
	1987	5,989,792	40.0%	8,617,183	48.5%	11,400,000	55.4%
	1988	5,500,926	37.7%	8,128,317	46.6%	11,000,000	53.7%
	1989	4,891,834	35.6%	7,519,225	44.8%	10,300,000	52.2%
	1990	4,902,728	34.8%	7,530,119	44.1%	10,400,000	51.6%
	1991	4,671,854	34.7%	7,299,245	44.0%	10,100,000	51.5%
	1992	6,299,921	36.2%	8,927,313	45.4%	11,800,000	52.6%
	1993	6,233,880	32.9%	8,861,271	42.5%	11,700,000	50.2%
	1994	6,354,836	35.1%	8,982,227	44.3%	11,800,000	51.8%
	1995	5,822,961	33.1%	8,450,352	42.6%	11,300,000	50.3%
	1996	5,651,819	33.3%	8,279,210	42.9%	11,100,000	50.5%
	1997	5,185,593	32.9%	7,812,984	42.5%	10,600,000	50.2%
	1998	4,869,771	30.6%	7,497,162	40.5%	10,300,000	48.4%
	1999	4,454,344	27.5%	7,081,736	37.9%	9,911,625	46.2%
Post-2000	2000	7,696,804	37.5%	11,100,000	46.4%	16,000,000	55.6%
	2001	7,312,754	35.2%	10,700,000	44.4%	15,600,000	54.0%
	2002	7,152,252	36.1%	10,500,000	45.2%	15,500,000	54.7%
	2003	7,336,184	37.0%	10,700,000	46.0%	15,700,000	55.3%
	2004	7,286,110	35.7%	10,700,000	44.9%	15,600,000	54.4%
	2005	7,108,696	34.0%	10,500,000	43.4%	15,400,000	53.2%
	2006	6,919,571	34.1%	10,300,000	43.5%	15,300,000	53.2%
	2007	6,652,990	33.0%	10,000,000	42.6%	15,000,000	52.5%
	2008	6,526,403	34.0%	9,920,160	43.4%	14,900,000	53.1%
	2009	6,630,334	32.5%	10,000,000	42.2%	15,000,000	52.1%
	2010	6,953,488	32.1%	10,300,000	41.8%	15,300,000	51.9%
	2011	6,892,056	33.6%	10,300,000	43.1%	15,200,000	52.9%

Notes: 1. The number of job offshored is the sum of job offshored across all occupations within an occupational group.
2. The offshoring percentage is the average offshoring percentage across all occupations within an occupational group.
3. A cubic offshoring cost function is assumed.

Table 7.2: Calculated Number of Jobs Offshored and Offshoring Percentage for Group 2 (Professional and Related Occupations) from NLS Method

	Year	20% Scenario		40% Scenario		80% Scenario	
		No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage
Pre-2000	1983	13,300,000	46.8%	17,800,000	54.4%	23,400,000	61.2%
	1984	13,200,000	46.6%	17,700,000	54.3%	23,300,000	61.1%
	1985	12,800,000	46.1%	17,300,000	53.8%	22,900,000	60.7%
	1986	12,500,000	44.8%	17,100,000	52.7%	22,600,000	59.8%
	1987	12,400,000	45.5%	16,900,000	53.3%	22,500,000	60.3%
	1988	12,000,000	43.1%	16,500,000	51.3%	22,100,000	58.5%
	1989	11,700,000	44.0%	16,300,000	52.0%	21,800,000	59.2%
	1990	11,200,000	40.9%	15,700,000	49.4%	21,300,000	56.9%
	1991	11,100,000	39.5%	15,700,000	48.2%	21,200,000	55.9%
	1992	11,000,000	41.0%	15,500,000	49.4%	21,100,000	57.0%
	1993	10,600,000	39.1%	15,100,000	47.8%	20,700,000	55.6%
	1994	10,900,000	40.1%	15,500,000	48.6%	21,000,000	56.3%
	1995	10,600,000	40.1%	15,100,000	48.7%	20,700,000	56.4%
	1996	10,100,000	38.9%	14,700,000	47.6%	20200,000	55.4%
	1997	9,780,010	37.5%	14,300,000	46.4%	19,900,000	54.4%
	1998	9,640,700	36.4%	14,200,000	45.5%	19,700,000	53.6%
	1999	8,816,018	34.8%	13,300,000	44.1%	18,900,000	52.5%
Post-2000	2000	12,300,000	39.4%	17,300,000	48.1%	24,800,000	57.2%
	2001	11,800,000	38.3%	16,800,000	47.1%	24,200,000	56.4%
	2002	11,600,000	38.5%	16,600,000	47.3%	24,000,000	56.5%
	2003	11,500,000	37.8%	16,500,000	46.7%	24,000,000	56.1%
	2004	11,400,000	37.4%	16,400,000	46.3%	23,800,000	55.7%
	2005	11,200,000	37.2%	16,200,000	46.1%	23,600,000	55.6%
	2006	11,000,000	36.1%	16,000,000	45.2%	23,500,000	54.8%
	2007	10,400,000	35.5%	15,400,000	44.7%	22,900,000	54.4%
	2008	10,100,000	35.0%	15,100,000	44.3%	22,500,000	54.1%
	2009	9,978,409	34.9%	15,000,000	44.2%	22,400,000	54.0%
	2010	10,000,000	34.2%	15,000,000	43.6%	22,500,000	53.5%
	2011	9,962,497	34.2%	15,000,000	43.6%	22,400,000	53.5%

Notes: 1. The number of job offshored is the sum of job offshored across all occupations within an occupational group.
2. The offshoring percentage is the average offshoring percentage across all occupations within an occupational group.
3. A cubic offshoring cost function is assumed.

Table 7.3: Calculated Number of Jobs Offshored and Offshoring Percentage for Group 4 (Sales and Related Occupations) from NLS Method

	Year	20% Scenario		40% Scenario		80% Scenario	
		No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage
Pre-2000	1983	4,489,843	35.1%	6,585,252	44.3%	10,800,000	56.7%
	1984	4,182,837	32.5%	6,278,245	42.1%	10,500,000	55.0%
	1985	4,178,781	32.4%	6,274,190	42.0%	10,500,000	54.9%
	1986	4,014,622	30.7%	6,110,031	40.6%	10,300,000	53.8%
	1987	3,805,164	29.2%	5,900,573	39.3%	10,100,000	52.8%
	1988	3,846,256	30.6%	5,941,665	40.5%	10,200,000	53.7%
	1989	3,670,658	30.7%	5,766,067	40.6%	9,987,918	53.8%
	1990	3,370,897	29.0%	5,466,306	39.1%	9,688,157	52.6%
	1991	3,407,134	30.8%	5,502,543	40.7%	9,724,394	53.9%
	1992	3,370,818	27.4%	5,466,226	37.8%	9,688,077	51.6%
	1993	3,440,809	27.9%	5,536,218	38.2%	9,758,068	51.9%
	1994	4,456,491	34.7%	6,551,899	44.0%	10,800,000	56.5%
	1995	4,284,704	32.7%	6,380,113	42.3%	10,600,000	55.1%
	1996	4,027,732	31.4%	6,123,140	41.1%	10,300,000	54.3%
	1997	3,933,802	31.0%	6,029,211	40.8%	10,300,000	54.0%
	1998	3,888,172	30.2%	5,983,581	40.2%	10,200,000	53.5%
	1999	4,005,604	28.9%	6,101,013	39.0%	10,300,000	52.6%
Post-2000	2000	5,993,041	32.1%	9,110,449	41.8%	5,993,041	32.1%
	2001	5,701,304	28.8%	8,818,713	39.0%	5,701,304	28.8%
	2002	5,635,168	28.9%	8,752,576	39.1%	5,635,168	28.9%
	2003	5,805,051	29.9%	8,922,459	39.9%	5,805,051	29.9%
	2004	5,677,808	29.7%	8,795,216	39.7%	5,677,808	29.7%
	2005	5,556,994	30.0%	8,674,402	40.0%	5,556,994	30.0%
	2006	5,363,608	27.9%	8,481,016	38.2%	5,363,608	27.9%
	2007	5,251,183	28.0%	8,368,592	38.3%	5,251,183	28.0%
	2008	5480,845	29.9%	8,598,254	39.9%	5,480,845	29.9%
	2009	5,400,839	29.6%	8,518,247	39.7%	5,400,839	29.6%
	2010	5,567,462	31.5%	8,684,871	41.3%	5,567,462	31.5%
	2011	5,655,523	32.4%	8,772,932	42.0%	5,655,523	32.4%

Notes: 1. The number of job offshored is the sum of job offshored across all occupations within an occupational group.
2. The offshoring percentage is the average offshoring percentage across all occupations within an occupational group.
3. A cubic offshoring cost function is assumed.

Table 7.4: Calculated Number of Jobs Offshored and Offshoring Percentage for Group 5 (Office and Administrative Support Occupations) from NLS Method

	Year	20% Scenario		40% Scenario		80% Scenario	
		No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage
Pre-2000	1983	10,200,000	41.9%	14,600,000	50.2%	21,800,000	59.6%
	1984	10,400,000	43.7%	14,800,000	51.7%	21,900,000	60.8%
	1985	10,200,000	43.1%	14,600,000	51.2%	21,700,000	60.4%
	1986	10,100,000	41.8%	14,500,000	50.1%	21,600,000	59.5%
	1987	9,897,058	40.4%	14,300,000	48.9%	21,400,000	58.5%
	1988	9,852,361	41.0%	14,200,000	49.5%	21,400,000	59.0%
	1989	9,901,249	39.6%	14,300,000	48.2%	21,400,000	58.0%
	1990	9,387,039	36.5%	13,800,000	45.6%	20,900,000	55.8%
	1991	9,582,273	36.2%	14,000,000	45.3%	21,100,000	55.6%
	1992	9,565,003	36.1%	13,900,000	45.2%	21,100,000	55.5%
	1993	9,722,870	35.8%	14,100,000	44.9%	21,200,000	55.3%
	1994	11,800,000	42.2%	16,200,000	50.5%	23,400,000	59.8%
	1995	11,800,000	42.5%	16,200,000	50.7%	23,300,000	60.0%
	1996	11,700,000	41.6%	16,100,000	49.9%	23,200,000	59.4%
	1997	11,800,000	40.4%	16,200,000	48.9%	23,300,000	58.5%
	1998	11,800,000	39.5%	16,200,000	48.2%	23,300,000	57.9%
	1999	11,800,000	40.3%	16,200,000	48.8%	23,300,000	58.5%
Post-2000	2000	10,600,000	36.7%	15,400,000	45.7%	22,900,000	55.5%
	2001	10,600,000	38.6%	15,400,000	47.4%	23,000,000	56.9%
	2002	10,900,000	39.9%	15,800,000	48.5%	23,300,000	57.8%
	2003	11,000,000	36.6%	15,800,000	45.7%	23,300,000	55.5%
	2004	11,100,000	36.1%	16,000,000	45.2%	23,500,000	55.1%
	2005	11,100,000	35.3%	15,900,000	44.5%	23,400,000	54.5%
	2006	11,000,000	36.6%	15,900,000	45.6%	23,400,000	55.4%
	2007	11,200,000	38.8%	16,100,000	47.6%	23,600,000	57.0%
	2008	11,000,000	38.3%	15,900,000	47.1%	23,400,000	56.7%
	2009	11,500,000	39.9%	16,400,000	48.5%	23,900,000	57.8%
	2010	11,600,000	39.3%	16,500,000	48.0%	24,000,000	57.3%
	2011	12,000,000	40.3%	16,900,000	48.9%	24,400,000	58.1%

Notes: 1.The number of job offshored is the sum of job offshored across all occupations within an occupational group.
2. The offshoring percentage is the average offshoring percentage across all occupations within an occupational group.
3. A cubic offshoring cost function is assumed.

Table 7.5: Calculated Number of Jobs Offshored and Offshoring Percentage for Group 9 (Production Occupations) from NLS Method

	Year	20% Scenario		40% Scenario		80% Scenario	
		No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage	No. of Jobs Offshored	Offshore Percentage
Pre-2000	1983	6,709,289	36.5%	9,768,267	45.6%	15,700,000	57.4%
	1984	6,856,422	38.4%	9,915,399	47.2%	15,800,000	58.7%
	1985	6,862,317	37.9%	9,921,295	46.8%	15,900,000	58.4%
	1986	6,864,584	37.9%	9,923,561	46.8%	15,900,000	58.4%
	1987	6,944,952	38.7%	10,000,000	47.5%	15,900,000	58.9%
	1988	7,105,089	38.4%	10,200,000	47.2%	16,100,000	58.7%
	1989	6,948,416	37.9%	10,000,000	46.8%	15,900,000	58.4%
	1990	6,878,102	37.1%	9,937,079	46.1%	15,900,000	57.8%
	1991	7,062,489	38.8%	10,100,000	47.6%	16,100,000	59.0%
	1992	7,208,100	39.1%	10,300,000	47.8%	16,200,000	59.2%
	1993	7,240,489	40.0%	10,300,000	48.6%	16,200,000	59.8%
	1994	8,090,008	43.1%	11,100,000	51.2%	17,100,000	61.8%
	1995	8,044,484	43.7%	11,100,000	51.8%	17,000,000	62.3%
	1996	7,987,601	44.3%	11,000,000	52.3%	17,000,000	62.7%
	1997	8,040,568	44.1%	11,100,000	52.1%	17,000,000	62.5%
	1998	8,274,450	44.4%	11,300,000	52.3%	17,300,000	62.7%
	1999	8,496,861	46.3%	11,600,000	54.0%	17,500,000	64.0%
Post-2000	2000	4,711,486	36.1%	6,992,078	45.2%	9,611,898	52.9%
	2001	4,922,465	36.6%	7,203,058	45.6%	9,822,878	53.3%
	2002	5,399,961	40.9%	7,680,554	49.4%	10,300,000	56.5%
	2003	5,928,591	42.0%	8,209,184	50.3%	10,800,000	57.3%
	2004	6,092,295	44.3%	8,372,887	52.2%	11,000,000	59.0%
	2005	6,095,895	44.4%	8,376,488	52.4%	11,000,000	59.1%
	2006	6,241,160	45.6%	8,521,752	53.4%	11,100,000	60.0%
	2007	6,225,142	45.7%	8,505,735	53.5%	11,100,000	60.0%
	2008	6,290,275	47.3%	8,570,868	54.8%	11,200,000	61.2%
	2009	6,905,819	49.8%	9,186,411	57.0%	11,800,000	63.0%
	2010	6,962,225	49.1%	9,242,818	56.4%	11,900,000	62.5%
	2011	6,812,466	48.5%	9,093,059	55.9%	11,700,000	62.1%

Notes: 1. The number of job offshored is the sum of job offshored across all occupations within an occupational group.
2. The offshoring percentage is the average offshoring percentage across all occupations within an occupational group.
3. A cubic offshoring cost function is assumed.

Table 8: Scenario Comparison among the Five Relatively Offshorable Occupational Groups from NLS Method

	Year	Group 1 (20%)		Group 2 (20%)		Group 4 (20%)		Group 5 (40%)		Group 9 (80%)	
		Offshored		Offshored		Offshored		Offshored		Offshored	
		Jobs	%	Jobs	%	Jobs	%	Jobs	%	Jobs	%
Pre-2000	1983	7,771,465	47.6%	13,300,000	46.8%	4,489,843	35.1%	14,600,000	50.2%	15,700,000	57.4%
	1984	7,085,993	45.8%	13,200,000	46.6%	4,182,837	32.5%	14,800,000	51.7%	15,800,000	58.7%
	1985	6,707,947	46.1%	12,800,000	46.1%	4,178,781	32.4%	14,600,000	51.2%	15,900,000	58.4%
	1986	6,292,123	42.1%	12,500,000	44.8%	4,014,622	30.7%	14,500,000	50.1%	15,900,000	58.4%
	1987	5,989,792	40.0%	12,400,000	45.5%	3,805,164	29.2%	14,300,000	48.9%	15,900,000	58.9%
	1988	5,500,926	37.7%	12,000,000	43.1%	3,846,256	30.6%	14,200,000	49.5%	16,100,000	58.7%
	1989	4,891,834	35.6%	11,700,000	44.0%	3,670,658	30.7%	14,300,000	48.2%	15,900,000	58.4%
	1990	4,902,728	34.8%	11,200,000	40.9%	3,370,897	29.0%	13,800,000	45.6%	15,900,000	57.8%
	1991	4,671,854	34.7%	11,100,000	39.5%	3,407,134	30.8%	14,000,000	45.3%	16,100,000	59.0%
	1992	6,299,921	36.2%	11,000,000	41.0%	3,370,818	27.4%	13,900,000	45.2%	16,200,000	59.2%
	1993	6,233,880	32.9%	10,600,000	39.1%	3,440,809	27.9%	14,100,000	44.9%	16,200,000	59.8%
	1994	6,354,836	35.1%	10,900,000	40.1%	4,456,491	34.7%	16,200,000	50.5%	17,100,000	61.8%
	1995	5,822,961	33.1%	10,600,000	40.1%	4,284,704	32.7%	16,200,000	50.7%	17,000,000	62.3%
	1996	5,651,819	33.3%	10,100,000	38.9%	4,027,732	31.4%	16,100,000	49.9%	17,000,000	62.7%
	1997	5,185,593	32.9%	9,780,010	37.5%	3,933,802	31.0%	16,200,000	48.9%	17,000,000	62.5%
	1998	4,869,771	30.6%	9,640,700	36.4%	3,888,172	30.2%	16,200,000	48.2%	17,300,000	62.7%
	1999	4,454,344	27.5%	8,816,018	34.8%	4,005,604	28.9%	16,200,000	48.8%	17,500,000	64.0%

Table 8 (cont'd)

Post-2000	2000	7,696,804	37.5%	12,300,000	39.4%	5,993,041	32.1%	15,400,000	45.7%	9,611,898	52.9%
	2001	7,312,754	35.2%	11,800,000	38.3%	5,701,304	28.8%	15,400,000	47.4%	9,822,878	53.3%
	2002	7,152,252	36.1%	11,600,000	38.5%	5,635,168	28.9%	15,800,000	48.5%	10,300,000	56.5%
	2003	7,336,184	37.0%	11,500,000	37.8%	5,805,051	29.9%	15,800,000	45.7%	10,800,000	57.3%
	2004	7,286,110	35.7%	11,400,000	37.4%	5,677,808	29.7%	16,000,000	45.2%	11,000,000	59.0%
	2005	7,108,696	34.0%	11,200,000	37.2%	5,556,994	30.0%	15,900,000	44.5%	11,000,000	59.1%
	2006	6,919,571	34.1%	11,000,000	36.1%	5,363,608	27.9%	15,900,000	45.6%	11,100,000	60.0%
	2007	6,652,990	33.0%	10,400,000	35.5%	5,251,183	28.0%	16,100,000	47.6%	11,100,000	60.0%
	2008	6,526,403	34.0%	10,100,000	35.0%	5480,845	29.9%	15,900,000	47.1%	11,200,000	61.2%
	2009	6,630,334	32.5%	9,978,409	34.9%	5,400,839	29.6%	16,400,000	48.5%	11,800,000	63.0%
	2010	6,953,488	32.1%	10,000,000	34.2%	5,567,462	31.5%	16,500,000	48.0%	11,900,000	62.5%
	2011	6,892,056	33.6%	9,962,497	34.2%	5,655,523	32.4%	16,900,000	48.9%	11,700,000	62.1%

Notes: 1. The number of job offshored is the sum of job offshored across all occupations within an occupational group.
2. The offshoring percentage is the average offshoring percentage across all occupations within an occupational group.
3. A cubic offshoring cost function is assumed.
4. In 20%, 40% and 80% scenario, offshoring is set not to exceed the 20%, 40% and 80% of the maximum adjusted employment of all occupations across all years within each occupational group respectively.

Table A: Monotonic Cubic Spline Interpolation Method Preliminary Point Estimates of Parameterized Offshoring Cost Function $t(i)$

Group	Value of $t(i)$ at Control Points i Pre-2000: 1983-1999										
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
1	3.02	8.98	14.1	26.2	36.3	48.6	61.7	80.1	98.83	126.5	185.1
2	1.11	2.65	8.75	15.4	32.5	72.0	121.4	138.1	131.7	123.4	109.1
3	8.40	6.90	12.8	18.7	47.3	174.3	262.4	372.7	298.5	452.6	259.2
4	0.04	7.00	12.3	20.6	38.8	57.8	87.8	120.9	185.8	167.1	144.0
5	13.9	5.53	11.5	20.2	30.6	43.2	59.5	79.1	103.7	131.8	146.1
6	8.82	13.4	20.2	32.6	46.2	83.6	119.4	182.9	272.1	401.7	537.2
7	5.37	9.24	17.2	25.2	52.4	75.5	92.5	136.1	191.1	307.4	438.8
8	8.09	0.12	15.3	14.7	75.6	110.6	131.8	172.0	266.1	355.9	552.8
9	8.29	0.14	0.94	7.27	18.9	54.0	104.4	136.7	151.5	173.3	165.1
10	8.25	10.1	15.8	35.6	71.7	208.7	284.9	421.4	561.2	798.0	1011.5
	Value of $t(i)$ at Control Points i Post-2000 Period: 2000-2011										
1	3.09	6.85	12.6	20.5	30.8	43.05	58.9	78.18	102.2	121.8	186.0
2	8.49	2.09	4.45	7.80	29.7	110.2	157.6	197.4	225.4	173.1	459.4
3	17.4	26.9	55.4	69.5	141.6	232.7	180.7	405.3	533.4	744.8	1076.7
4	0.87	6.92	9.56	19.8	24.4	51.8	59.7	86.4	102.0	129.5	184.9
5	3.27	1.01	0.88	37.2	33.8	48.0	64.3	85.5	101.7	133.3	165.2
6	22.4	23.2	25.3	35.7	53.5	77.0	111.3	165.6	249.8	215.3	259.1
7	2.21	27.9	26.6	40.8	23.2	82.3	116.8	203.8	265.3	369.0	533.2
8	5.69	7.30	2.14	18.2	34.6	41.3	62.5	92.1	134.7	182.3	269.8
9	0.70	0.09	1.32	40.6	19.5	71.3	105.2	95.2	85.91	117.7	124.6
10	16.1	11.2	11.4	53.7	79.8	99.4	132.5	171.3	124.0	195.0	241.0

Notes: 1. No other control variables are included in the model.

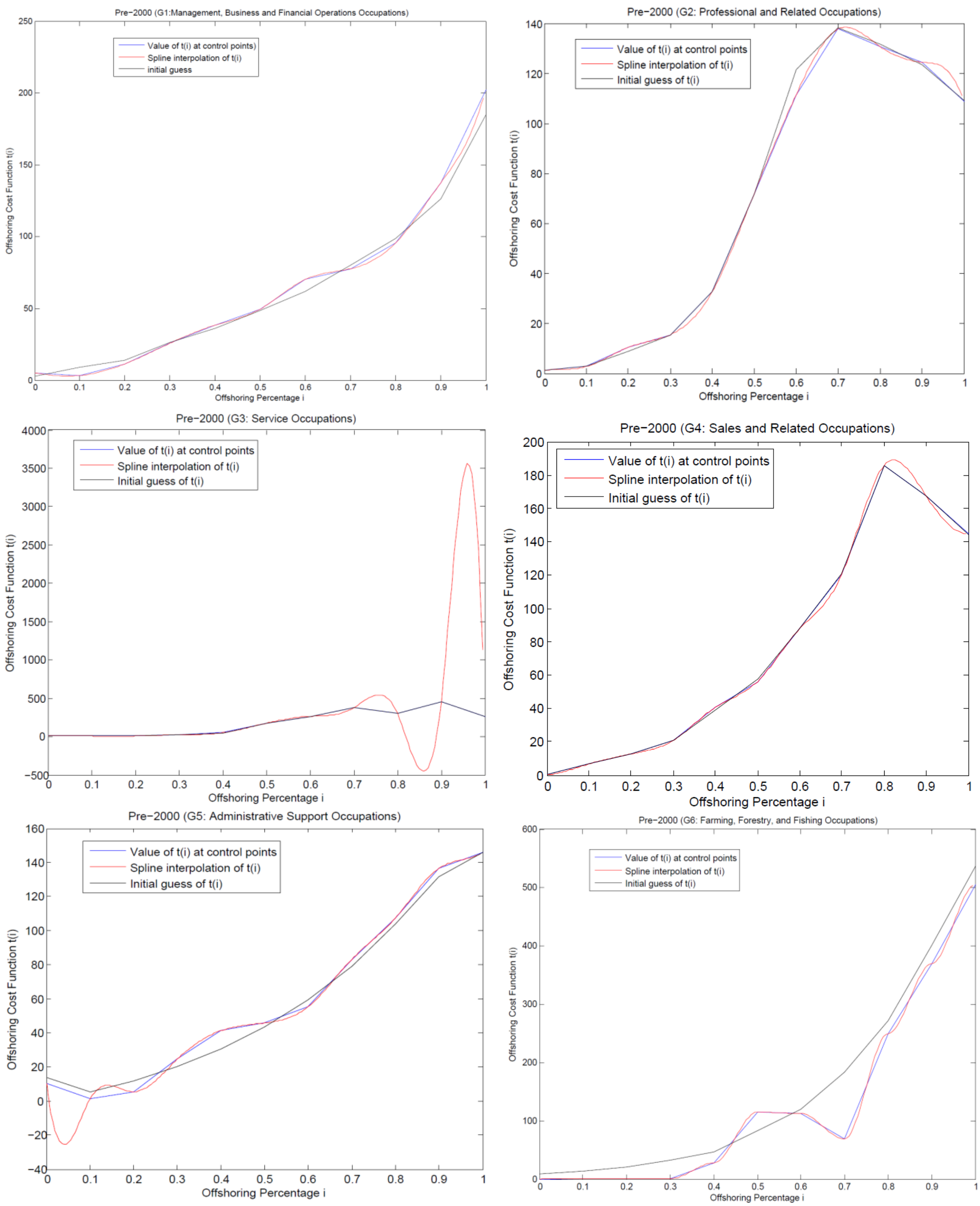
2. The upper bound is set that offshoring cannot exceed the 10% of the maximum employment of all occupations across all years within each group.

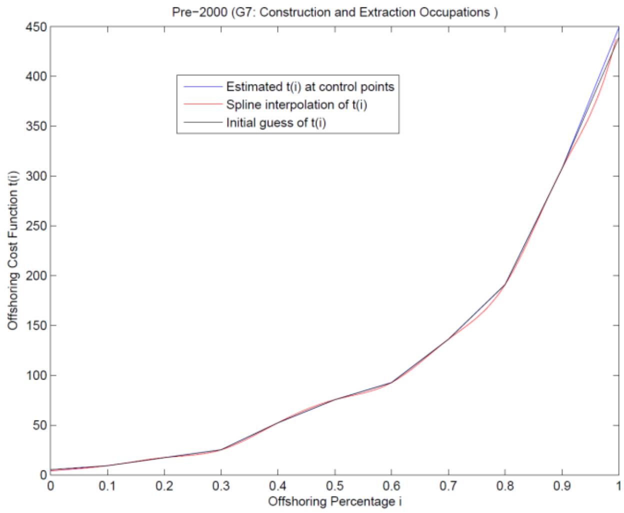
3. No observations are dropped.

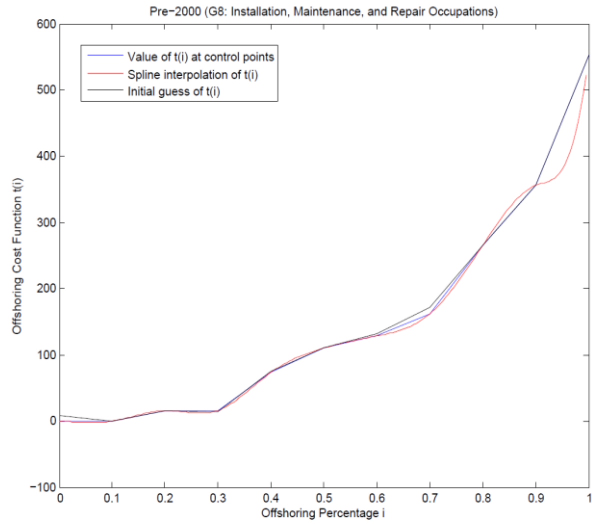
4. The maximum iterations is500 times.

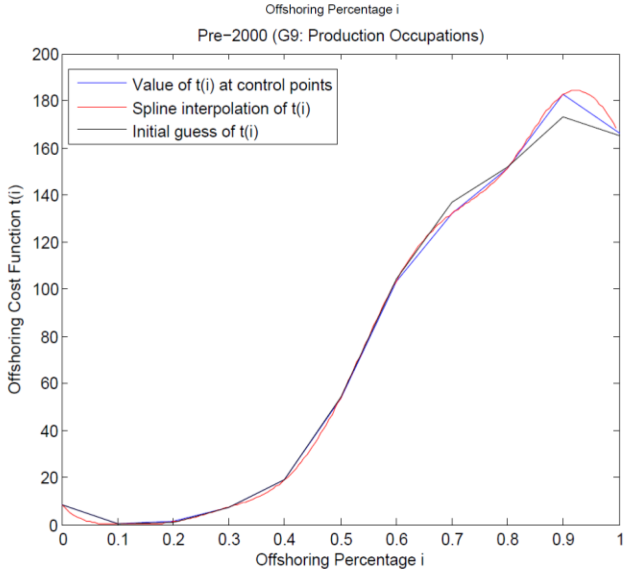
5. For Group 1, 2, 4, 5, 9the functional form for iteration to start with is $(4x + 1.5)^3 + \varepsilon$, where ε is a random shock with normal distribution $N(0,\ 0.01)$. For Group 3, 6, 7, 8 and 10, the functional form for iteration to start with is $10 * exp(4x) + \varepsilon$, where ε is a random shock with normal distribution $N(0,\ 0.01)$.

Figure 2.1: Monotonic Cubic Spline Interpolation Method Offshoring Cost Function by Occupational Groups in Pre-2000 Period (1983-1999)




Pre−2000 (G7: Construction and Extraction Occupations)
Estimated t(i) at control points
Spline interpolation of t(i)
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage i


Pre−2000 (G8: Installation, Maintenance, and Repair Occupations)
Value of t(i) at control points
Spline interpolation of t(i)
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage i


Pre−2000 (G9: Production Occupations)
Value of t(i) at control points
Spline interpolation of t(i)
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage i

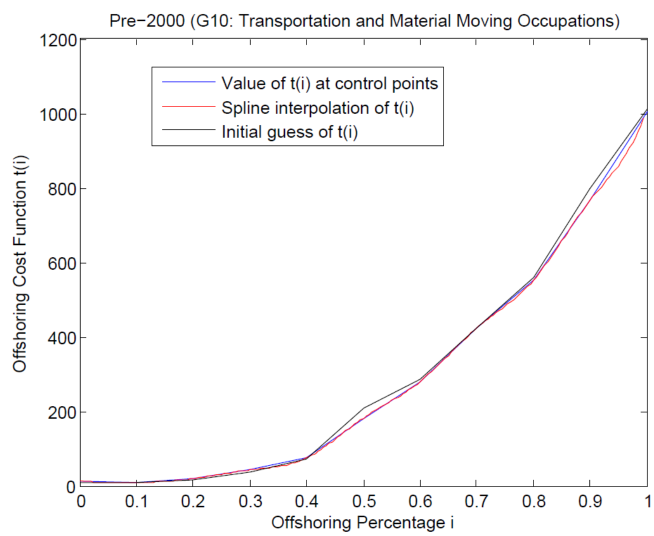
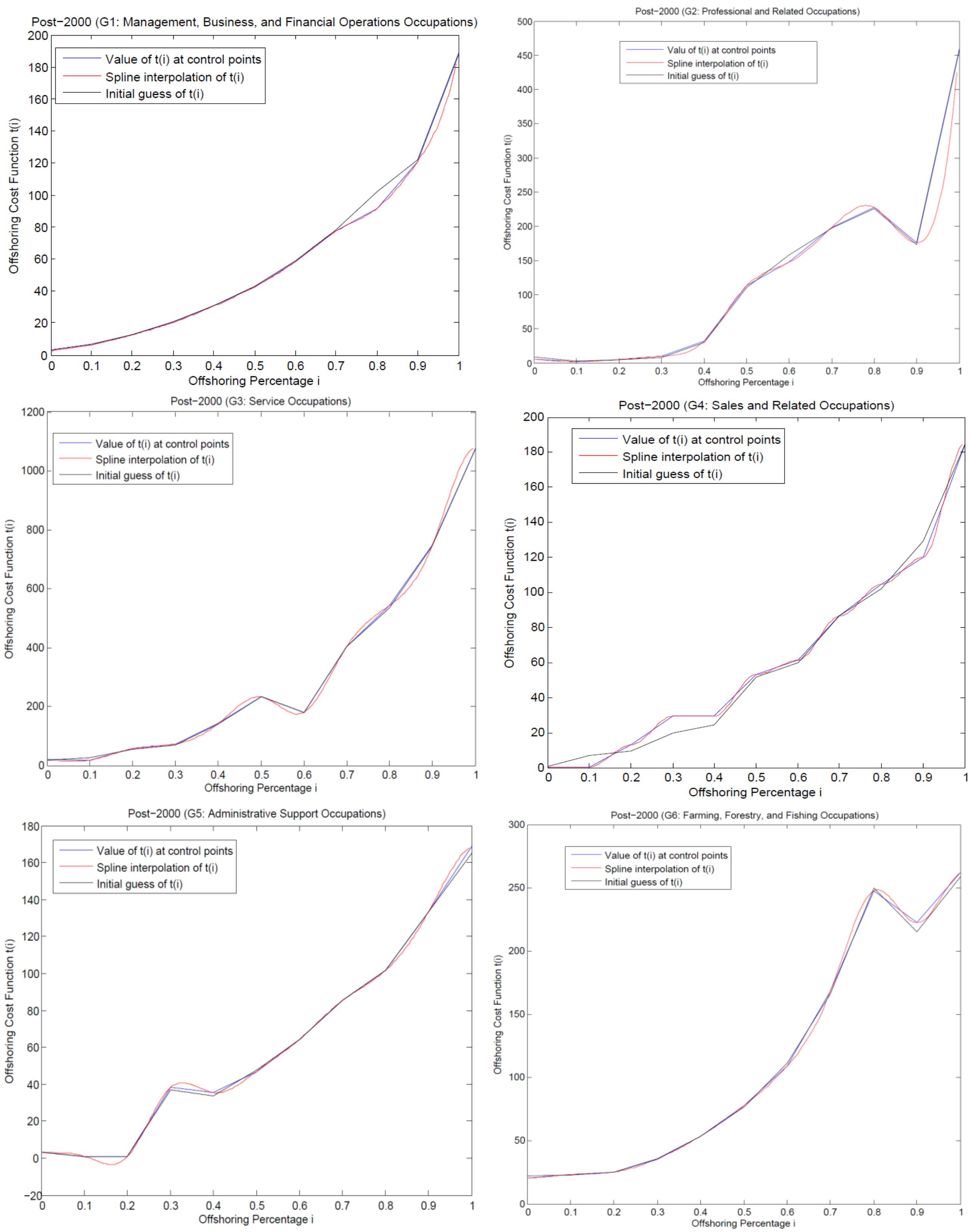
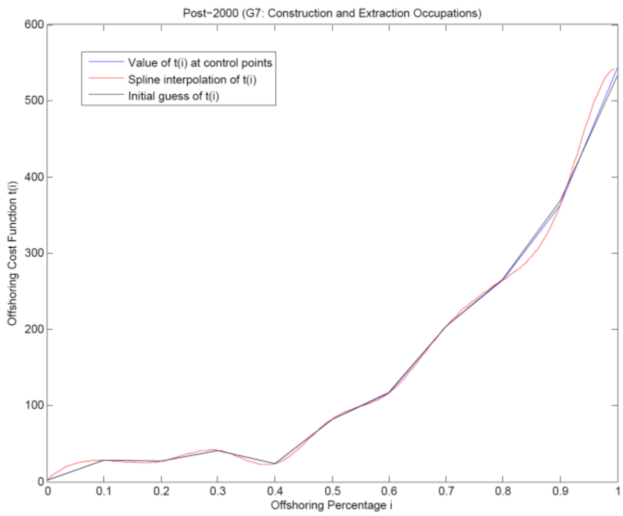
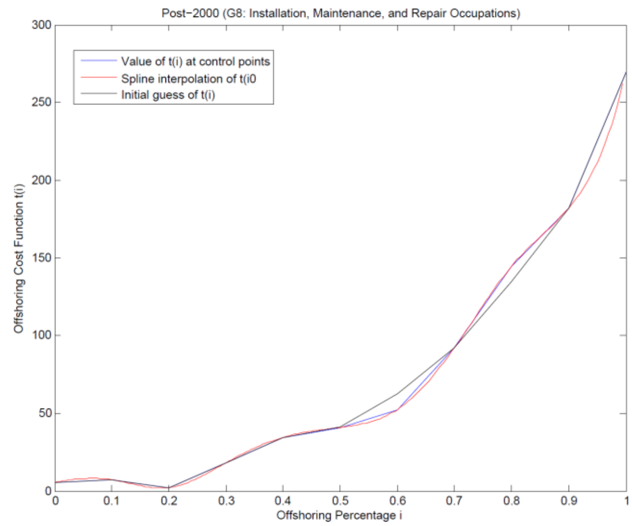
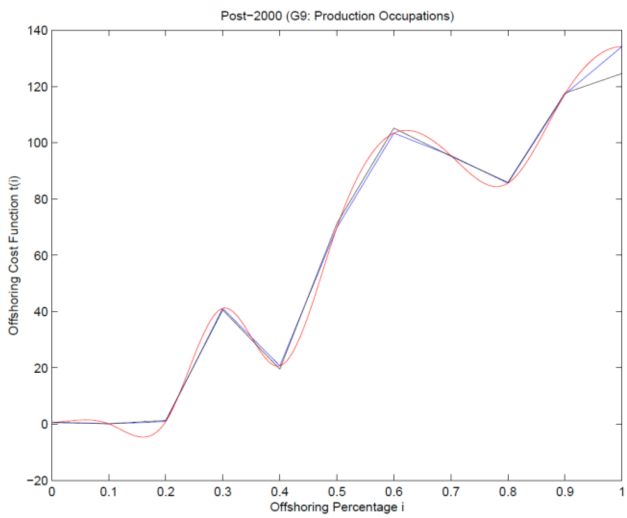

Pre−2000 (G10: Transportation and Material Moving Occupations)
Value of t(i) at control points
Spline interpolation of t(i)
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage i

Figure 3.2.2: Monotonic Cubic Spline Interpolation Method
Offshoring Cost Function by Occupational Groups in Post-2000 Period (2000-2011)




Post−2000 (G7: Construction and Extraction Occupations)
Value of t(i) at control points
Spline interpolation of t(i)
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage i


Post−2000 (G8: Installation, Maintenance, and Repair Occupations)
Value of t(i) at control points
Spline interpolation of t(i0
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage i


Post−2000 (G9: Production Occupations)
Offshoring Cost Function t(i)
Offshoring Percentage i

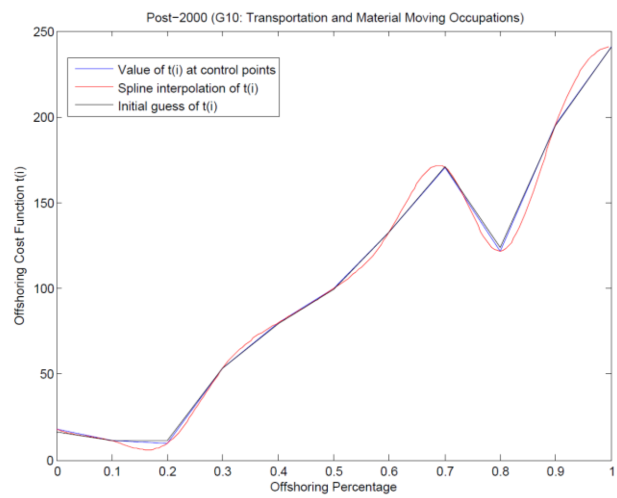
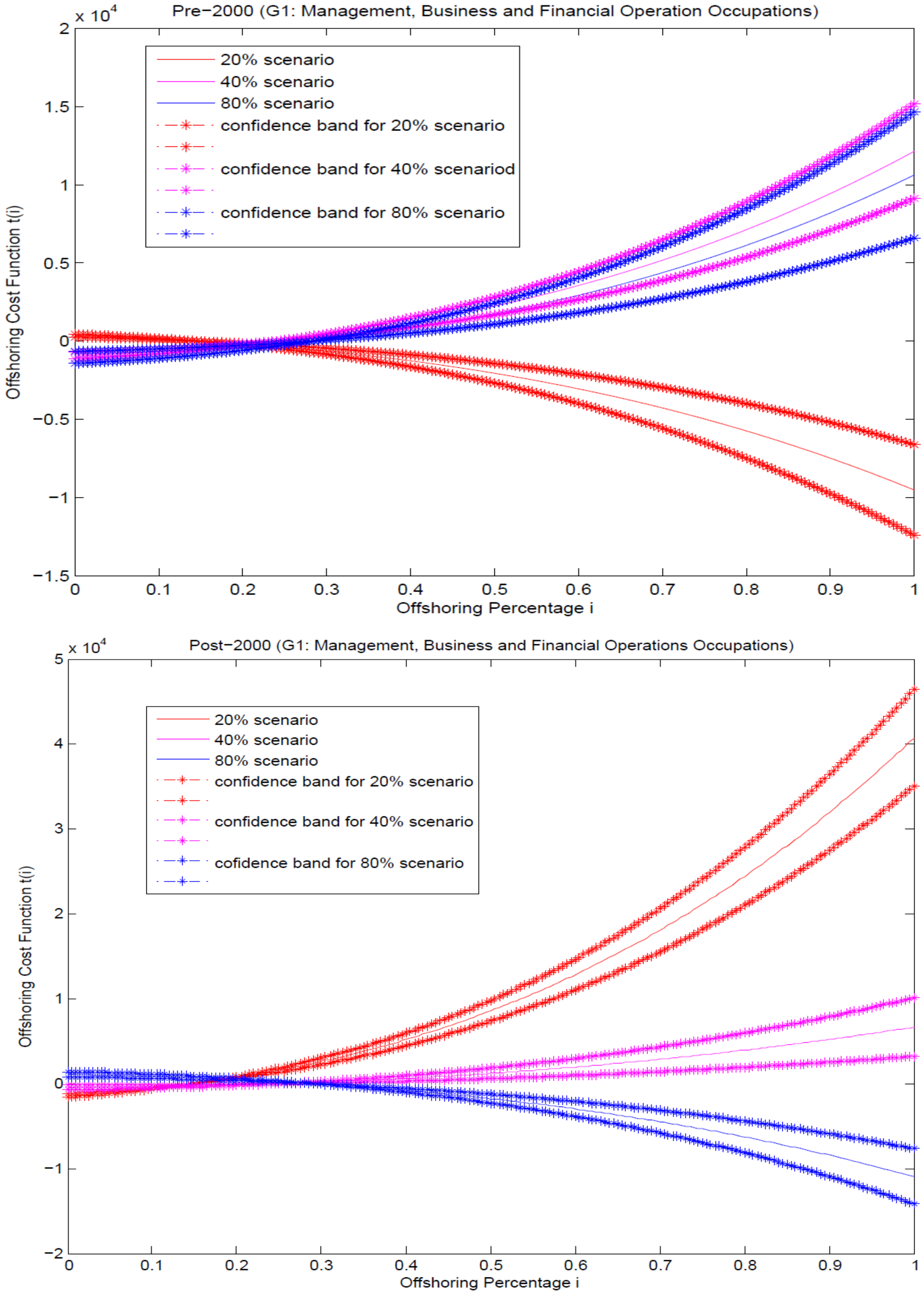
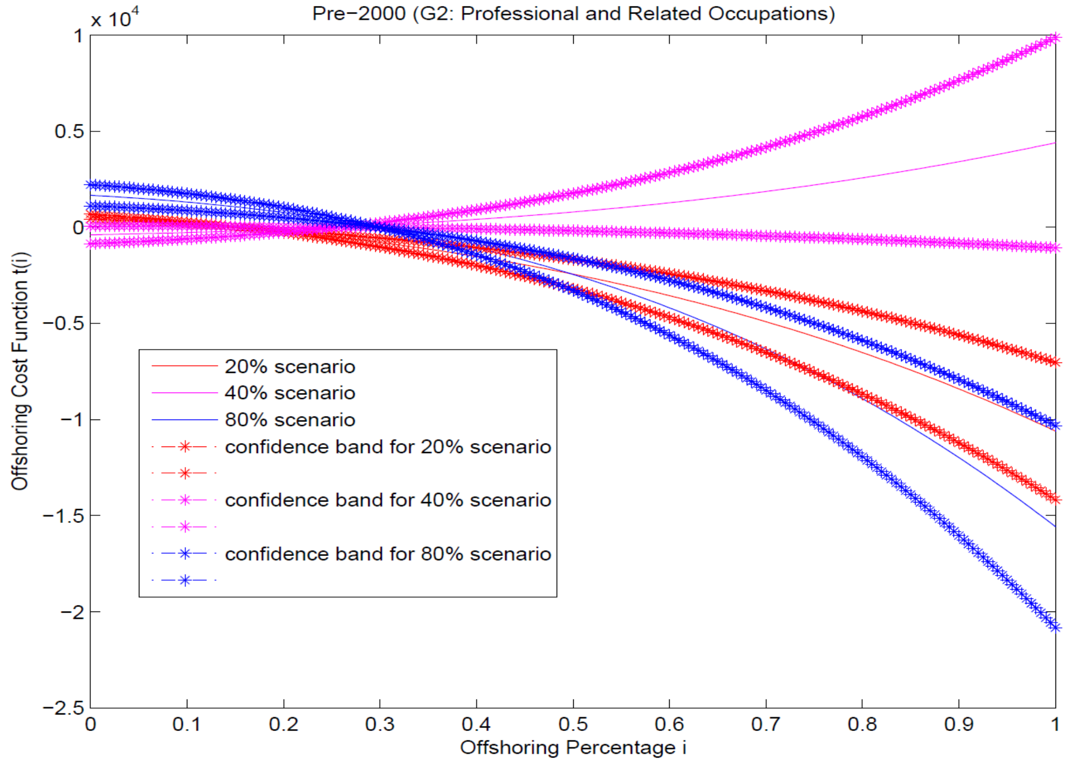

Post−2000 (G10: Transportation and Material Moving Occupations)
Value of t(i) at control points
Spline interpolation of t(i)
Initial guess of t(i)
Offshoring Cost Function t(i)
Offshoring Percentage

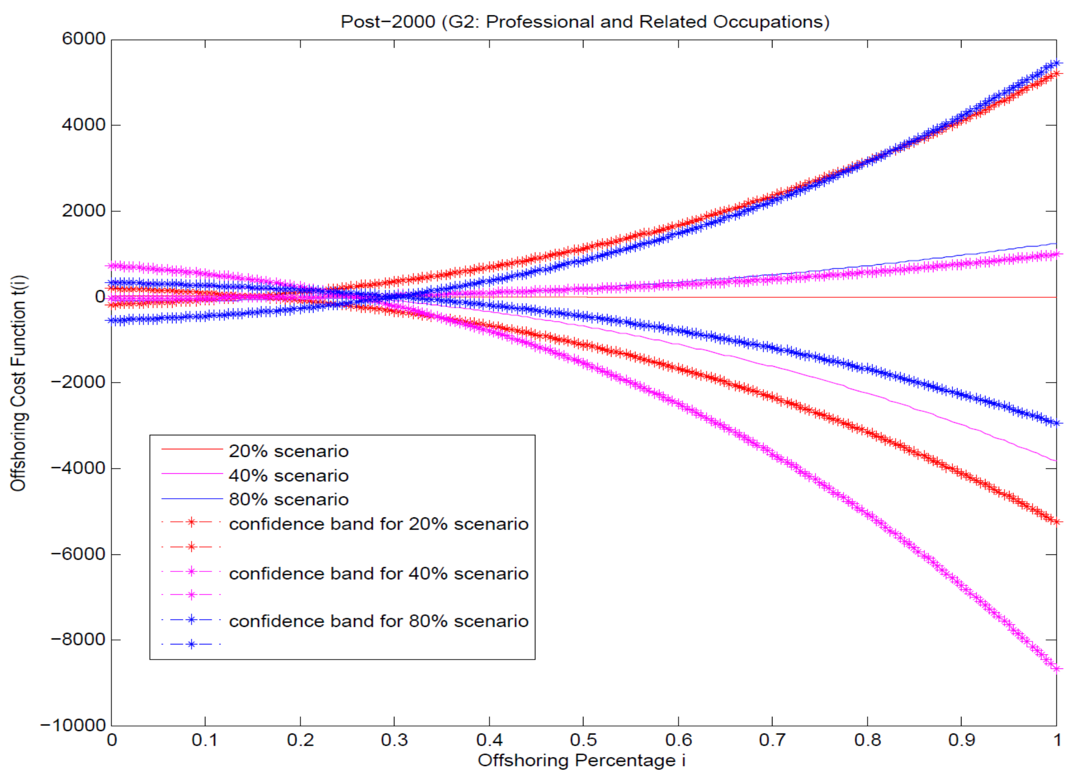
Figure 3.1: NLS Method
Cubic Offshoring Cost Function for
G1 (Management, Business and Financial Operations Occupations)



Notes: 95 percent confidence band is calculated with 50 times bootstrapping.

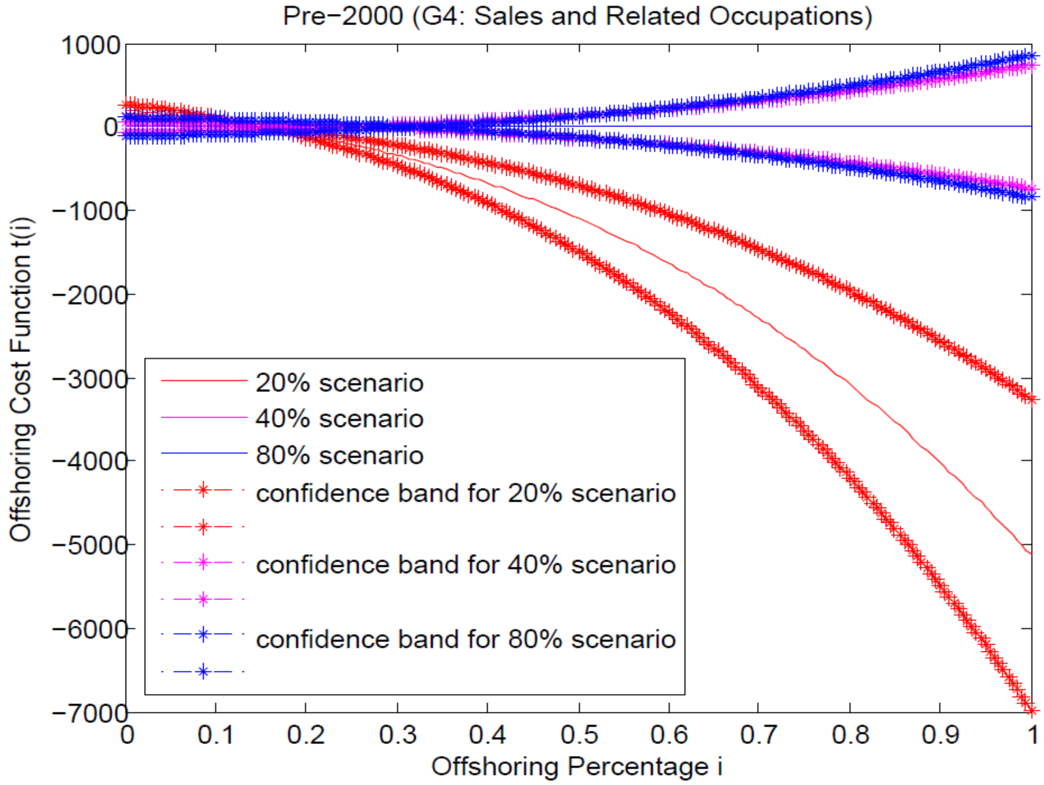
Figure 3.2: NLS Method
Cubic Offshoring Cost Function for G2 (Professional and Related Occupations)

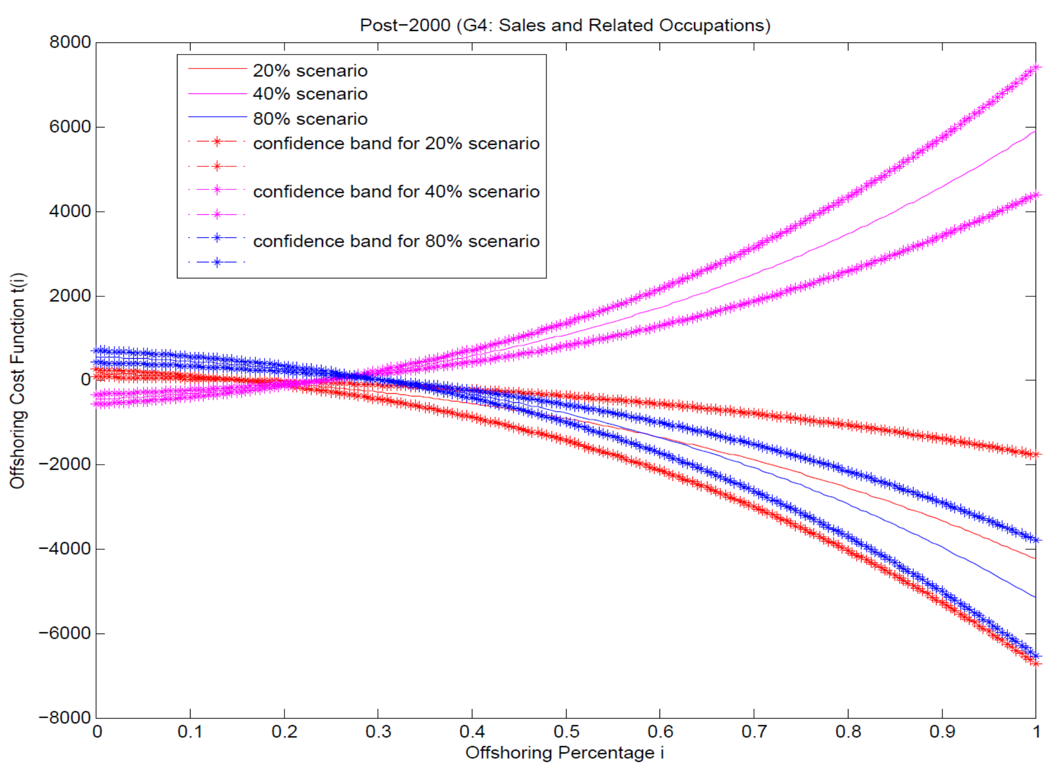




Notes: 95 percent confidence band is calculated with 50 times bootstrapping.

Figure 3.3: NLS Method
Cubic Offshoring Cost Function for G4 (Sales and Related Occupations

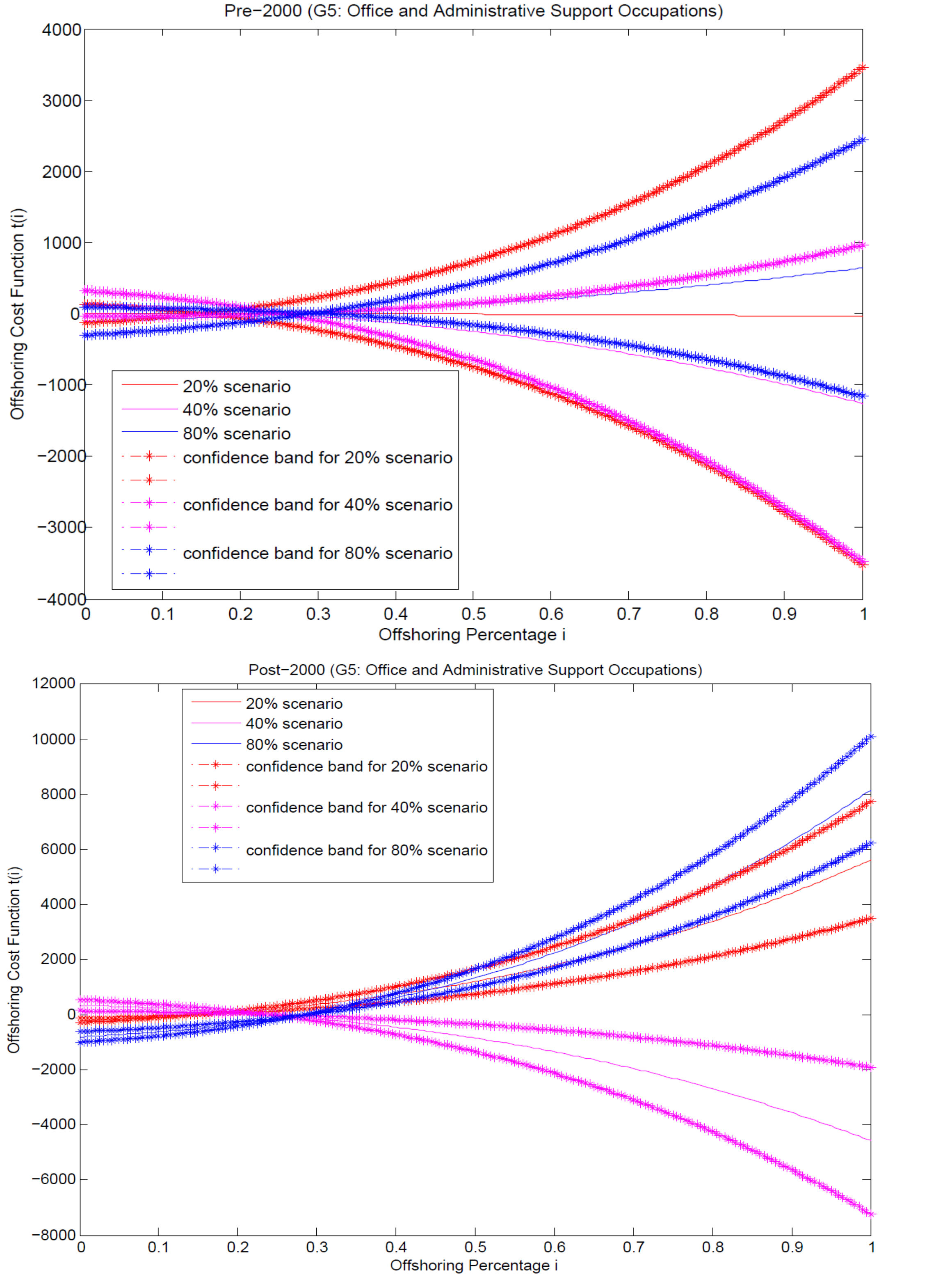




Notes: 95 percent confidence band is calculated with 50 times bootstrapping.

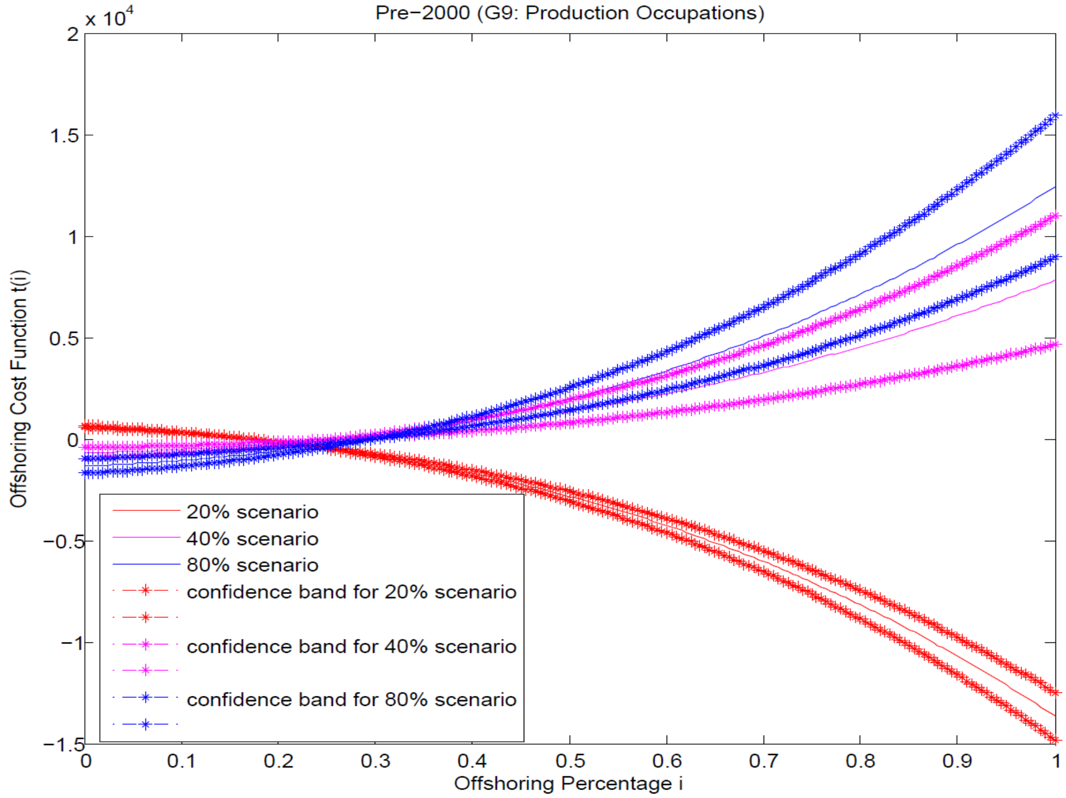
Figure 3.4: NLS Method

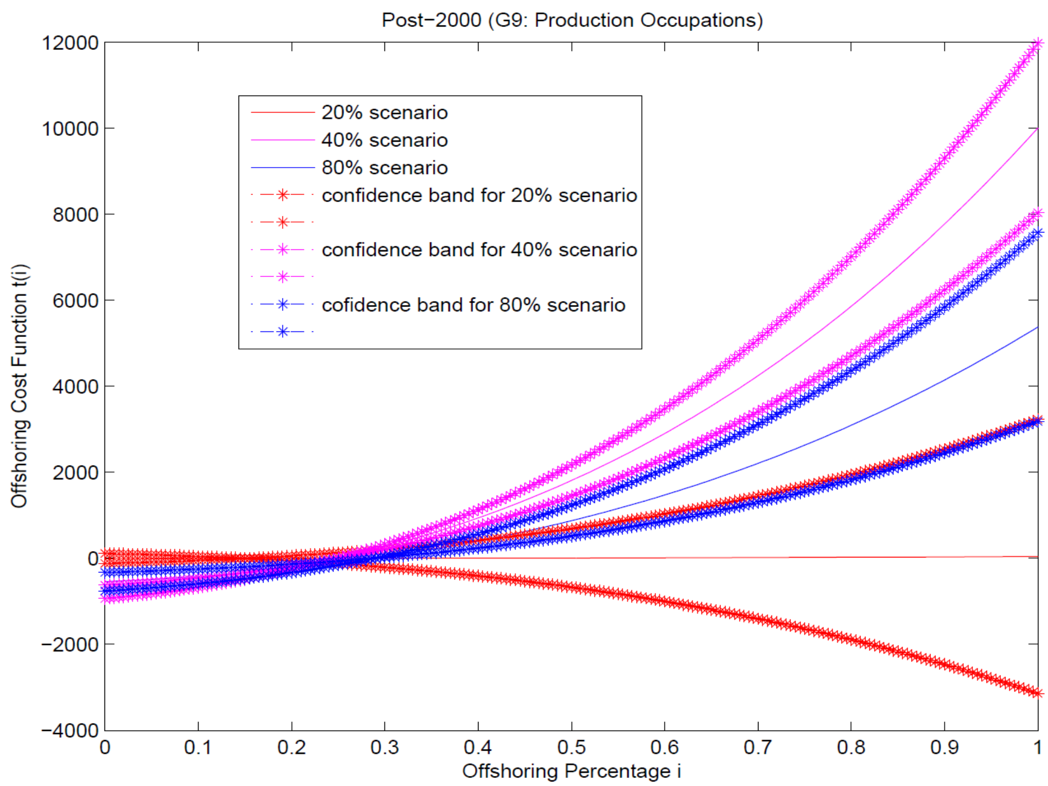
Cubic Offshoring Cost Function for G5 (Office and Administrative Support Occupations)



Notes: 95 percent confidence band is calculated with 50 times bootstrapping.

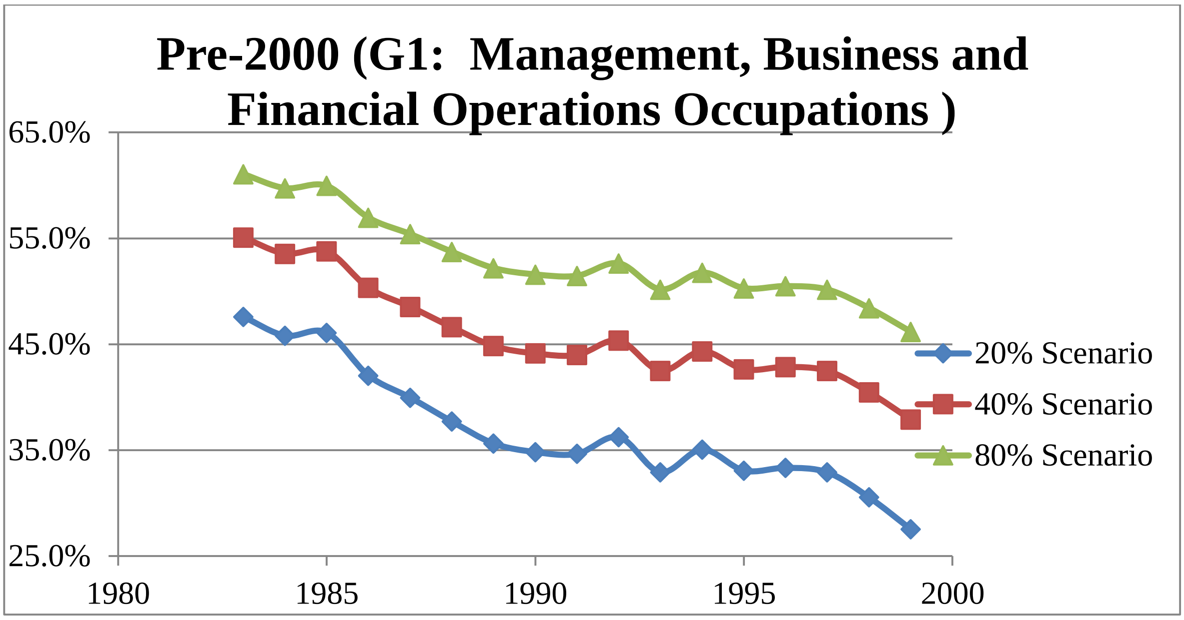
Figure 3.5: NLS Method
Cubic Offshoring Cost Function for G9 (Production Occupations)





Notes: 95 percent confidence band is calculated with 50 times bootstrapping.

Figure 4.1: Change of Offshoring Percentage for G1 (Management, Business and Financial Operations Occupations)



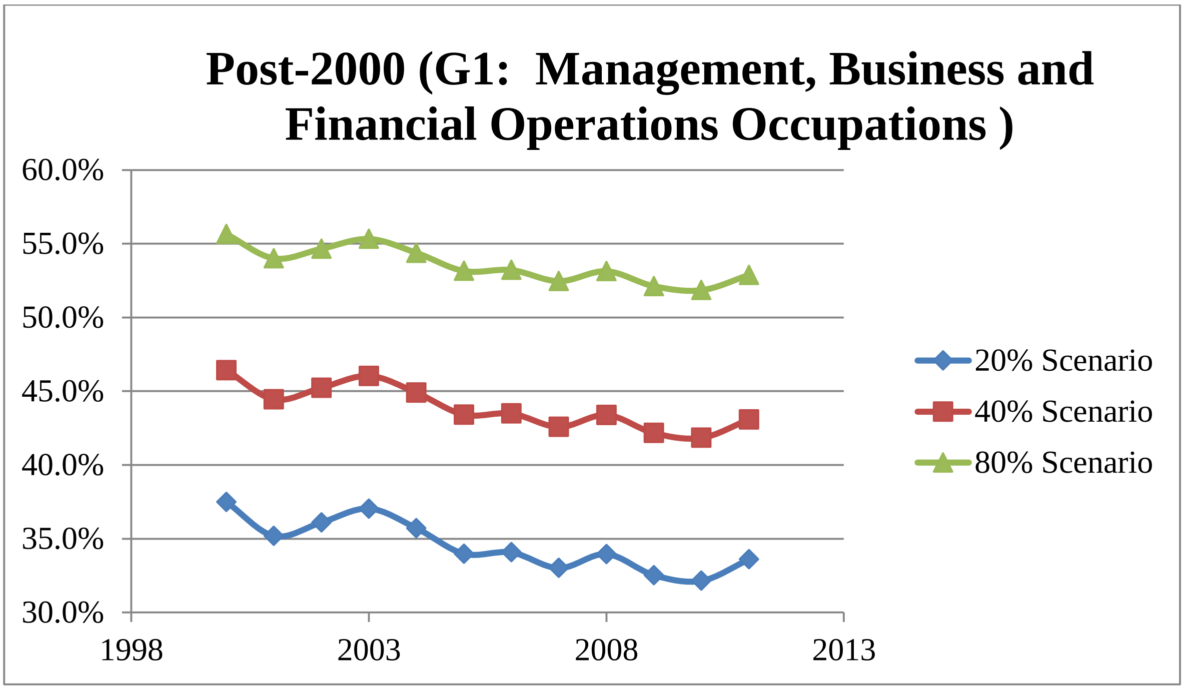
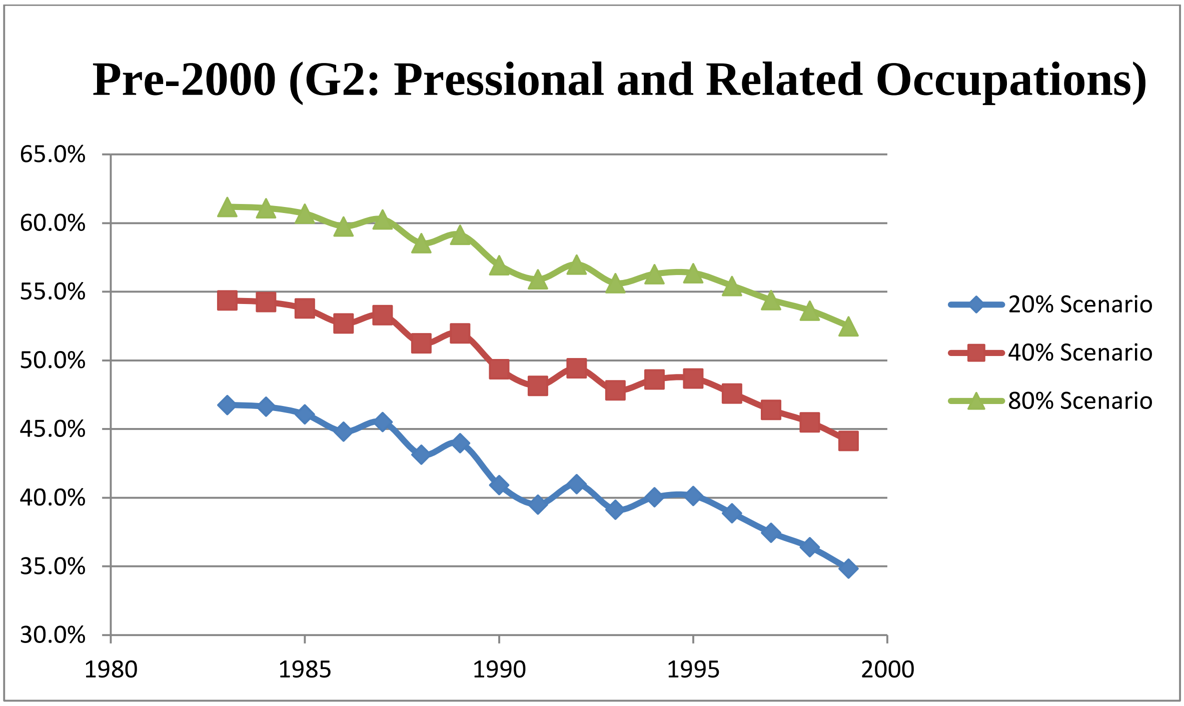


Figure 4.2: Change of Offshoring Percentage for G2 (Professional and Related Occupations)



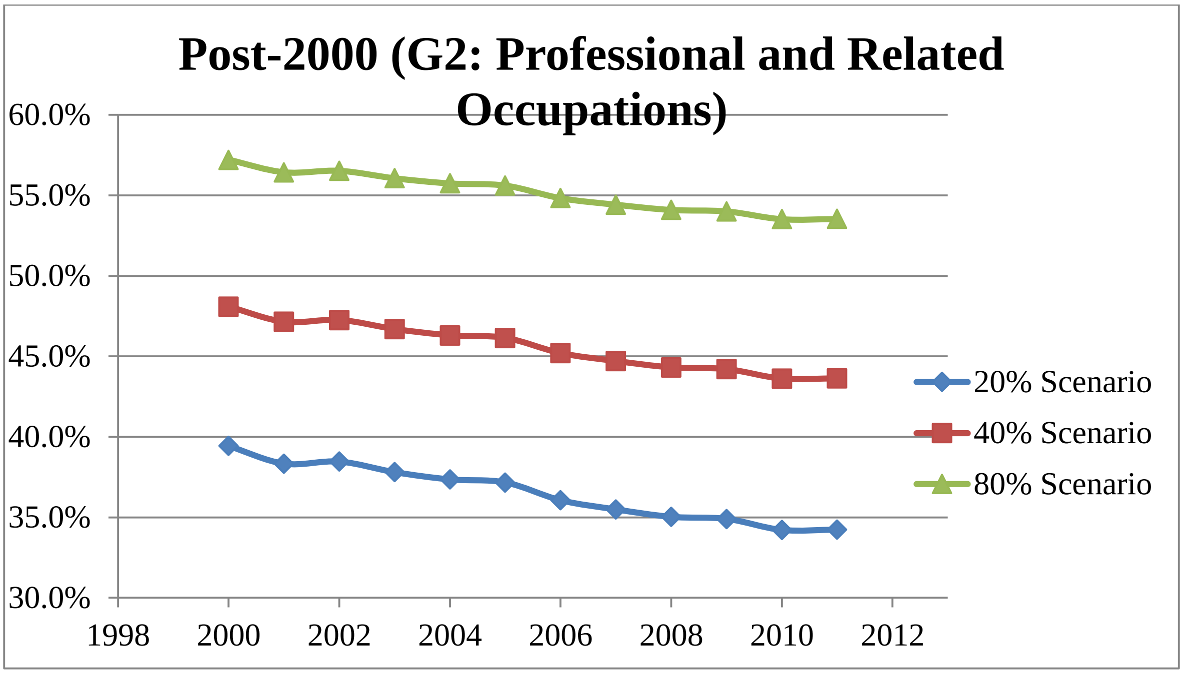
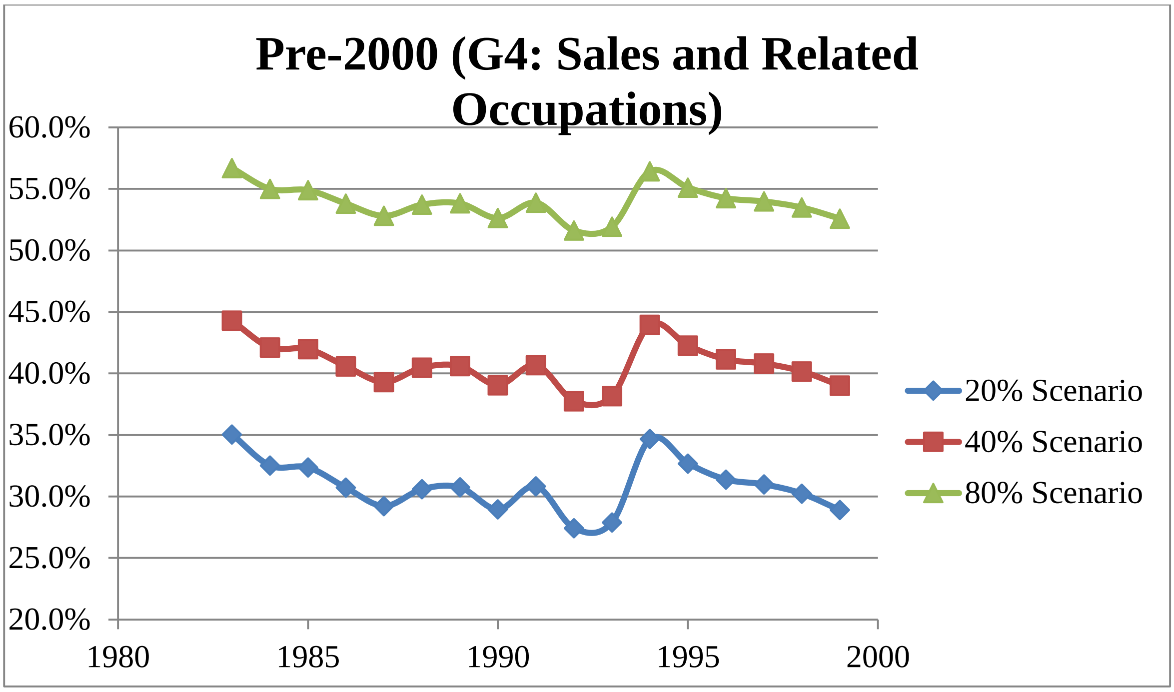


Figure 4.3: Change of Offshoring Percentage for G4 (Sales and Related Occupations)



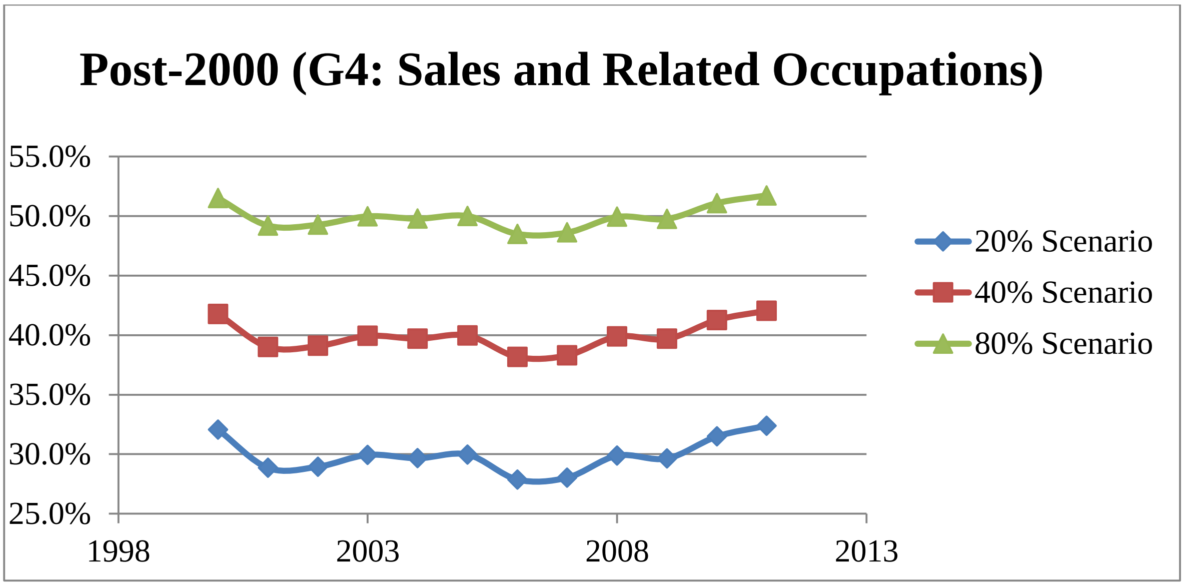
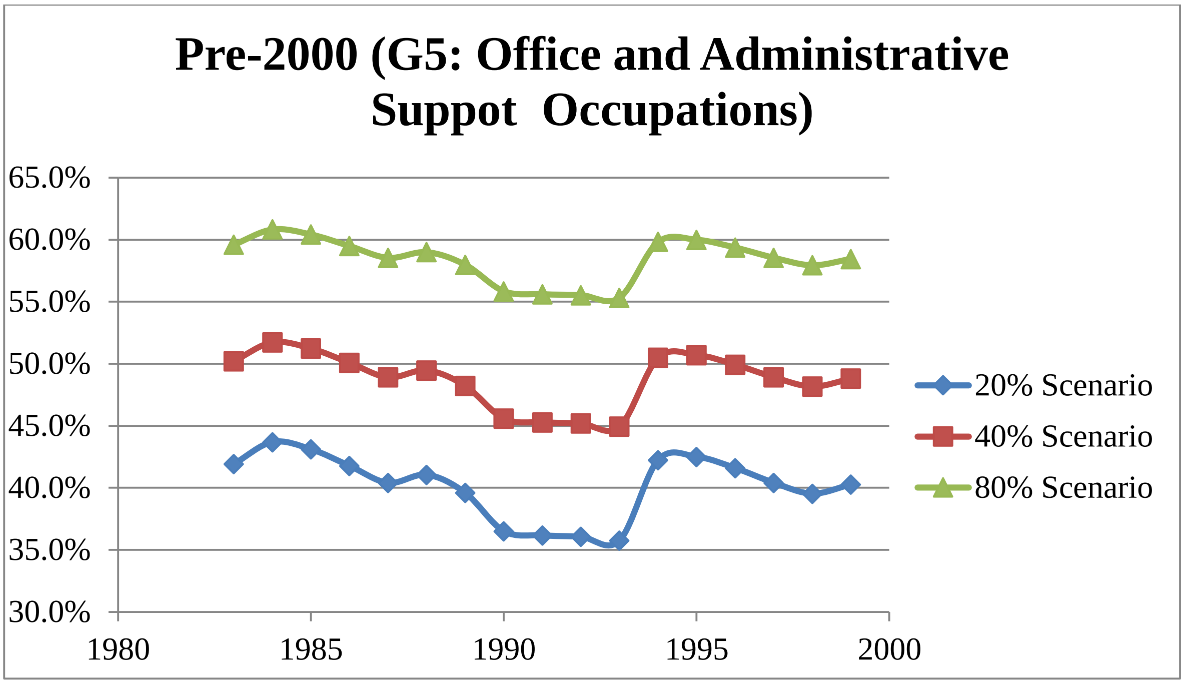


Figure 4.4: Change of Offshoring Percentage for G5 (Office and Administrative Support Occupations)



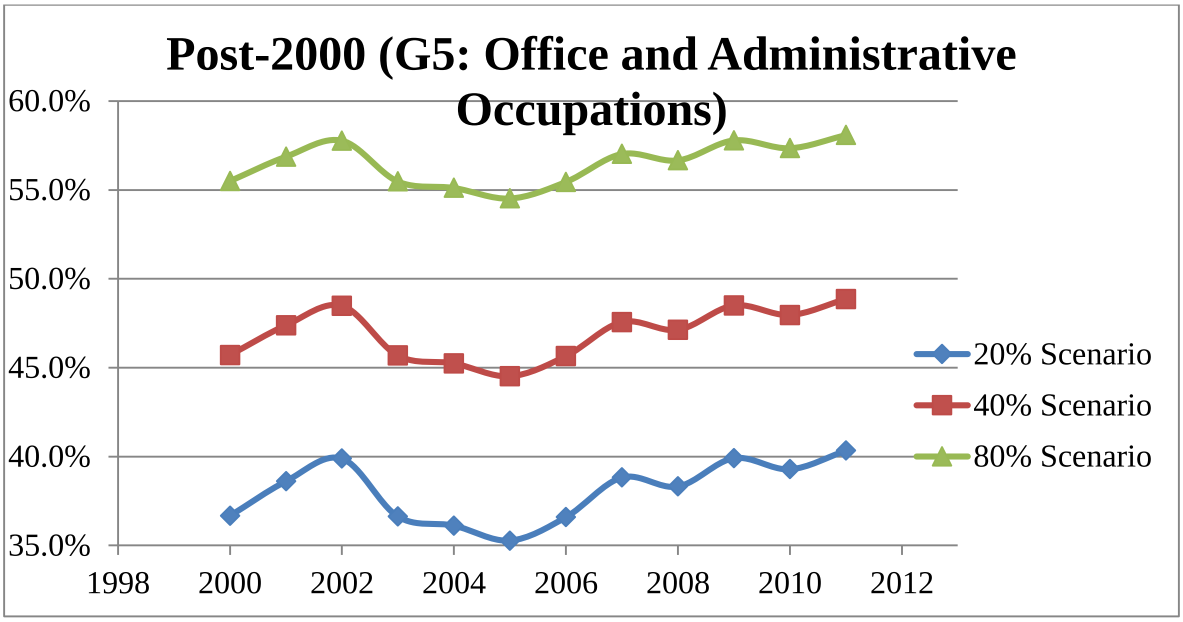
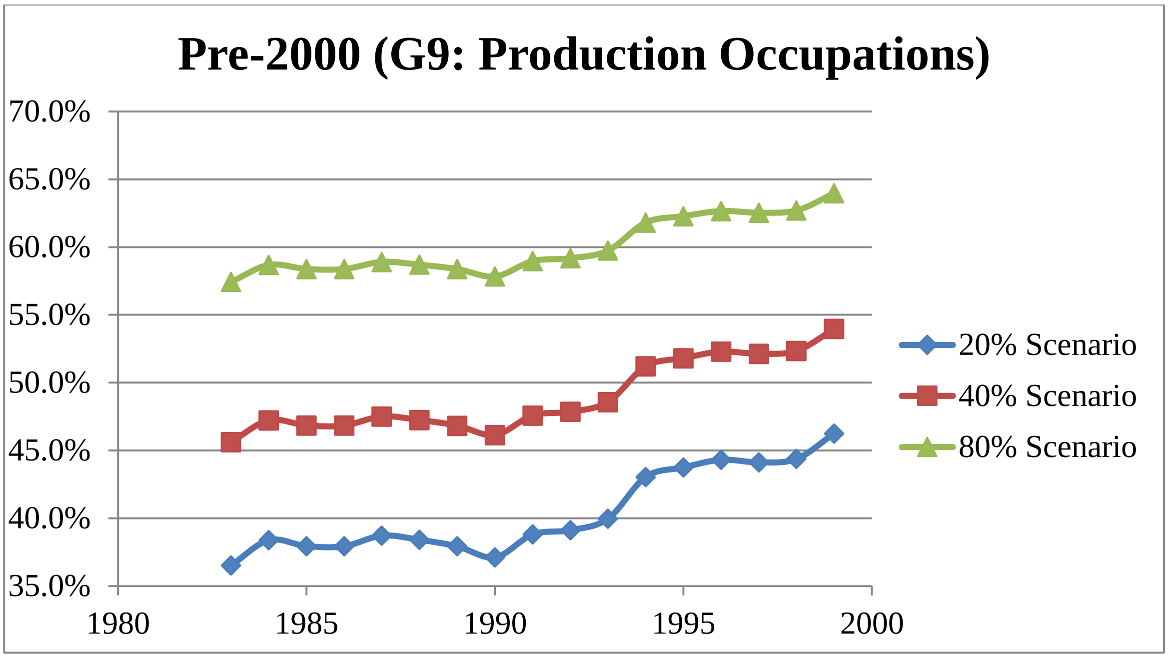


Figure 4.5: Change of Offshoring Percentage for G9 (Production Occupations)



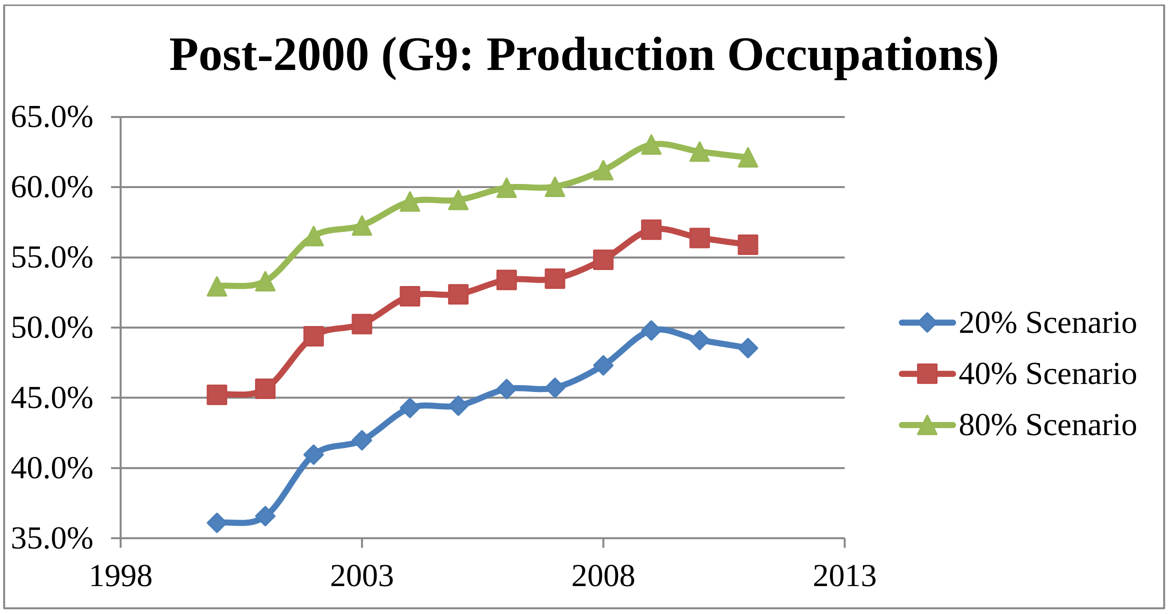
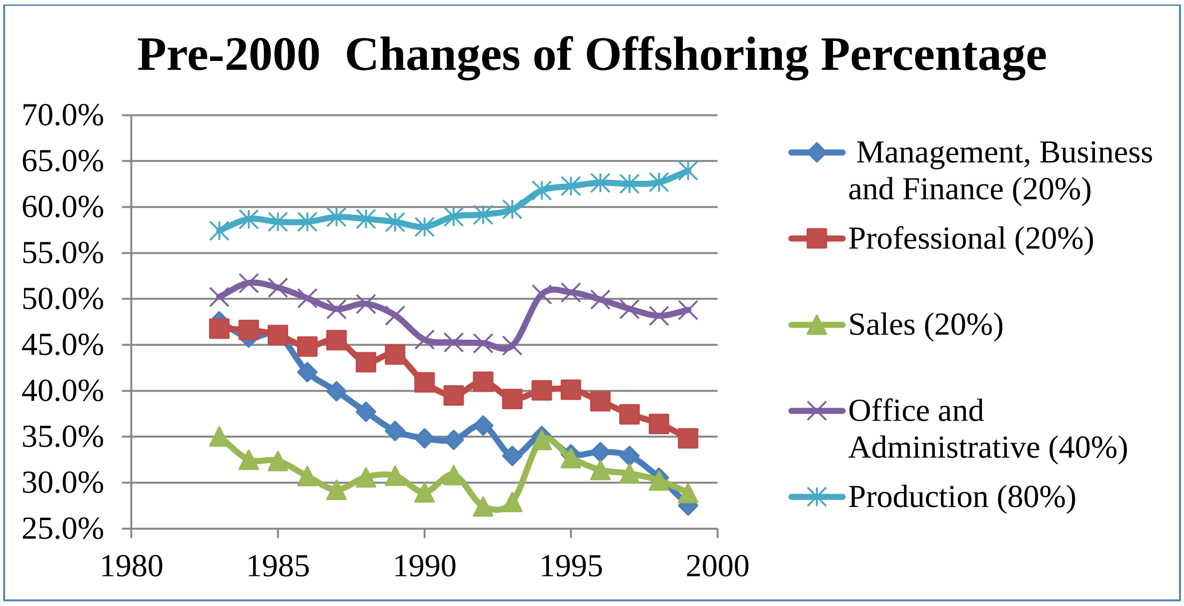
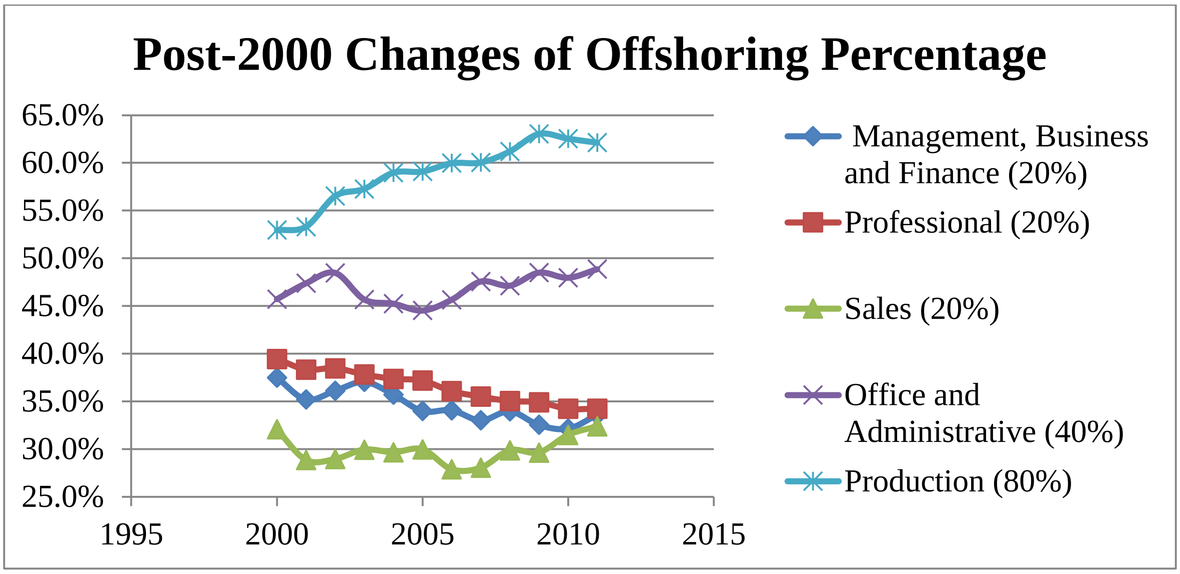


Figure 5: Changes of Offshoring Percentage for the Five Relatively Offshorable Occupational Groups





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