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Índice

Presentación

La revista **Banca Central,** enero-junio 2013, presenta tres trabajos de investigación elaborados por técnicos de los departamentos del Banco de Guatemala, uno de ellos con el apoyo de **Andrew Pickering** de la Universidad de York.

Una tasa de interés natural variable en el tiempo para la economía guatemalteca es el aporte de **Hilcías Estuardo Morán Samayoa** en el que comienza señalando que el Banco de Guatemala estableció en 2005 un esquema de metas explícitas de inflación, el cual requirió establecer la tasa de interés de política a fin de propiciar ajustes necesarios en la tasa de interés real de corto plazo por arriba o por debajo de su nivel natural para contrarrestar perturbaciones que podrían poner en riesgo la estabilidad del nivel de precios. El autor parte de una metodología que utiliza el Filtro de Kalman, desarrollada por T. Laubach y J. Williams, para presentar los resultados obtenidos en la estimación de una tasa de interés real natural variable en el tiempo para la economía guatemalteca durante los últimos 15 años, utilizando como base un modelo macroeconómico pequeño; después utiliza la tasa natural real de interés estimada para evaluar el comportamiento de la política monetaria guatemalteca. Los resultados que obtiene indican que los períodos para los cuales la brecha de la tasa de inerés real, definida como la diferencia entre la tasa de interés real observada y la tasa natural real de interés estimada, fue significativamente negativa, y coinciden temporalmente con los períodos en donde la inflación de la economía guatemalteca fue relativamente alta (mayor que la meta de inflación establecida por el Banco de Guatemala).

Deidad maya que aparece en los billetes de veinte quetzales. Es una estilización elaborada por el pintor guatemalteco Alfredo Gálvez Suárez que tomó la figura representada en la página doce del Códice Maya, conservado en la biblioteca de Dresde, Alemania. Dicha figura fue identificada por los historiadores J. Antonio Villacorta C. y Carlos A. Villacorta en su libro *Códices Mayas* —impreso en la Tipografía Nacional de Guatemala en 1930— como "Dios E: con un vaso de plantas en las manos y una cruz en el adorno de la cabeza. Su signo está en el jeroglífico 2; representa la divinidad del maíz o de la agricultura, llamada *Yun Kax"*.

Oil shocks and monetary policy is the second paper where authors, **Andrew Pickering** and **Héctor Augusto Valle Samayoa,** investigate theoretic and empirically the response of monetary policy to oil prices; then oil is explicitly introduced as an input in the production process of a new keynesian stochastic dynamic general equilibrium model. They obtained the optimal policy response with different degrees of oil intensity, price flexibility, relative importance of output in the loss function and the degree of persistence of the oil shock. Pickering and Valle contribute in showing that the optimal response can be positive, previous literature has suggested that the optimal reaction to oil shocks is negative; furthermore, the degree of persistence of oil shock can also determine the optimal sign of the policy reaction. Another authors´ contribution is the analysis of the effect of the type of ARMA process that an oil shock follows; they found that the type of this process might determine the magnitude and duration of the impact of the shock, and consequently the optimal policy response; the policy response to oil shocks in practice is analyzed by estimating policy rules of the taylor type with explicit oil prices.

Oscar Leonel Herrera Velásquez and **Héctor Augusto Valle Samayoa** expose their paper *Guatemala: estimation of bank efficiency with a production approach through a panel data methodology.* The purpose of their research is to assess the efficiency of the Guatemalan banking system from 1997 to 2007 –period that comprises changes in the financial legal framework– by using the methodology "production approach" that involves the analysis of inputs and outputs in the production process. Herrera and Valle say that bank efficiency provides relevant information to monetary and financial authorities about economic growth and the degree of development of a country; these two variables are subject to the overall degree of efficiency of the financial system in general and banking services in particular. In this sense, authors indicate, banks do not only affect the behavior of savings and investment, facilitating the payments system, but also influence the global competitive dynamics. The distinction of efficiency in terms of outputs and inputs in a production process is important for them because it allows them to infer economies of scale. With this purpose, Valle and Herrera employ panel data econometrics for estimating and identifying economies of scale based on the analysis of trans-logarithmic functions.

Una tasa de interés natural variable en el tiempo para la economía guatemalteca[1]

Hilcías Estuardo Morán S.[2]

Resumen

El Banco de Guatemala estableció en 2005 un esquema de metas de inflación explícitas, el cual requirió establecer la tasa de interés de política a fin de propiciar ajustes necesarios en la tasa de interés real de corto plazo por arriba o por debajo de su nivel natural para contrarrestar perturbaciones que podrían poner en riesgo la estabilidad del nivel de precios. Partiendo de una metodología que utiliza el Filtro de Kalman, desarrollada por [6], este estudio presenta los resultados obtenidos en la estimación de una tasa de interés real natural variable en el tiempo para la economía guatemalteca durante los últimos 15 años, utilizando como base un modelo macroeconómico pequeño. Luego, la tasa natural real de interés estimada es utilizada para evaluar el comportamiento de la política monetaria guatemalteca. Los resultados obtenidos indican que los períodos para los cuales la brecha de la tasa de inerés real, definida como la diferencia entre la tasa de interés real observada y la tasa natural real de interés estimada, fue significativamente negativa, coinciden temporalmente con los períodos en donde la inflación de la economía guatemalteca fue relativamente alta (mayor que la meta de inflación establecida previamente por el Banco de Guatemala).

[1] Las opiniones expresadas en este documento son responsabilidad del autor y no necesariamente reflejan los puntos de vista del Banco de Guatemala. El autor agradece los valiosos comentarios y sugerencias de Carlos Castillo. Banco de Guatemala, septiembre, 2010.

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1. Introducción

A partir de la revolución teórica de los ciclos económicos reales con el trabajo de [4] y de la popularización de las reglas de política monetaria a partir de [9], resurge la tasa natural real de interés como un concepto fundamental en la teoría macroeconómica y monetaria. La tasa de interés natural o neutral, comunmente definida como la tasa de interés real de corto plazo que es consistente con el producto a su nivel potencial y con una tasa de inflación estable en ausencia de shocks transitorios de demanda y de oferta, proporciona un punto de referencia para medir la postura de política monetaria de un banco central. Si la tasa de interés real se ubica por encima de la tasa natural, se dice que la política monetaria es restrictiva y, si se ubica por debajo de la tasa natural, se dice que la política monetaria es expansiva. Por consiguiente, la tasa natural real de interés es un concepto potencialmente relevante para la toma de decisiones de la autoridad monetaria. Desafortunadamente, la tasa de interés natural es una variable no observable y por lo tanto, la misma debe de ser estimada.

En este artículo se presenta la estimación de forma conjunta de la tasa natural real de interés y de la brecha del producto para la economía guatemalteca durante los últimos quince años. El método utilizado es el Filtro de Kalman, con el cual se estima un modelo pequeño semiestructural parecido a esos comúnmente utilizados en la literatura moderna sobre economía monetaria. Los resultados muestran que los períodos en los cuales la brecha de la tasa de inerés real, definida como la diferencia entre la tasa real observada y la tasa natural estimada, fue significativamente negativa, coinciden temporalmente con los períodos en que la inflación guatemalteca fue relativamente alta (mayor que la meta de inflación establecida previamente por el banco central). Los resultados son robustos a cambios de especificación y calibración del modelo. Considerando las deficiencias estadísticas de países como Guatemala, este primer esfuerzo para la estimación de la tasa natural de interés debería de apreciarse como un intento de estimación de dicha variable en un ambiente de escasa información estadística, el cual también representa el inicio de una agenda de investigación más amplia sobre el tema en un futuro cercano.

La organización de este artículo es la siguiente: en la sección 2 se presenta el fundamento teórico del modelo semiestructural utilizado para la estimación tanto de la tasa natural de interés como de la brecha del producto. En la 3 se discuten los datos utilizados y la metodología de estimación. En la sección 4 se muestran los resultados más relevantes y la 5 ofrece las conclusiones.

2. Marco conceptual básico

2.1. Definición

La tasa natural real de interés (TNRI) se define como la tasa real de corto plazo que es consistente con el nivel potencial del producto (PIB) y con una tasa de interés estable en ausencia de shocks temporales de demanda. El PIB potencial, a su vez, es definido como el nivel de producto consistente con una inflación estable, en ausencia de perturbaciones temporales de oferta. Por lo tanto, la TNRI es la tasa natural de corto plazo consistente con una inflación estable, en ausencia de shocks transitorios de demanda y de oferta. En el corto plazo la brecha entre la TNRI y la tasa real observada puede ser diferente de cero porque, bajo el supuesto de la existencia de rigideces nominales en la economía, existen perturbaciones de demanda u oferta que pueden afectar la estabilidad de precios. Esta definición de la TNRI corresponde a una perspectiva de largo-plazo que se refiere al nivel de tasa de interés que prevalecería en los próximos cinco o diez años, después de la extinción de los efectos ya sea de un ciclo de expanción o de recesión económica. En la práctica, sin embargo, la TNRI es no observable y puede ser estimada sólo sobre la base de supuestos específicos y con un alto grado de incertidumbre. Esto dificulta la utilización de dicha variable como indicativa del estado de la política monetaria en tiempo real.

En el largo plazo, como es evidente, la TNRI se encuentra intimamente asociada con el nivel de la tasa natural del producto, la cual es también una variable no observable. La teoría económica sugiere que la tasa natural de interés varía en el tiempo como respuesta a cambios en las preferencias de los consumidores y en la tasa de crecimiento de la actividad económica. La maximización de la utilidad intertemporal de los hogares en un modelo clásico de crecimiento económico, sin crecimiento poblacional, genera la relación entre la tasa de interés real de equilibrio, r^* , y el crecimiento del producto per cápita, a, que se indica en la siguiente expresión:

$$r^*=\theta a + \rho \qquad (1)$$

donde $\theta \equiv 1/\sigma$ es la inversa de la elasticidad de sustitución intertemporal (σ), y ρ denota la tasa de preferencia temporal de los hogares. Tomando en cuenta que los determinantes de la tasa natural de interés son no observados, la metodología adoptada en este estudio combina un modelo macroeconómico pequeño y el Filtro de Kalman. Dicha metodología para la estimación conjunta de la tasa natural de interés y la brecha del producto (la diferencia entre el PIB observado y el PIB potencial en porcentajes) ha sido también utilizada en estudios recientes [6, 7, 1]. Cabe indicar que los modelos macroeconómicos son similares a los utilizados comunmente en economía monetaria [8, 2].

2.2. Especificación del modelo

Siguiendo la estrategia de identificación empleada por [6], la identificación econométrica de la tasa natural descansa en la especificación de una ecuación *IS* de forma reducida, similar a la utilizada por [8], donde la brecha del producto, Z_t, es determinada por sus propios rezagos y por los rezagos de la brecha de la tasa de interés real (la diferencia entre la tasa de interés real observada ex-ante, definida como $r_t = i_t - \pi_{t+1}$, y la tasa natural real, r^*). Adicionalmente, similar a [1], se incluye también como variable explicativa

[3] De conformidad con [10], los economistas debemos reconocer que en la práctica, el seguimiento perfecto de la tasa natural de interés es imposible, debido a que la información en tiempo real de la tasa natural es inevitablemente imprecisa.

el nivel de producto de los principales socios comerciales de Guatemala, y^f_t . Por lo tanto, la forma reducida de la ecuación de demanda agregada o "*curva IS*", en el período *t+1* es la siguiente:

$$Z_{t+1} = \phi(L)Z_t + \lambda(L)(i_t - \pi_{t+1|t} - r^*_t) + \delta(L)\, Y^f_t + \varepsilon^Z_{t+1}, \quad (2)$$

donde i_t es la tasa nominal de corto plazo y L representa el operador de rezagos. Por su parte, la expresión que representa a la oferta agregada, denominada comúnmente como "*Curva de Phillips*", relaciona la tasa de inflación, π_{t+1}, medida por el índice de precios al consumidor, con sus propios rezagos, con la brecha del producto rezagada, Z_t , y con la tasa de variación rezagada de los precios internacionales del diésel, variable que se utiliza como *proxi* de la inflación importada, m_t :

$$\pi_{t+1} = \alpha(L)\pi_t + \beta(L)Z_t + \gamma(L)m_t + \varepsilon^{\pi}_{t+1}, \quad (3)$$

donde, igualmente, L es un operador de rezagos. Una importante característica del modelo utilizado en este estudio es que la política monetaria únicamente afecta la inflación indirectamente a través de la brecha del producto. Además, cabe notar que la tasa de interés nominal de corto plazo es exógenamente introducida en el modelo, o dicho de otra manera, la función de reacción del banco central está implícita en la especificación del modelo. Las restantes ecuaciones que integran el modelo semiestructural para la estimación de la tasa natural de interés son las siguientes:

$$r^*_t = \mu_r + \theta a_t \quad (4)$$

$$a_{t+1} = \psi a_t + \varepsilon^a_{t+1} \quad (5)$$

$$\Delta Y^*_t = \mu_y + a_t + \varepsilon^y_{t+1} \quad (6)$$

$$Y_t = Y^*_t + Z_t \quad (7)$$

En las ecuaciones (2), (3), (5) y (6) ε^j_{t+1} para $j = z, \pi, y, a$, representa un vector de errores serialmente no correlacionados. La ecuación (4) representa la TNRI, dicha expresión es basada en la relación teórica de la TNRI y la tasa de crecimiento del ingreso per cápita especificada en (1). Similar a [7], como se indica en la expresión (6), la TNRI, r^*_t sigue un proceso autorregresivo de primer orden, *AR(1)*, y no un camino aleatorio como es asumido en [6].

Dicho proceso captura las variaciones de baja frecuencia en la tasa de crecimiento del producto potencial, lo cual también es aparente en la ley de movimiento especificada para la tasa de crecimiento del producto potencial, Δy^*_t , en la ecuación (6). Por consiguiente, se asume que tanto la TNRI, como la tasa de crecimiento del PIB potencial comparten la ley de movimiento. Además, la ecuación de la evolución del PIB potencial (6) incluye un componente estacionario (ε^y_{t+1}) que puede tomar en consideración otras fuentes de discrepancias, tales como shocks a las preferencias o cambios en la política fiscal. La ecuacion (7) es una simple definición, donde el producto en el período *t*, y_t , es igual a la suma del producto potencial, y^*_t, más la brecha del producto, Z_t. El conjunto de cuaciones (2)-(7) que definen el modelo semiestructural para la estimación conjunta de la tasa natural de interés y del producto potencial pueden ser representadas en forma de estado-espacio, donde las ecuaciones de medida son la "Curva de Phillips" (ecuación 3) y la tasa de crecimiento del producto (Δy_t).[4]

3. Metodología

3.1. Contexto

En esta sección se describe brevemente el contexto de la economía guatemalteca, los datos utilizados y el método de estimación. La política macromonetaria guatemalteca gradualmente ha transitado hacia un esquema de metas de inflación basada en una política cambiaria más flexible. Hasta finales de los años 80, del siglo XX, el tipo de cambio era fijado por el Banco de Guatemala, las tasas de interés reguladas y la política monetaria se centraba en el seguimiento de los agregados monetarios. Luego de experimentar en 1990 la tasa de inflación más alta de su historia y después de liberar tanto el mercado cambiario (noviembre de 1989) como las tasas de interés bancarias (agosto de 1989) y de operar aún bajo un esquema de metas monetarias, el Banco de Guatemala comienza a anunciar públicamente una meta de inflación, la cual es utilizada como guía para controlar el crecimiento de los agregados monetarios.[5] De esta manera, la tasa de inflación se estabilizó significativamente a partir de la

[4] La tasa de crecimiento se obtiene combinando (6) y (7) tal que $\Delta y_t = \Delta y^*_t + \Delta Z_t$.

[5] La meta de inflación se comienza a anuncia en 1991. En los primeros años se anuncia una meta puntual y a partir de 1995 se establece una meta rango.

segunda mitad de los años 90 (siglo XX). [6] A partir del año 2000 se inicia una transición gradual hacia un esquema de metas explícitas de inflación. Sin embargo, no es sino hasta el 2005 cuando el Banco de Guatemala anuncia públicamente el establecimiento formal de dicho esquema y se comienza a utilizar formalmente la tasa de interés de corto plazo como instrumento de política monetaria.

3.2. Datos

Para todas las estimaciones se utilizaron observaciones trimestrales de la economía guatemalteca que cubren el período a partir del primer trimestre de 1996 (1996Q1) hasta el primer trimestre de 2010 (2010Q1). El tamaño de la muestra y las variables seleccionadas para la estimación del modelo semiestructural descrito anteriormente fueron seleccionadas tomando en consideración dos criterios prácticos: disponibilidad y racionalidad económica o teórica. Las variables observadas incluyen: la tasa de inflación, la inflación importada, el PIB trimestral, el PIB de los principales socios comerciales de Guatemala y la tasa nominal de corto plazo. La inflación interanual trimestral (π_t) es medida como el cambio porcentual en el índice de precios al consumidor (IPC), la cual es publicada de forma periódica por el Instituto Nacional de Estadística. El índice de demanda agregada (IDA) se utiliza como proxi del PIB trimestral, el IDA es un idicador calculado como una agregación ponderada de las exportaciones totales, del consumo nacional e importado computado a partir del impuesto al valor agregado recolectado sobre el consumo nacional y sobre las importaciones de bienes y servicios y obtenido de la Superintendencia de Administración Tributaria (SAT).[7] La inflación importada es aproximada utilizando los precios internacionales del diésel convertidos a moneda nacional por el tipo de cambio nominal (cantidad de quetzales por un dólar de los Estados Unidos de América) y el PIB de los principales socios comerciales es aproximado utilizando el PIB de los Estados Unidos de América.[8] Finalmente, como *proxi* de la tasa nominal de corto plazo se utiliza la tasa promedio ponderada activa del sistema bancario nacional. Dicha tasa es calculada tomando como ponderación los montos de crédito en moneda nacional otorgados por los bancos del sistema. Cabe señalar que la mayor cantidad de créditos corresponden a créditos de corto plazo. La tasa real de interés ex-ante, r_t, es calculada restando de la tasa de interés nominal del período corriente la tasa de inflación un período adelantado estimada por el modelo, $\pi^e_{t+1|t}$.[9] Cabe indicar que todas las variables, excepto la tasa de interés, fueron ajustadas estacionalmente.

Considerando las deficiencias estadísticas de países como Guatemala, este primer esfuerzo para la estimación de la tasa natural de interés debería de apreciarse como un intento de estimación de dicha variable en un ambiente de escasa información estadística, el cual representa un primer paso de un proceso continuo de mejora a través de la construcción e incorporación de nuevas y más confiables estadísticas.

3.3. Estimación

El sistema de ecuaciones (2)-(7) puede ser escrito en forma estado-espacio, y los parámetros del modelo pueden ser estimados maximizando la función de versimilitud del Filtro de Kalman. Este filtro consiste en un algoritmo recursivo que posibilita la estimación de variables no observadas. Dado un conjunto de ecuaciones de medida y de transición, el Filtro de Kalman proporciona el mejor estimador insesgado lineal de las variables de estado. Particularmente, las ecuaciones de la brecha del producto, Z_t, y de la tasa de crecimiento de la productividad, a_t, conforman las ecuaciones de transición, mientras que la "Curva de Phillips", π_t, y la tasa de crecimiento del producto, y_t, confroman el sistema de ecuaciones de medida. Una característica particular de este método de estimación es que permite cuantificar la incertidumbre alrededor de las variable estado estimadas.[10]

[6] De una inflacción anual de 59.8% alcanzada en 1990, la inflación guatemalteca pasó a una tasa de inflación anual promedio de 7.8% entre 1995 - 1999.

[7] Las ponderaciones para el cálculo del IDA son tomadas de la estructura del PIB.

[8] Los Estados Unidos de América es el principal socio comercial de Guatemala, la proporción que representa dicho país en el comercio exterior de Guatemala es de más del 50%.

[9] Para el cómputo de la inflación esperada, $\pi^e_{t+1|t}$ se utilizaron los parámetros estimados obtenidos por el Filtro de Kalman para construir la serie de la inflación estimada o ajustada por el modelo. Luego se utiliza esa serie de inflación un período adelante para obtener la tasa real de interés ex-ante. Esta metodología de cálculo es similar a la utilizada por (7).

[10] Ver [3] y [5] para una revisión de los modelos estado-espacio y del Filtro de Kalman con aplicaciones.

La estimación por máxima verosimilitud sin restricciones o libre del modelo tiene dos problemas potenciales ampliamente discutidos por [7]. Dichos problemas se producen porque la estimación del modelo es altamente inestable, lo que afecta la predictibilidad y confiabilidad de los parámetros estimados. El primer problema da inicio con la estimación del parámetro θ de la ecuación (4). La dificultad para estimar dicho coeficiente aparece porque el mismo relaciona dos variables no observadas, lo cual hace la estimación inestable y en muchos casos estadísticamente no significativa. Un segundo problema se produce al estimar las desviaciones estándar, ya sea σ_z o σ_y, debido a que su valor tiende a cero. En este caso, como puede observarse en la columna (3) de la Tabla 1, el valor estimado de σ_z es igual a cero. Esto podría sugerir que los shocks idiosincráticos al producto potencial son difíciles de distinguir de los shocks trasitorios al producto, lo cual es consistente con el hecho de que regularmente la brecha del producto es altamente persistente.

Para resolver esos problemas de estimación, en este trabajo se sigue la misma estrategia utilizada en trabajos precedentes [6, 7]. La estrategia consiste en combinar la estimación y la calibración de los coeficientes cuando se estima el modelo semiestructural en su conjunto. De esta forma, los parámetros θ y la relación σ_y / σ_z, son calibrados, mientras que el resto de coeficientes del modelo son estimados optimizando la función de máxima verosimilitud del Filtro de Kalman. Cabe indicar que los valores seleccionados para dichos parámetros son basados en dos criterios: primero, que sean consistentes con la evidencia empírica;[11] y, segundo, que generen como resultado la mejor aproximación posible a los datos guatemaltecos. De esta manera, el valor seleccionado para la relación σ_y / σ_z, es igual a 0.5, el cual es similar al valor utilizado por [7], mientras que para θ se utilizan dos valores dintintos, $\theta = 6$ y $\theta = 16$, los cuales son reportados en las columnas (1) y (2) de la Tabla 1, respectivamente.[12]

La estimación del sistema de ecuaciones también requiere la selección adecuada del número de rezagos que deben incluirse como regresores en las ecuaciones de demanda y de oferta agregada (ecuaciones 2 y 3). Los rezagos incluidos son aquellos que resultaron estadísticamnete significativos después de estimar las variables dependientes utilizando el Filtro de Hodrick y Prescott (HP) para calcular la brecha del producto y la brecha de la tasa de interés real. De esta manera, para estimar la "curva IS" derecho se consideró el primer rezago de la brecha del PIB guatemalteco, el primer rezago del PIB de los Estados Unidos de América y el cuarto rezago de la brecha de la tasa de interés real. Es importante resaltar que la falta de significancia estadística de los hecho rezagos 1 al 3 de la brecha de la tasa de interés real podría indicar que los efectos de la política monetaria sobre la brecha del producto son relevantes solo después de un año de aplicado el shock monetario. Esto último es un resultado esperado si se considera el bajo nivel de desarrollo mercado financiero y de capitales de la economía guatemalteca pues, por ejemplo, para la Zona del Euro, [7] encuentran que la política monetaria afecta al producto con sólo un trimestre de rezago. Por su parte, para la estimación de la "Curva de Phillips" se incluyeron como variables explicativas la inflación rezagada un período, el primer rezago de la brecha del producto y el primer rezago de la inflación importada.

[11] Ver [7].

[12] Los estudios empirícos citados por [7] reportan un intervalo de valores para θ de entre 0 y 20.

4. Resultados

Los resultados númericos obtenidos de las estimaciones alternativas de los parámetros por el método del Filtro de Kalman se reportan en la Tabla 1. La primera y segunda columnas muestran los resultados de las estimaciones del modelo utilizando una calibración de 0.5 para el parámetro σ_y / σ_z. Sin embargo, los resultados de la primera columna se basan en un valor de 6 para el parámetro θ, mientras que los resultados de la segunda columna se basan en un valor de 16 para dicho parámetro. Las estimaciones de la tasa natural real resultantes de ambas estimaciones se muestran en las Figuras 1 y 2. Por su parte, la tercera columna presenta los resultados de las estimaciones del modelo sin restricciones. A pesar de que se realizó un mayor número de estimaciones, en la Tabla 1 se presentan únicamente las que generaron una estimación aparententemente más consistente con la serie de la tasa de interés real de la economía guatemalteca.

Los parámetros de transmisión de la política monetaria muestran los signos esperados, mientras que la asociación entre la inflación, π_t, y la brecha del producto rezagada un período, z_{t-1}, es positiva en la estimación de la "Curva de Phillips", la cual es dada por el valor de β. La relación entre la brecha del producto, Z_t, y la brecha de la tasa de interés real rezagada cuatro períodos es negativa, esta úlitma asociación es reflejada por el valor de λ en la Tabla 1. Nótese que el estimador de λ no es estadísticamente significativo tanto en las estimaciones cuando $\theta=6$ como cuando $\theta=16$, lo que podría estar indicando un débil canal de transmisión de la política monetaria a través de la tasa de interés. Por consiguiente, un análisis empírico más profundo es requerido para verificar o desestimar este último resultado.

4.1. Análisis retrospectivo de la política monetaria guatemalteca

En esta sección se analiza la política monetaria guatemalteca de forma retrospectiva a partir de 1998, utilizando como base para el análisis la tasa natural real de interés (TNRI) estimada a partir de los resultados de la columna (1) en la Tabla 1 (es decir, cuando $\sigma_y/\sigma_z=0.5$ y $\theta=6$,). La Figura 1 muestra la evolución de la tasa natural real de interés conjuntamente con la tasa de interés real observada y el intervalo de confianza al 95% de los estimadores de las variables estado. La brecha entre la tasa real de interés observada y la TNRI representa un indicador del estado de la política monetaria. Cuando dicha brecha es positiva significa que la política monetaria busca desacelerar la tasa de inflación corriente, mientras que cuando es negativa indica que el banco central está dispueto a permitir un incremento en la inflación corriente.

De acuerdo con las estimaciones de la TNRI (las cuales toman en cuenta la incertidumbre asociada con las variables de estado) y de la tasa real observada durante el período 1998Q1-2010Q1, la política monetaria guatemalteca parece haber sido significativamente expansiva durante los siguientes períodos: 1) del segundo semestre de 2001 a los primeros tres trimestres de 2002; 2) durante el período 2004-2006; y 3) durante el segundo semestre de 2007 y los primeros tres trimestres de 2008. Es importante notar que los períodos de política monetaria expansionista coinciden efectivamente de forma contemporánea con los períodos de relativamente alta inflación. Esto último puede apreciarse claramente en la Figura 3, donde la tasa de inflación en los tres subperíodos mencionados alcanzó niveles mayores al 7%, lo que significó desvíos importantes de la inflación observada respecto de las metas de inflación previamente establecidas por el Banco de Guatemala.[13] La tasa de interés real parece haber sido similar, en términos estadísticos, a la TNRI en el período comprendido entre 1998 y el primer semestre de 2001, a partir del cuarto trimestre de 2002 hasta finales de 2003 y a partir del cuarto trimestre de 2008. Tratando de determinar los efectos de la crisis financiera internacional sobre la actividad económica guatemalteca y a la luz de estos resultados, es decir del comportamiento de la política monetaria en los trimestres previos a la crisis y durante el inicio de la crisis, parece ser que el hecho de haber tenido una política monetaria relajada, entre otros factores, contribuyó a amortiguar los efectos negativos de la crisis global. En efecto, mientras otros países de la región de América Latina como México, Costa Rica y El Salvador experimentaron fuertes caídas en su tasa de crecimiento económico en el año 2009 (-7.3%, 1.5% y 2.7%, respectivamente),[14] Guatemala creció 0.4% en el mismo año.

Las estimaciones de la brecha del producto (la primera diferencia del logaritmo natural del PIB observado menos el logaritmo natural del PIB potencial en porcentajes) utilizando los resultados obtenidos por el método del Filtro de Kalman aplicado en este estudio y los obtenidos de aplicar un simple Filtro de Hodrick-Presscot (HP) se muestran en la Figura 4. Asimismo, se muestran el intervalo al 95% de confianza de la estimación de la brecha del producto por medio del primer método. Como se mencionó, una ventaja importante de estimar las variables no observadas utilizando una combinación de un modelo pequeño semiestructural y el método del Filtro de Kalman es que se puede obtener el grado de incertidumbre asociado a las variables estimadas. En efecto, la brecha del producto obtenida utilizando el Filtro HP indica que la brecha fue positiva durante los períodos 1998-2001 y 2006Q1-2008Q3; y por eliminación dicha variable fue negativa para el resto de subperíodos incluidos en el análisis. Sin embargo, cuando se observa el comportamiento de la brecha del producto utilizando el método del Filtro de Kalman se puede apreciar que dicha variable fue significativamente positiva solo en dos períodos relativemente cortos. Esos períodos son: el año 2001 y del cuarto trimestre de 2006 al segundo trimestre de 2008 y el resto de subperíodos parece ser que el producto potencial no fue estadísticamente diferente del producto observado. De esta manera, el utilizar filtros univariados,

[13] A partir de 2001 la meta rango de inflación objetivo ha estado entre 4% y 6%, excepto en 2008 que se ubicó entre 4% y 7%.

[14] La fuente para estos datos es: International Monetary y Fund, World Economic Outlook Database, October 2009.

como el de HP, puede conducir a conclusiones erróneas sobre el comportamiento de la brecha del producto, lo cual obedece a que tales métodos ignoran la incertidumbre asociada con las variables estimadas, lo cual también aplica a la estimación de la tasa natural de interés.

5. Conclusión

El estudio estimó la tasa natural de interés conjuntamente con la brecha del producto utilizando el Filtro de Kalman. La tasa natural real de interés muestra variaciones significativas durante los últimos quince años, con una tendencia a la baja. Este resultado puede originarse por una política macroeconómica, tanto monetaria como fiscal, más ordenada y menos volátil. Además, las estimaciones de la TNRI permitieron identificar los distintos estados de la política monetaria de forma restrospectiva, apreciándose una política monetaria relajada tanto en los momentos previos a la crisis financiera internacional como en los trimestres iniciales de dicha crisis. Dicho comportamiento podría haber contribuido a suavizar los efectos negativos de la misma crisis sobre la actividad económica guatemalteca. Asimismo, se mostraron los potenciales problemas que surgen cuando se estiman variables no observadas utilizandos series univariadas, los cuales pueden llevar a toma de decisiones erróneas. De esta manera, surge la necesidad de emplear modelos semiestructurales combinados con técnicas que permitan cuantificar la incertidumbre asociada con las estimaciones de las variables estado o variables no observadas. Esto último se ilustró utilizando la estimación de la brecha del producto por los filtros HP y de Kalman. Las estimaciones que se presentaron en este documento son robustas a cambios de calibración y especificación del modelo semiestructural. Sin embargo, tomando en cuenta las deficiencias tanto en calidad como cantidad estadísticas disponibles para Guatemala que permitan profundizar en el análisis empírico de la tasa natural de interés, se considera que la evidencia empírica desarrollada en este estudio es sólo el primer paso hacia una agenda de investigación futura.

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Tabla 1: Parámetros estimados del Modelo Semiestructural

Parámetro	Calibración (1)	Calibración (2)	Sin Restricciones
	$\theta = 6$ y $\sigma_y/\sigma_z = 0.5$	$\theta = 16$ y $\sigma_y/\sigma_z = 0.5$	
	(1)	**(2)**	**(3)**
α	0.8395***	0.832***	1.0538***
	(0.0809)	(0.0835)	(0.1962)
γ	0.0532***	0.0525***	0.0688*
	(0.0172)	(0.0166)	(0.0405)
β	0.2939*	0.2302	0.6367**
	(0.1587)	(0.1781)	(0.3087)
ϕ	0.8071**	0.8263***	0.2936
	(0.2858)	(0.3021)	(0.4931)
λ	-0.0797	-0.0634	-0.2148
	(0.1172)	(0.1682)	(0.3224)
μ_r	14.363	17.3964	20.1318
	(13.8243)	(29.6171)	(19.9878)
ψ	0.6938	0.6706	1.1643***
	(0.5245)	(0.7575)	(0.1439)
μ_y	0.9852**	0.8612**	2.1462***
	(0.4683)	(0.4098)	(0.4371)
δ	0.3937	0.4284	-2.1538
	(0.8282)	(1.0824)	(1.6182)
σ_π	1.0810	1.1166	1.2188***
	(1.1620)	(1.1562)	(0.436)
σ_a	0.6049	0.6003	0.6021
	(3.0961)	(7.1164)	(1.8255)
θ	6	16	16.4369
			(21.3624)
σ_z	3	3	0.0000
			(1200)
σ_y	1.5	1.5	0.9263
			(1.6740)
Log likelihood	-173.6920	-173.0179	-205.6210

Fuente de los datos: Cálculos propios *significante al 10%, **significante al 5%, ***significante al 1%

Figura 1: Tasa natural real de interés (r^*) cuando $\theta = 6$ y $\sigma_y / \sigma_z = 0.5$ y tasa real observada

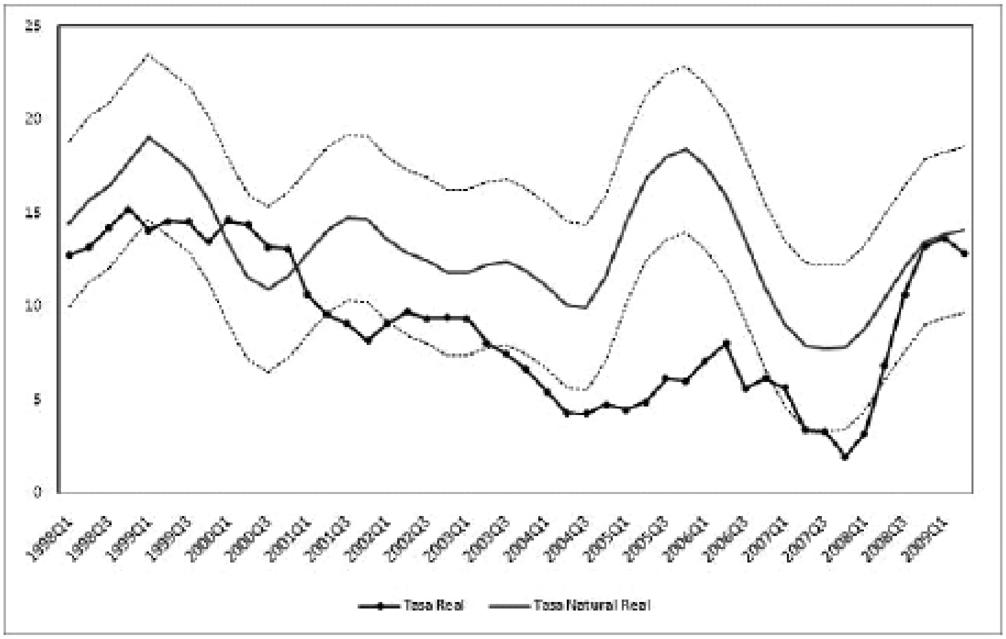


Figura 2: Tasa natural real de interés (r^*) cuando $\theta = 16$ y $\sigma_y / \sigma_z = 0.5$ y tasa real observada

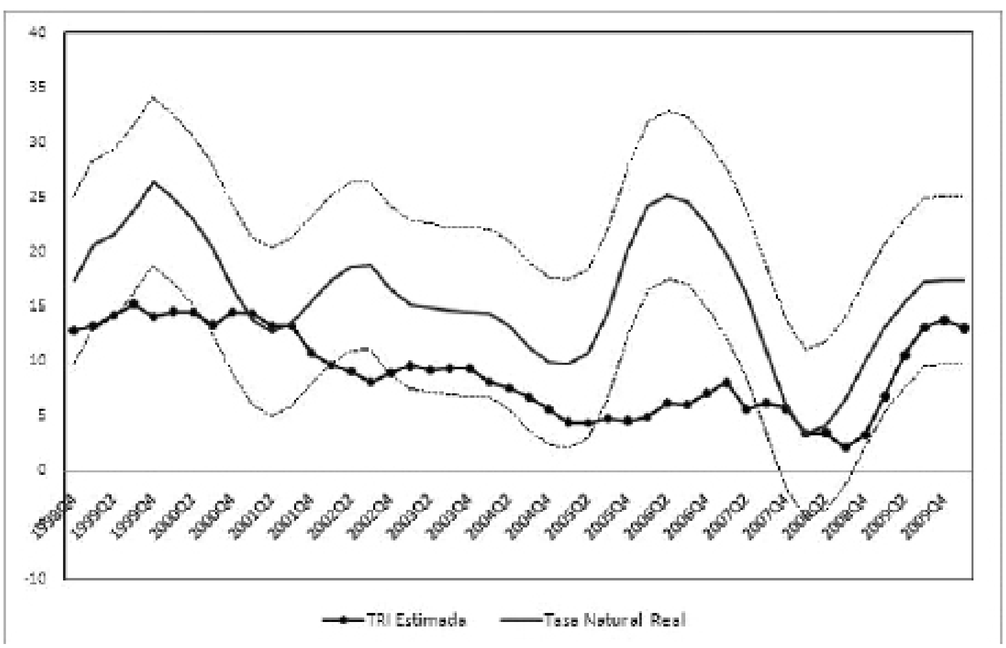


Figura 3: Tasa de inflación interanual (π_t)

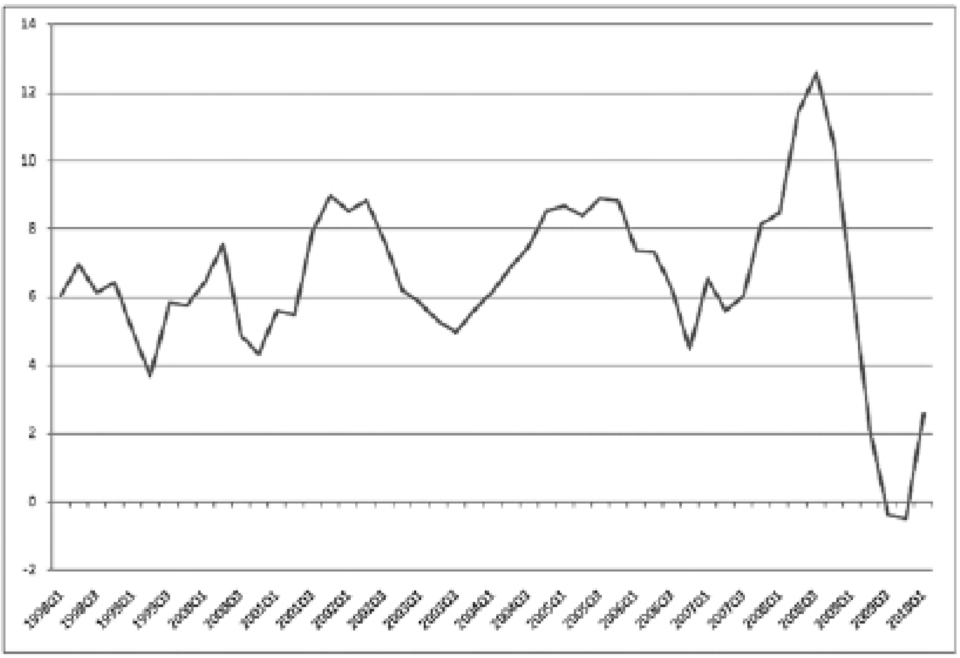
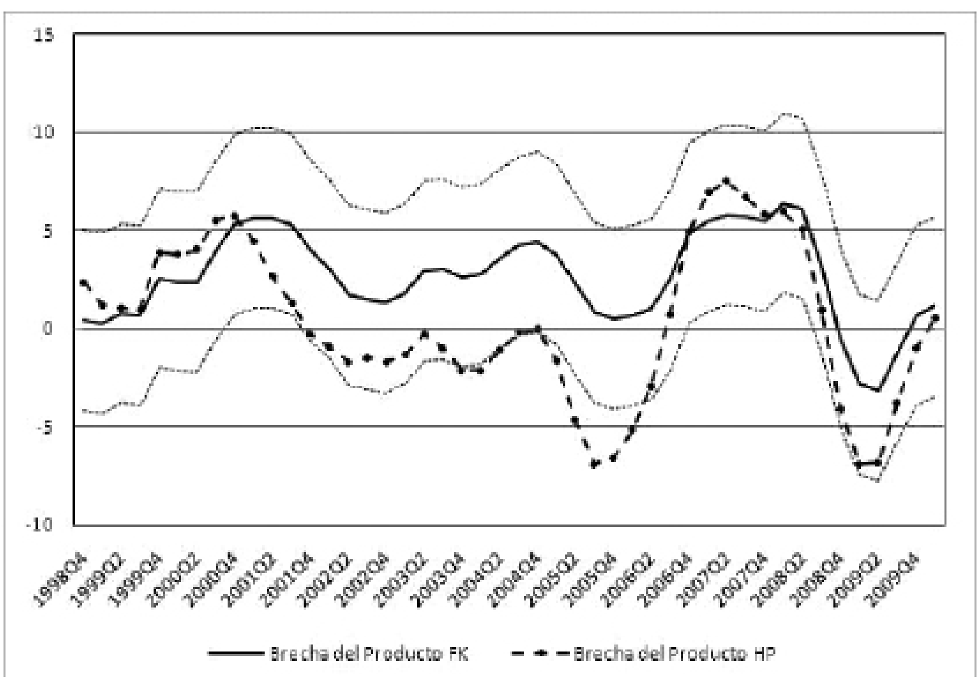


Figura 4: Brecha del producto utilizando el Filtro de Kalman (FK) y el Filtro HP



Oil shocks and monetary policy

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Abstract

This paper investigates the response of monetary policy to oil prices both theoretically and empirically. Oil is explicitly introduced as an input in the production process of a New Keynesian stochastic dynamic general equilibrium model. The optimal policy response is obtained with different degrees of oil intensity, price flexibility, relative importance of output in the loss function and the degree of persistence of the oil shock. The paper contributes in showing that the optimal response can be positive, previous literature has suggested that the optimal reaction to oil shocks is negative.

Furthermore, the degree of persistence of the oil shock can also determine the optimal sign of the policy reaction. The analysis of the effect of the type of ARMA process that an oil shock follows is another contribution of this paper. It was found that the type of this process might determine the magnitude and duration of the impact of the shock, and consequently the optimal policy response. The policy response to oil shocks in practice is analyzed by estimating policy rules of the Taylor type with explicit oil prices.

1. Introduction

This paper investigates the response of monetary policy to oil prices. Macroeconomic fluctuations, in the shape of recessions and high inflation have been linked to oil-price shock in the economic literature. Whether it is the initial surges in oil prices, or the subsequent monetary policy response that causes these non-desirable economic events, is not still completely clear. What is clear is that the way the central bank responds to these shocks is of paramount importance. It might actually trigger the crisis, deepen it or, if implemented ideally, ameliorate it or even prevent it.

Should a central bank firmly committed to low and stable inflation, react strongly to oil prices as it does with headline inflation? Or should it respond less than proportionally, not respond at all or accommodate oil prices decreasing the interest rate instead, as some have suggested? Moreover, what historically has actually been the systematic policy response to oil prices and shocks?

Oil-price shocks are different in nature to other price shocks. They are ostensibly exogenous caused by political events (wars or the risk of them). A central bank pledged to low inflation normally reacts by increasing interest rates by more than one to one to inflation shocks (Taylor, 1993). However, this is at the expense of sacrificing economic growth. This policy succeeds in the case of domestic (demand-pull) inflation, because it dampens expectations of higher inflation. But given the particular characteristics of oil shocks, should the monetary authority react in the same form? The hike in oil prices reduces output because it becomes more expensive to produce, and the increase in the interest rate adds to production costs reducing output even more.

This paper deals with these questions. It builds on Pickering and Valle (2008) where oil is explicitly introduced, in

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addition to labor, as an input in the production process of a New Keynesian stochastic dynamic general equilibrium model. This represents an extended production function to the one in Clarida, Galí and Gertler (2000) in which labor is the only input.

Oil shocks are simulated in the model to estimate the optimal policy response with different degrees of oil intensity, price flexibility, relative importance of output in the loss function and the degree of persistence of the oil shock. In this sense, the contribution of this chapter is to show that the optimal policy response can also be positive. Previous literature has suggested that the optimal reaction to oil shocks is negative (cutting interest rates), and this type of optimal response is in fact also found here. Nonetheless, it is also found that under certain circumstances the optimal response can be positive (increasing interest rates). Furthermore, the persistence of the oil shock can also determine the optimal sign of the policy reaction.

The analysis of the effect of the type of ARMA process that an oil shock follows is another contribution of this chapter. ARMA processes are identified for different samples of the actual oil price series and simulated in the model. It was found that the type of this process might determine the magnitude and duration of the impact of the shock and consequently the optimal policy response. The results suggests that when a shock is purely characterized by an autoregressive process the central bank reaction should be stronger than when the shock follows a moving average process.

Finally, the policy response to oil shocks is estimated based on policy rules of the Taylor type with explicit oil prices. They are estimated for the periods 1960-1979, 1979-1996 and 1979-2007 in the United States. The first two periods represent two different monetary policy regimes (as documented by Clarida, Galí and Gertler, 2000), and the third one constitutes an update. It turns out that the reaction of the Federal Reserve to oil shocks was, in general, small, positive and statistically significant in the first two periods. However, the results suggest that this response has tended to become insignificant in the most recent period.

The ARMA oil price process of the oil shock was also taken into account in this analysis. There is some evidence that oil shocks followed an AR, ARMA and MA processes respectively to the samples. This suggests that the policy response to oil shocks should have been stronger in the first spell and that it can afford to be weak in the last one.

Some of the most relevant literature regarding the effect of oil prices on the economy and the appropriate policy response is reviewed in the second part of the chapter. In the third part, a dynamic stochastic general equilibrium model is employed to perform oil shocks simulations. The fourth part describes in detail the estimation of the monetary policy rules. Section five concludes.

2. Literature review

The effects of oil-price shocks on the economy have been the focus of a large amount of research. Oil shocks have been linked to recessions, stagflation and increased macroeconomic volatility. The economic literature provides clear statistical evidence of the relationship between oil shocks and key macroeconomic variables, but also questions whether the oil price hikes that, more often than not, have preceded economic downturns are merely coincidental or indeed whether it is policy responses to oil shocks which exacerbate the macroeconomic effects.

This section examines some of the most influential literature on the oil and macroeconomy relationship. First, the effect of oil shocks on the economy are discussed. In the second part the role of monetary policy in the context of oil shocks is examined. Part three is about the optimal response to oil shocks with Taylor type rules.

2.1 The oil price - macro relationship

2.1.1 Introduction

This subsection first brings up the discussion on whether and how oil shocks have indeed affected the economy. Then definitions and asymmetric effects of oil shocks are discussed in the second part. Finally, the evolution of the impact of oil shocks is reviewed in part three.

2.1.2 Oil shocks, monetary policy response and economic downturns

Hamilton (1983) points out that all but one of the U.S. recessions since World War II have been preceded by a surge in oil prices. In search for an explanation, he considers three hypotheses, 1) it is a mere coincidence,

2) there is a third set of variables that causes both rises in oil prices and recessions, and 3) some of the recessions were in fact caused by exogenous increases in the price of crude petroleum. Using Granger causality tests Hamilton found that oil prices are statistically informative about the future state or performance of the economy, i.e. output, employment, inflation and money; but that the opposite is not true (the macroeconomic variables do not Granger cause oil prices). The Granger causality analysis used United States data from 1948 to 1972, to avoid structural breaks originating from the different arrangements under which the price of oil has been determined (i.e. pre-and post-OPEC).

Extending the Granger-causality regression, Hamilton analyzes output as a function of an indefinite number of lags of only oil prices[1]. The estimated coefficients suggest that typically an increase in oil prices was followed 3 to 4 quarters later by slower output growth, with a recovery beginning after 6-7 quarters. Moreover looking for robustness, the relationship between output and oil was also evaluated for the extended period 1973-1980, and indeed this later period is also characterized by a statistically significant relationship between oil prices and real GDP, i.e. oil prices again Granger-cause real GDP. Also, the relationship of output to oil-prices lags depicts a similar pattern, 4 quarters of slower growth and recovery at the fifth. Nevertheless, the magnitude of the lag coefficients is smaller in the second subsample (1973-1980). As it is shown in Table 4.1, the cumulative effect of four lags of oil prices over quarterly changes in log of real GNP, is -1.039 in the first subsample and -0.461 in the second. Hence, even though there appear to be similar dynamics across the two periods, there are smaller coefficients on the oil price for the later period.

[1] This is obtained by inverting the autoregressive lag polynomial in the bivariate four-lag regression of the Granger-causality test (four oil lags and four output lags).

Table 4.1. Results from Hamilton (1983)

Sample	1949:2-1972:4	1973:1-1980:3
Constant	0.011***	0.023***
	(0.0016)	(0.0050)
y_{t-1}	0.19*	0.20
	(0.097)	(0.18)
y_{t-2}	0.15	-0.64***
	0.097	(0.20)
y_{t-3}	-0.49***	-0.088
	(0.097)	(0.20)
y_{t-4}	-0.28***	-0.34*
	0.092	(0.19)
o_{t-1}	-0.61***	-0.23***
	(0.056)	(0.028)
o_{t-2}	-0.082	-0.038
	(0.056)	(0.028)
o_{t-3}	-0.170***	-0.078***
	(0.057)	(0.030)
o_{t-4}	-0.177***	-0.115***
	(0.059)	(0.033)
Sample Size	95	31
F-statistic	5.55	5.71
p-value	0.0005	0.003

Notes:
y_t denotes quarterly changes in log of real GNP, o_t denotes quarterly changes in nominal end-of-period crude oil prices. Standard errors of coefficients are in parentheses. Significant at 1% (***), significant at 5% (**), significant at 10% (*).

Because of the high rates of inflation occurring between 1973 and 1980, Hamilton suggests that the response of output to the same oil price increase might be smaller during inflationary times than in noninflationary times.

Since oil prices consistently Granger-cause output and oil prices are not caused by the other macroeconomic variables, hypotheses 1 and 2 are rejected by Hamilton. As for hypothesis 3, he does not conclude that oil prices alone necessarily triggered the recessions, but he does argue that the dramatic increase in oil prices affected the magnitude and duration of them.

2.1.3 The asymmetry of oil-shocks effects

Mork (1989) argues that the effect of oil prices on output is asymmetric. He indicates that Hamilton's (1983) findings pertain to a period when all the large oil price movements were upward, and so it is not clear whether a decline in oil prices would have a significant effect on output. Mork then investigates separately the effect of positive and negative oil shocks on output, including the price falls of the 1980s. He based his empirical work on the Sims's (1980) six-variable vector autoregressive model, which includes: GNP growth, GNP deflator, the deflator of imports, average hourly earning for production workers in manufacturing, real GDP and the 90-day Treasury bill rate (or M1 alternatively). The data is quarterly and the sample 1949:1-1988:2. Mork augments the six-variable model with three alternative oil-price variables (oil prices with positive and negative realizations, positive realizations only and negative realizations only) and their individual statistical significance are tested. Out of the three series tested, the one with increases only was the only variable whose four lags are negative and significant. The coefficients for price declines, are smaller, insignificant and of varying signs. Mork concludes then that the relationship between GNP and oil prices is asymmetric, and that there is indeed a negative correlation between GNP and oil prices increases but the correlation with price decreases is not significantly different from zero.

The relationship between oil and macroeconomic variables investigated by Hamilton (1983) may have evolved over time. Hooker (1996) argues that oil prices no longer Granger cause many U.S. macroeconomic indicator variables in data after 1973. Based on Hamilton's historical analysis of oil market arrangements, he splits the data into two subsamples 1948- 1973 and 1973-1994. The asymmetric effect of oil prices is introduced according to Mork's definition, i.e. the oil-price variable accounts for price increases only, price decreases are regarded as zero (no price change). He argues that the effect of oil prices on the economy has dramatically decreased. Despite larger changes in oil prices in the later subsample, oil prices apparently did not have a statistically significant impact on unemployment or real GDP. In particular, the null hypothesis of "oil prices do not Granger cause GDP (or employment)" can be rejected at 5% of significance level for the early subsample, but it cannot be rejected at any conventional level in the later one.

Hamilton (1996) responds to Hooker (1996) theorizing about the nature of the asymmetry of the effects of oil prices and coming up with a new measure of oil shocks. He reasons firstly, as Hooker does, and following Mork (1989) that the effects of oil prices on the economy are not symmetric. Increases in oil prices are related to decreases in output but the opposite is not true; decreases in oil prices are not accompanied by a rise in output. Hamilton argues that this is because adverse oil shocks affect the economy by depressing demand for key non-durable consumption and investment goods (energy-using goods). Investment decisions are postponed for concern of future prices and availability of energy. This in turn depresses demand and contracts the economy. The rationale provided by Hamilton (1988) is that the change in demand from energy intensive goods to energy saving goods caused by an oil shock generates a reallocation of production. This transition does not take place smoothly and generates costs and unemployment associated with the investment in new machinery and relocation of workers. On the other hand, the positive effect on output of falling oil prices (lower production costs) is offset by these same transition costs. In this case the costs cancel the positive effect of oil prices on output instead of reinforcing them.

Hooker took into account this asymmetry but Hamilton secondly points out that most of the oil price increases between 1986 and 1992 have immediately followed even larger decreases. Essentially, many of the individual price increases observed since 1986 were simply corrections to earlier declines. These types of price adjustments are unlikely to affect spending decisions. Instead of using Mork's series, which is based on quarterly price changes, Hamilton (1996) proposes the use of what he calls the net price increase. This compares the price of oil each quarter with the maximum value observed during the preceding four quarters. If the values for the current quarter exceeds the previous year's maximum, the net price increase is positive.

If the price of oil in quarter t is lower than it was at any point during the previous four quarters, the series is defined to be zero for date t. Hamilton (1996) then replicated Hooker's regressions using the original price series and his modified net oil price increase. He reports that for the first subsample 1948:I to 1973:III, it makes little difference whatever series is employed. Both series reveal a highly significant and negative relation to GDP. Nonetheless, contrasting with Hooker's findings, when the full sample from 1948:I to 1994:II is used, the relation between GDP growth and net oil price increases is still statistically significant when the net price increase variable is used. The null hypothesis of no-Granger causality can be rejected at 1% and 5% significance in each period respectively.

Hamilton therefore concludes that the weakening of the statistical relationship between output and oil prices since 1985, is due firstly to a non-linear relationship: oil price increases affect the economy whereas decreases do not, and secondly increases that come after a long period of stable prices have a bigger effect than those that simply correct previous decreases.

As further evidence, albeit anecdotal, Hamilton points out that the biggest shock in this series, originated by the invasion of Kuwait by Iraq, coincides with the first recession in the United States since the recession that followed the Iran-Iraq war in 1980.

2.1.4 Oil shocks in the 2000s

Blanchard and Galí (2008) (BG) identify differences in the observed response of the macroeconomy to oil shocks in the 2000s compared with the 1970s. Hamilton's study discussed above covers up to 1994, and BG find that the oil shocks of 1999 and 2002 induced smaller responses of output and inflation compared with shocks of similar magnitude in the 70s. They define a large oil shock as "an episode involving a cumulative change in the (log) price of oil above 50 percent, sustained for more than four quarters". BG analyze four episodes starting in 1973 (O1), 1979 (O2), 1999 (O3), and 2002 (O4). They examined the change in inflation and the cumulative change in GDP growth in the eight quarters following the shock compared with the eight quarters that preceded it, for the G-7 countries individually and the three aggregates G7, euro-12 and OECD. Their findings are presented in Tables 4.2 and 4.3. As can be seen in the average columns, AVG(1,2) and AVG(3,4), there is clear evidence of much weaker response of prices and output in the 1999 and 2002 episodes, in all cases. They argue that other non-oil shocks coincided with the oil shocks, either reinforcing (in the 70s) or dampening them (in the most recent cases). Due to the partial identification strategy, they do not identify the exact nature of these other shocks, although they give some evidence that increases in other commodity prices were important in the 1970s. In general, their findings are supported in vector autoregression analysis and rolling bivariate regressions.

Table 4.2. Oil Shock Episodes: Change in Inflation
Blanchard and Galí (2008)

	O1	O2	O3	O4	AVG(1,2)	AVG(3,4)
Canada	4.7	1.8	2.2	0.5	3.3	1.4
Germany	0.1	2.6	1.1	-0.2	1.4	0.4
France	5.4	3.1	1.3	0.5	4.2	0.9
U.K.	10.2	4.3	0.0	0.5	7.3	0.3
Italy	7.7	5.6	1.0	-0.1	6.6	0.4
Japan	7.9	1.0	-1.7	0.9	4.4	-0.4
U.S.	4.9	4.0	1.7	-0.2	4.5	0.7
G7	4.8	1.9	0.3	0.0	3.3	0.2
Euro 12	4.3	2.7	1.3	-0.5	3.5	0.4
OECD	4.9	1.8	0.1	-0.5	3.4	-0.2

Table 4.3. Oil Shock Episodes: Cumulative GDP Change
Blanchard and Galí (2008)

	O1	O2	O3	04	AVG(1,2)	AVG(3,4)
Canada	-8.3	-1.0	-1.5	3.2	-4.6	0.8
Germany	-9.6	-3.5	1.3	-2.5	-6.6	-0.6
France	-7.6	-4.4	0.6	1.2	-6.0	0.9
U.K.	-16.4	-9.2	0.4	2.5	-12.8	1.4
Italy	-8.6	0.4	3.0	-2.0	-4.1	0.5
Japan	-16.1	-4.4	7.6	3.3	-10.3	5.4
U.S.	-13.3	-11.8	-3.7	7.1	-12.5	1.7
G7	-12.6	-7.7	-0.2	3.9	-10.2	1.8
Euro12	-9.1	-2.9	1.0	-0.4	-6.0	0.3
OECD	-11.2	-6.5	0.1	4.1	-8.9	2.1

Blanchard and Galí propose three hypothesis to explain the different responses of the economy to oil price shocks in the 1970s and 2000s. First, real wage rigidities may have decreased over time thereby reducing the trade-off between the stabilization of inflation and stabilization of the output gap. Second, changes in the way monetary policy is conducted, specifically with the widespread adoption of inflation targeting which in principle implies a stronger commitment by central banks to maintaining a low and stable rate of inflation. Third, the share of oil in the economy has declined since the 1970s. We now address these explanations in turn.

Wage rigidity. BG utilize a standard new-Keynesian model, where oil is introduced as both an input in production and consumption. In the following exposition, all the relations are log-linearized versions of the original equations and lower case letters denote logarithms of the original variables. The price of consumption is a composite of the price of domestic output and oil prices:

$$p_{c,t} = p_{q,t} + \chi s_t$$

where $p_{c,t}$ is the price of consumption in period t, $p_{q,t}$ is the price of domestic output and S_t is the real price of oil,

$$S_t = P_{m,t} - P_{q,t}$$

where $P_{m,t}$ is the price of oil and $P_{q,t}$ is the price of domestic output .

Households smooth consumption and supply labor. Wage rigidity is introduced in the form of equation (1).

$$w_t - p_{c,t} = (1 - \gamma)(c_t + \varphi n_t) \quad (1)$$

where w_t is the nominal wage, c_t is consumption, the parameter $\gamma \in [0, 1]$ is an index of wage rigidity and constitutes the key parameter in this analysis, φ is the inverse of the Frish elasticity supply and n_t is employment. The term in the second parenthesis constitutes the marginal rate of substitution between consumption and leisure. When γ is zero, wages are perfectly flexible and the real consumption wage is equal to the marginal rate of substitution. Production is given by

$$q_t = a_t + \alpha_n n_t + \alpha_m m_t \quad (2)$$

where q_t is output, a_t is an exogenous technology variable, α_n is the labor parameter, α_m is the oil parameter and m_t is the quantity of imported oil used in production.

Cost minimization implies that the firms' demand for oil is given by

$$m_t = -\mu^p_t - s_t + q_t \quad (3)$$

where μ^p_t is the price markup and s_t is the real oil price. A reduced form production function is obtained by substituting (3) in (2) and it can be seen that output is a decreasing function of the real price of oil, given employment and technology.

$$q_t = \frac{1}{1 - \alpha_m}(\alpha_t + \alpha_n n_t - \alpha_m S_t - \alpha_m \mu^p{}_t) \qquad (4)$$

Combining the cost minimization conditions for oil and labor with the aggregate production function gives the factor price frontier. It shows that, given productivity, an increase in the real price of oil leads to a lower consumption wage, lower employment and a lower markup. The authors define the consumption wage as the wage that equates to the marginal rate of substitution between consumption and leisure. They also find that, with flexible prices and wages, the entire burden of the adjustment in response to an increase in s_t falls on the consumption wage.

$$(1 - \alpha_m)(w_t - p_{c,t}) + (\alpha_m + (1 - \alpha_m)\chi)S_t + (1 - \alpha_n - \alpha_m)n_t - a_t + \mu^p{}_t = 0 \qquad (5)$$

where χ is the weight of oil in total consumption.

Price stickiness is introduced in the model using Calvo pricing, which in combination with an expression for the markup consistent with equilibrium, yields a characterization of domestic inflation.

$$\pi_{q,t} = \beta E_t\{\pi_{q,t+1}\} + \lambda_p \mu^p{}_t$$

$$\mu^p{}_t = \Gamma_n n_t + \Gamma_S S_t - \Gamma_a a_t \qquad (6)$$

where $\pi_{q,t}$ is domestic output price inflation, $\mu^p{}_t$ is the price markup, β is a discount factor and $\lambda_p \equiv [(1 - \theta)(1 - \beta\theta)/\theta][(\alpha_m + \alpha_n) / (1 + (1 - \alpha_m + \alpha_n)(\epsilon - 1))]$, θ denotes the fraction of firms that leave prices unchanged and ϵ is the elasticity of substitution between domestic goods in consumption. The parameters Γ_n, Γ_a and Γ_s are given by

$$\Gamma_n \equiv \frac{(1 - \alpha_n - \alpha_m)\gamma + (1 - \alpha_m)(1 - \gamma)(1 + \varphi)}{1 - (1 - \gamma)(\alpha_m - (1 - \alpha_m)\eta)} \geq 0$$

$$\Gamma_a \equiv \frac{\gamma}{1 - (1 - \gamma)(\alpha_m - (1 - \alpha_m)\eta)} \geq 0$$

$$\Gamma_s \equiv \frac{\gamma(\alpha_m + (1 - \alpha_m)\chi)}{1 - (1 - \gamma)(\alpha_m - (1 - \alpha_m)\eta)} \geq 0$$

where $\eta = \alpha_m/(M^p - \alpha_m)$,with M^p denoting the steady state gross markup.

When there are no real wage rigidities Γ_s and Γ_a are equal to zero (because $\gamma = 0$), and therefore domestic inflation only depends on employment. The authors show that the level of employment under perfect competition ($\mu^p{}_t = 0$ *and* $\gamma = 0$) is invariant to oil-price changes. Consequently, stabilizing domestic inflation is equivalent to stabilizing employment as close as possible to perfect competition level (first best). This is what the authors call the "divine coincidence". They further explain that since positive values of γ lead to positive values of Γ_s and Γ_a, the higher the value of γ the worse the trade-off between stabilization of employment and stabilization of domestic inflation in response to an oil shock.

Assuming no technology shocks and that the real price of oil follows an AR(1) process, the equilibrium dynamics of inflation and output are summarized in the following system:

$$S_t = \rho_s S_{t-1} + \varepsilon_t \qquad (7)$$

$$\pi_{q,t} = \beta E_t\{\pi_{q,t+1}\} + \kappa y_t + \lambda_p \Gamma_S St \qquad (8)$$

$$y = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{q,t+1}\}) + \frac{\alpha_m(1 - \rho_s)}{1 - \alpha_m} S_t \qquad (9)$$

$$i_t = \varphi_\pi \pi_{q,t} \qquad (10)$$

Equation (7) is the oil price process, equation (8) constitutes a Phillips curve, the IS curve is (9) and the system is completed with a policy rule given by (10), where it is nominal interest rate in period t, φ_π is a constant and $\pi_{q,t}$ is domestic output inflation: $P_{q,t} - P_{q,t-1}$. Since this definition of inflation does not include oil prices, it can be interpreted as core inflation, with $\varphi_\pi > 1$. Moreover ρ_s and κ are parameters and ε_t is an stochastic disturbance, as standard.

According to this system of equations, a positive shock on oil prices will increase core inflation. As a consequence, in order to stabilize inflation the central bank would react by rising the nominal interest rate, which would have a negative impact on output. This means that there is a trade-off between inflation and output. In this context, the higher the degree of wage rigidity (γ) the higher the effect on inflation and the cost in output of stabilizing it.

In order to quantitatively assess the effect of an oil shock, the model was calibrated and simulated. The authors report that a moderate reduction in the degree of real wage rigidity can account for a substantial improvement in the policy trade-off, and hence on a simultaneous reduction in the volatility of inflation and GDP resulting from oil price shocks. Specifically, the model was simulated with three different levels of wage rigidity: Total wage flexibility (no wage rigidity at all), moderate and high rigidity. The exercise was carried out under the assumption of a favorable environment, i.e. full credibility of monetary, policy, 1997 oil shares, and alternative inflation coefficients of the Taylor rule varying from 1 to 5.

Under total flexibility the relation between the standard deviation of inflation and GDP is positive, hence as described above no trade-off between inflation and output stabilization. A policy that aims to stabilize inflation can at the same time stabilize output. This shows, as in many Keynesian formulations of the macroeconomy, that the presence of real wage rigidity is a key element that enables the generation of significant fluctuations in inflation and output. However, when some degree of rigidity is introduced in the calibration of the model, the relationship between the standard deviation of CPI inflation and output becomes negative.

Moreover, greater rigidity generates higher volatility in both variables and therefore a higher trade-off between inflation variability and output volatility.

Blanchard and Galí provide some evidence of a decrease in real wage rigidity by making use of rolling bivariate regressions. They found that the consumption wage tends to decline in response to a permanent ten percent increase in the price of oil, and that this response is stable over the sample (1970-2000). On the other hand, unemployment increases in response to the same shock but this response has declined dramatically over time. The authors interpret these two results as indication of the trend towards greater wage flexibility, i.e. "the decrease in real wages, which required a large increase in unemployment in the 1970s, is now achieved with barely any increase in unemployment today".

However, the model simulations still fall short of matching the conditional standard deviations of CPI inflation and GDP observed in practice. The model predicts lower standard deviations for output and inflation when simulated with lower wage rigidity but the values generated are considerably smaller than those actually observed in the post 1984 sample.

Similarly, whilst higher real wage rigidity generates bigger volatility in both variables the standard deviation values are again smaller than observed in reality in the pre 1984 sample. This suggests that it is not just changes in wage rigidity that account for the changes in output and inflation volatility.

Better monetary policy. Blanchard and Galí argue that a higher commitment of central banks to low and stable inflation in the post 1984 era might have improved credibility and hence reduced volatility. To examine this hypothesis they model credibility by assuming that the central bank *declares* the interest rate rule in equation (10). The public is assumed to *perceive* that actual interest rate decisions are made according to

$$i_t = \varphi_\pi (1 - \delta) \pi_{q,t} + \upsilon_t \qquad (11)$$

where $\{\upsilon_t\}$ is an exogenous i.i.d. monetary policy shock, and $\delta \in [0, 1]$ can be interpreted as a measure of the credibility gap.

The model was simulated with $\delta = 0$ (full credibility) and $\delta = 0.5$ (low credibility), high real wage rigidity for both cases, oil shares calibrated to their 1997 values and for different values of φ_π. As before, the simulations show a negative correlation between the standard deviations of output (SD_y) and inflation (SD_π). The results also show, as would be expected, that the standard deviations of GDP (SD_y) and inflation (SD_π) with full credibility are lower than those with low credibility. The sacrifice ratio of inflation in terms of GDP, measured in standard deviation, is also lower under credibility: lower variability in inflation can be achieved with lower variability in GDP. However, the simulated values again fall short of that observed in the post-84 sample. Under low credibility, the resultant SD_y and SD_π are higher than under full credibility but lower than the observed in the pre-84 period. So central bank credibility can indeed reduce volatility.

Share of oil in the economy. Finally, the same procedure was followed to simulate the model with the oil shares in consumption and production of 1973 and 1997. The results indicate that reduced oil shares reduce the volatility of the economy in response to oil shocks, but again, it is not enough by itself to explain the historical pattern of macroeconomic volatility described above.

Blanchard and Galí conclude that it is actually the combination of the three hypothesis which can explains the difference between the 70s and the 2000s.

2.1.5 Summary

Summarizing, oil prices have an effect on the economy. They might not be sufficient to cause downturns but do help to exacerbate their effects by delaying expenditure and investment decisions. The effect of oil prices on the economy is not symmetric; negative oil shocks (a decrease in its price) appear not to have a significant effect on output or prices. The relationship between oil and the macroeconomy has evolved over time; the response of output, inflation and employment to oil shocks has apparently dwindled. This may be the result of greater wage flexibility, better monetary policy and a smaller share of oil in production and consumption.

2.2 Monetary policy and oil prices

In this section we explore some of the most relevant literature on whether and how monetary policy should respond to oil shocks. We focus on what have been the contributions of monetary policy to both economic downturns and macroeconomic stability.

The most relevant literature on the contribution of monetary policy to economic downturns is presented in the first part. In the second part, the role of monetary policy in the age of "the great moderation", i.e. low macroeconomic volatility from 1984 to 2007 is examined.

2.2.1 Contribution of monetary policy to economic downturns

Bernanke, Gertler and Watson (1997) (BGW) argue that it is the central bank's response which actually cause volatility and not the oil shocks themselves. They base their study on counter factual experiments applying a modified Sims and Zha's (2006) methodology. Sims and Zha provide estimates of the contribution of endogenous monetary policy changes by "shutting down" the implied policy responses that would otherwise had occurred, and then simulating the effects of oil shocks holding the federal funds rate constant. These simulations are based on the estimates of a vector autoregression model (VAR). The difference, between the total effect of the exogenous non-policy shock and the estimated effect when the policy response is shut down, is then interpreted as a measure of the contribution of the endogenous policy response. This is equivalent to combining the initial non-policy shock with a series of policy innovations just sufficient to offset the endogenous policy response, as the authors point out. This procedure implies that people in the economy are repeatedly "surprised" by the failure of policy to respond to the non policy shock in its accustomed way. However people cannot be constantly surprised; they learn, change their expectations and choices and the estimates of the model would no longer be valid to forecast, as they would not have the new information. This is the focus of the Lucas critique. To cope with this issue, BGW introduce rational expectations in the financial markets, i.e. interest rate expectations are formed rationally, and alternative policy paths are anticipated.

The variables included in the VAR model are: real GDP growth, the GDP deflator, the commodity price index, a measure of oil prices, the Fed funds rate, the 3-month Treasury bill rate, and the 10-year Treasury bond rate. It is assumed that the federal funds rate does not directly affect output and prices but it does affect them indirectly through its effect on short-term and long-term interest rates, which, in turn, enter the equations that determine output and prices. It is also assumed that interest rates do not affect output and prices contemporaneously. Furthermore, the funds rate causes the other market interest rates but they do not cause the funds rate. BGW's procedure consists of generating a series of innovations of the Federal funds rate that would reset the rate to zero, and then add this shock in before calculating the responses of the treasury bill rate to the oil shock. The restricted VAR system is written as

$$Y_t = \sum_{i=1}^{p} (\pi_{yy,i} Y_{t-i} + \pi_{yr,i} R_{t-i}) + G_{yy} \varepsilon_{y,t} \qquad (12$$

$$F F_t = \sum_{i=1}^{p} (\pi_{fy,i} Y_{t-i} + \pi_{fr,i} R_{t-i} + \pi_{ff,i} F F_{t-i}) + \varepsilon_{ff,t} + G_{fy} \varepsilon_{y,t} + G_{fr} \varepsilon_{r,t} \tag{13}$$

$$R_t = \sum_{i=1}^{p} (\pi_{ry,i} Y_{t-i} + \pi_{rr,i} R_{t-i} + \pi_{rf,i} F F_{t-i}) + \varepsilon_{r,t} + G_{ry} \epsilon_{y,t} + G_{rf} \epsilon_{ff,t} \qquad (14)$$

where Y_t denote a set of macroeconomic variables, including the price of oil, $R_t = (R^s_t, R^l_t)$ represent the set of market interest rates; specifically, the three-month Treasury bill rate (the "short rate," R^s_t) and the ten-year Treasury bond rate (the "long rate," R^l_t) and the scalar $F F_t$ is the federal funds rate. Also, π and G terms are matrices of coefficients of the appropriate dimensions, the terms are vectors of orthogonal error terms, and constant terms have been omitted for notational convenience.

In order to introduce the expectations component in the model, the market rates are decomposed into two parts: a part reflecting expectations of future values of the nominal funds rate, and a term premium (equations 15 to 18).

$$\bar{R}^s_t = E_t\left(\sum_{i=0}^{ns-1} \omega_{s,i} F F_{t+i}\right) \tag{15}$$

$$\bar{R}^l_t = E_t\left(\sum_{i=0}^{nl-1} \omega_{l,i} F F_{t+i}\right) \qquad (16$$

$$S^s_t = R^s_t - \bar{R}^s_t \tag{17}$$

$$S^l_t = R^l_t - \bar{R}^l_t \tag{18}$$

where ns = 3 months and nl = 120 months are the terms of the short-term and long-term rates, respectively; the weights, ω, are defined by $\omega = \frac{\beta_i}{\sum_{i=0}^{ns-1} \beta j}$ and $\omega_{l,i} = \frac{\beta_i}{\sum_{i=0}^{nl-1} \beta j}$, and E is the expectations operator. The monthly discount factor The $\bar{R}$ variables constitute the expectations components of the short and long market interest rates, and the residual S terms are time-varying risk premiums associated with rates at the two maturities. With these definitions BGW rewrite the system of equations from (12) to (14) as follows:

$$Y_t = \sum_{i=1}^{p} [\pi_{yy,i} Y_{t-i} + \pi_{yr,i}(\bar{R}_{t-i} + S_{t-i})] + G_{yy} \varepsilon_{y,t} \tag{19}$$

$$FF_t = \sum_{i=1}^{p} (\pi_{fy,i} Y_{t-i} + \pi_{fr,i} R_{t-i} + \pi_{ff,i} F F_{t-i}) + \varepsilon_{ff,t} + G_{fy} \varepsilon_{y,t} + G_{fs} \varepsilon_{s,t} \tag{20}$$

$$S_t = \sum_{i=1}^{p} (\lambda_{sy,i} Y_{t-i} + \lambda_{sr,i} R_{t-i} + \lambda_{sf,i} F F_{t-i}) + \varepsilon_{s,t} + G_{sy} \varepsilon_{y,t} + G_{sf} \varepsilon_{ff,t} \tag{21}$$

Equations (19) to (21) correspond to equations (13) and (14) with the interest rates replaced by the corresponding term premiums, S. Since the difference between R and S is the expectations component, which is constructed as a projection on current and lagged values of observable variables, equation (21) is equivalent to equations (13) and (14).

With the equations arranged this way, BGW can perform a variety of experiments. Their main identifying assumption is that changes in the federal funds rate occur prior to the other interest rates in the model; this corresponds to the assumption that $G_{fs} = 0$ in equation (20). Alternatively, two-way causality between the funds rate and market rates can also be simulated in the model. In this case, it is assumed that shocks to the federal funds rate affect other interest rates contemporaneously only through their impact on expectations of the future funds rate; this corresponds to the restriction that $G_{sf} = 0$ in equation (21). This alternative assumption allows the funds rate to respond to innovations in term premiums.

Using the system of equations (19) to (21) the authors carried out policy experiments. They first estimated the vector autoregression model in the conventional way, which constitutes the base case. This estimation accounts for the effects of the endogenous policy response. The standard impulse-response function shows the dynamic impact of an oil price shock on the variables of the system, including the policy variables. In order to simulate the effects of an oil price shock under a counterfactual policy regime, the authors specify an alternative path for the federal funds rate, that is deviations from the baseline impulse response of the funds rate. The method is exactly the same as the one employed by Sims and Zha (1995) up to this point. The novel feature in the BGW procedure is the assumption that financial markets understand and anticipate this alternative policy response. Sims and Zha assume that market participants are purely backward-looking whereas BGW assume maximum credibility of the Fed's announced future policy. This latter argument is incorporated into the simulation by first calculating the expectations component of the interest rates ($\overline{R}_{t+i}$) that is consistent with the assumed path of the funds rate, and also choosing values of $\epsilon_{ff,t}$ such that the assumed future path of the funds rate is realized.

BGW constructed two additional scenarios for their policy experiments. The second scenario is a small variation of Sims and Zha's procedure. The funds rate was fixed at its base values throughout the simulation but, unlike Sims and Zha, the funds rate does not enter directly into the block of macroeconomic variables. Consequently, the funds rate exerts its macroeconomic effects only indirectly, through the short-term and long-term interest rates included in the system.

The third scenario is called "anticipated policy" by the authors. The funds rate is set equal to its baseline values again so that the response of monetary policy is shut off to the oil shock. But in this case the two components of short-term and long-term interest rates are allowed to be determined separately. The expectations component of both interest rates is set to be consistent with the future path of the funds rate, as assumed in the scenario.

Additionally, the short and long term premiums are allowed to respond as estimated in the base model. The advantage of BGW the approach over Sims and Zha's (1995) is that it allows for distinction between policies that differ only in the expected future values of the funds rate.

The authors report that in the absence of an endogenously restrictive monetary policy, the drop in output is less severe than the one obtained with the aforementioned policy. The effects are large quantitatively and they demonstrate that a nonresponsive monetary policy suffices to eliminate most of the output effect of an oil price shock. With the anticipated policy scenario, in response to Hamilton's net oil price one percent increase, output decreases below 0.25 percent but recovers after six months reaching around 0.87 percent of growth before 12 months. In the base line scenario, with an endogenous policy response, the drop in output with the same shock, is well below 1.5 percent and start to recovers only after 24 months without never reaching positive values again. As for prices, the response in the base line scenario and anticipated policy is similar in magnitude, with inflation reaching a level slightly above 2 percent after 12 months; thereafter decreasing in the base line scenario but keeps growing indefinitely up to above 3.5 percent with anticipated policy. The anticipated policy simulation results in modestly higher output and price responses than the Sims-Zha simulation. The authors argue that the differences occur because the anticipated policy simulation involves a negative short- run response in both the short and long term premiums, and thus lower interest rates in the short run.

A variation of this experiment consisted in shutting off the response of the term premium. This means that the funds rate is allowed to affect the macroeconomic variables only through its effects on the expectations component of the market rates. Although the contribution of monetary policy to the recession is smaller, it is still important. It accounts for between two-thirds to three-fourths of the total effect of the oil price shock on output.

The three major oil price shocks followed by recessions were examined in another exercise of counterfactual policy experiments. That is, as identified by BGW, OPEC1 (1972-1976), OPEC2 (1979-83) and the Iraqi invasion of Kuwait (1988-1992). The actual behavior of output, prices and the Federal funds rate were compared with their predicted responses under two alternative scenarios. The first scenario, which describes an endogenous policy response, isolates the portion of each recession that results separately from the oil price shocks and the associated monetary policy response. In this framework the oil variable is repeatedly shocked so that it traces out its actual historical path. All other shocks in the system are set to zero and the funds rate is allowed to respond endogenously to changes in oil prices and the induced changes in output, prices, and other variables. The second scenario assumes no policy response, eliminating the policy component of the effect of the oil price shock. In this exercise oil prices equal their historical values, all other shocks are shut off, the nominal funds rate is arbitrarily fixed at a value close to its initial value in the period and term premiums are allowed to respond to the oil price shock.

The authors report that the decline in output in the first oil crisis (OPEC1) is not well explained by the oil price shock. Instead, the recession seems to be driven by the rise in commodity prices and the sharp monetary policy response. On the other hand, in the scenario in which the funds rate responds to neither commodity prices nor oil price shocks, the economy exhibits no recession at all. The results of the second episode (OPEC 2) indicate that the decline in output is well explained by the 1979 oil price shock and the subsequent response of monetary policy. If the monetary policy reaction is excluded in the exercise, the period exhibits only a modest slowdown, not a serious recession. Finally the experiment for the third episode, the invasion of Kuwait by Iraq, shows that shutting off the policy response to oil price shocks produces a higher path of output and prices than otherwise.

According to these results, these three recessions could have been much smaller by not responding to oil prices, i.e. keeping the federal funds rate constant.

Hamilton and Herrera (2001) challenge the BGW (1997) findings arguing that the length of the lags in the VAR estimations is too short. In their VAR estimations BGW include seven lags with monthly data. However, Hamilton and Herrera point out that previous empirical studies have found that the biggest effect of oil shocks on output occurs at the fourth lag, using quarterly data. Therefore, BGW rule out the biggest effect of oil prices on output. Moreover, the simulated constant Federal funds rate policy is not feasible in practice. Hamilton and Herrera replicate BGW's calculations of the innovations of the Fed funds rate that are necessary to sustain the policy experiment discussed above. That is, the policy movements or adjustments necessary to keep the rate constant. The results reveal that after the eleventh innovation, all the realizations are negative. Hamilton and Herrera consider this pattern unrealistic because it is not consistent with the liquidity effect that follows a monetary expansion.

The liquidity effect is the reduction in the short run of the interest rate that follows an increase in the rate of growth of money supply. However in the long run this monetary expansion leads to higher inflation and, consequently, to higher interest rates. In general, the liquidity effect is relatively short-lived.

Hamilton and Herrera finds that to keep the interest rate constant, as in BGW experiment, 36 months in succession of negative realizations are required. Something that the monetary authority cannot achieve according to the liquidity effect argument. That is, the central bank cannot reduce the interest rate with 36 consecutive monetary expansions. The public would learn and the interest rate would increase directly and there would not be any liquidity effect in the short run.

BGW (1997) and Hamilton and Herrera (2001) attempt to identify the role of monetary policy using vector autoregressive analysis, which is as pointed above subject to the Lucas critique and may not be appropriate to evaluate the effects of monetary policy. Leduc and Sill (2004) instead explore the role of alternative monetary policies in response to an oil-price shock in the framework of a dynamic stochastic general equilibrium (DSGE) model.

Leduc and Sill's model consists of *h* identical households that are monopolistically competitive, supply a differentiated labor service and face nominal wage rigidities (households pay a cost for adjusting nominal wages). Firms are monopolistically competitive and employ capital and labor to produce differentiated goods. To capture the impact of oil supply, the use of capital is tied to energy utilization: the more intensively capital is used, the greater the energy requirement. Firms face a quadratic cost when adjusting their prices but do not face price-adjustment costs in the steady state.

Monetary policy is introduced in the model with a policy rule similar to that used by Clárida, Gertler and Galí (2000).

$$i_t = \rho i_{t-1} + (1 - \rho)\Theta(\pi_t - \pi^*) + (1 - \rho)\Psi(Y_t - Y^*) \qquad (22)$$

Were π^* and Y^* are steady-state levels of GDP inflation and output and ρ, Θ, Ψ are parameters. This contemporaneous rule was chosen over a forward looking one because this tended to give a unique equilibrium for a wider range of model parameter values. The parameters for the benchmark case are taken from Orphanides (2001). Orphanides estimated Taylor rules for the U.S. using real time data for the periods 1966:1-1979:2 and 1979:3-1995:4 (see table 4)[2].

[2] Orphanides' estimate of Θ in the 1966:1-1979:2 sample is bigger than one, so it does not imply a destabilizing monetary policy as argued by Clarida, Galí and Gertler (2000),

Unlike CGG's (2000) estimates for the first period, Orphanides' do not give coefficients that suggest the same destabilizing behavior as in CGG (discussed above).

Table 4.4 Estimated Taylor rules using real time data (Orphanides, 2001)

	Dates	ρ	Θ	Ψ
Rule 1	1966:1-1979:2	0.70	1.64	0.57
Rule 2 (Benchmark)	1979:3-1995:4	0.79	1.80	0.27

When the model is simulated with the benchmark rule and under perfectly flexible prices, the authors state: "With a higher price of oil, the cost of capital utilization rises, so firms use capital less intensively. This leads to a direct effect on production that reduces output and reinforces the negative income effect of the rise in oil prices. Lower capital utilization also reduces the marginal productivity of labor and, thus the real wage. This induces households to substitute out of work effort and into leisure, with substitution effects dominating income effects. Capital accumulation is discouraged as agents smooth consumption and expect a lower return to investment. The persistence in the process for oil prices generates the persistence in these impulse responses". Thus, even with flexible prices, there are substantial and propagated real consequences to oil price shocks.

Leduc and Sill then studied the response of the economy to alternative monetary policy rules for 1966:1-1979:2 and 1979:3-1995:4, according to table 4, and assuming perfectly flexible prices. Specifically, they examined the responses of output and inflation for rules that differ in the weights placed on the inflation and output gaps, when the economy is hit by a doubling of the price of oil. In the experiment, they first let Θ vary over the range [1.64, 2.5] while holding $\rho = 0.70$ and $\Psi = 0.57$ constant. Then the parameters $\Theta = 1.64$ and $\rho = 0.70$ were held constant and Ψ allowed to vary in the range of [0.11, 2.5]. The same procedure was performed in the second sample, albeit using the corresponding parameter values.

Examining the impulse response functions of output and inflation from the experiment described above, it was found that policy rules that place a high weight on inflation lead to a smaller loss in output, a lower inflation rate, and a lower nominal interest rate. This is true for both samples, pre and post 1979. Policy rules that place a high weight on the output gap generally lead to worse outcomes for output, inflation and the interest rate. This is because a policy that aggressively responds to an oil shock lowering the interest rate, could offset the intended real effect. Specifically, in order to reduce the interest rate the central bank would need to inject liquidity into the economy but this would raise current and expected inflation.

In response to this inflationary pressures the interest rate would be raised (inflation has a positive weight in the reaction function) and this increase more than offsets the negative effect induced by the output response. This is, of course, assuming a non-trivial weight of inflation in the equation. This problem could be solved by reducing the inflation parameter. However, attempts to further reduce the inflation coefficient lead to indeterminacy.

To measure the policy contribution to economic downturns, the authors isolated the effect of the oil shock by simulating the model with no policy response, i.e. keeping the interest rate constant, and then comparing these results with the alternative policy rules. The results reveal that in the post-1979 sample almost 40 percent of the decline in output (cumulative drop in the short run), following a positive oil-price shock (doubling of the price of oil), is attributable to the way monetary policy responds to the shock. On the other hand in the pre-1979 spell, with a policy rule that places relatively more weight on the output gap, up to 75% of the decline in output can be blamed on monetary policy response.

The simulation of the model with price stickiness did not change dramatically the results under perfect price flexibility discussed above.

In summary, monetary policy might not be fully responsible for the economic downturns but both empirical and theoretical work suggest that it is accountable for an important share.

2.2.2 Monetary policy and "The Great Moderation"

Herrera and Pesavento (2007) (HP) investigate the contribution of systematic monetary policy to the "Great Moderation" (the period of reduced macroeconomic volatility from 1984 to 2007). They compare systematic monetary policy, i.e. the short run response to oil shocks, to no systematic monetary response. They extend the modified VAR framework of Bernanke, Gertler, and Watson (1997) and Hamilton and Herrera (2004) (HH) discussed above, with some modifications. First the data was divided in two samples from 1959:1 to 1979:4 and 1985:1 to 2006:4, that is prior and during the great moderation, whereas BGW and Hamilton and Herrera work with the whole sample. The spell of time in the middle was not included to avoid having to model the structural break of the series. Second, the specification of the macro block differs from that in BGW and HH in that Herrera and Pesavento include a measure of potential output and exclude the commodity price index. Moreover, instead of measuring oil prices by the net oil price increase, they use the growth rate of real oil prices.

The counterfactual experiment consists in delaying one year the response of monetary policy to an oil shock, to simulate no systematic response, and compare it with the results from the historical data. With this purpose, they employ the methodology proposed by Sims and Zha (2006) discussed above. First the structural VARs and their corresponding impulse-response functions are estimated. Then, using the coefficients of the estimated VARs, they calculate the value of the innovations in the Federal funds rate that would keep the rate at zero for four quarters, and add this shock at horizons 1, 2, 3 and 4. The effect of systematic policy is the difference between both outcomes.

The results indicate that preventing a change in the fed funds rate (in response to the oil price increase) would have resulted in a lower price level and a milder recession during the pre-Volcker period. Whereas during the Volcker-Greenspan years the contribution of systematic monetary policy is negligible, there is no noticeable difference between the historical and counterfactual impulse response functions, except for 2006. Therefore, they conclude that monetary policy plays a smaller role in the Great Moderation period in explaining macroeconomic fluctuations.

2.2.3 Summary

Bernanke, Gertler and Watson (1997) argue that it is the central bank response which actually cause volatility and not the oil shocks themselves. Using VAR analysis they carried out counterfactual experiments of a mute response of the Federal Reserve to oil shocks, and found that the negative impact on output would have been less severe than the one that actually observed. However Hamilton and Herrera (2001) challenge these findings. They argue that the number of lags in BGW's VAR exercises are not large enough to capture the full observed effects of oil shocks. Moreover, they point out that the counterfactual experiments are improbable in practice. They would require several of consecutive reductions of the interest rate by the monetary authority and this is something that cannot be achieved because the required liquidity effect is normally short lived.

Leduc and Sill (1994) employed a DSGE model to study the response of the economy to alternative monetary policy rules for 1966:1-1979:2 and 1979:3-1995:4. They found that policy rules that place a high weight on inflation lead to a smaller loss in output, a lower inflation rate, and a lower nominal interest rate, in both samples. On the other hand, policy rules that place a high weight on the output gap generally lead to worse outcomes for output, inflation and the interest rate. They also show that, following an oil shock, 75% of the short run decline in output can be attributed to monetary policy in the first sample. The figure reduces to 40% in the post 1979 sample.

Herrera and Pesavento (2007) investigate the contribution of monetary policy to the period of reduced macroeconomic volatility from 1984 to 2007, denominated the "Great Moderation". They conclude that the Federal Reserve's intervention resulted in a higher price level and deeper recession during the pre-Volcker period. In contrast, monetary policy plays a very small role in explaining macroeconomic volatility in the Great Moderation era (Volcker-Greenspan years).

It can be concluded that monetary policy intervention has indeed increased macroeconomic volatility, in particular before 1979. Since then, however, the central bank intervention has been less disruptive and has indeed contributed to macroeconomic stability. Moreover, it seems that a policy rule with a high weight on inflation achieve better results in the context of oil shocks.

2.3 How should a central bank respond to oil shocks?

2.3.1 Introduction

Having understood to some extent the way in which oil prices affect the economy and what constitutes an oil shock, the next natural question is what we *should* do the next time we face one. In this section we examine the most relevant and up to date literature on monetary policy and oil shocks. Due to the current widespread use of some sort of inflation targeting around the world, we concentrate on the response of monetary policy rules of the Taylor type to oil shocks.

Taylor (1993) describes how monetary policy rules, where interest rates respond systematically to changes on real output and inflation (Taylor type rules), work in practice. He argues that monetary policy rules should not be used mechanically: Policy makers should use them in conjunction with judgement. An example given is the oil-price shock of 1990 when Iraq invaded Kuwait. At that time, the Council of Economic Advisers forecast that the temporary increase in oil prices could temporarily raise the overall price level and, with a longer lag, cause real output to fall. According to a typical Taylor rule, the central bank should increase the interest rate, since in the short run the price level would rise more than real output would fall. However, in this particular case, the increase in oil prices was regarded as temporary (spot prices doubled but futures prices rose only slightly). Therefore, an increase in interest rates to counteract the increase in price level brought about by the oil shock might be inappropriate. The conclusion is drawn that monetary policy should not react to temporary oil price increases, i.e. judgement over-rules the mechanical application of the rule.

In the first part of this subsection monetary policy and the Taylor rules are reviewed in general. The second part examines the literature on the explicit inclusion of the price of oil Taylor rule. A summary is presented in part 4.

2.3.2 Monetary policy in general

To examine the role of monetary policy in a context without considering oil price shocks, CGG estimated forward-looking monetary policy reaction function for two periods of time. The first, from 1960 to 1979, corresponds to the tenures of William Martin, Arthur Burns and William Miller as Chairmen of the Federal Reserve. The second, for 1979-1996, is the Volcker and Greenspan era. CGG work with a simple forward looking rule as follows

$$r^*_t = r^* + \beta(E[\pi_{t,k} \mid \Omega_t]\, \pi^*) + \gamma E[x_{t,q} \mid \Omega_t] \qquad (23)$$

where $\pi_{t,k}$ denotes the percent change in the price level between periods t and $t+k$. π^* is the target for inflation. $x_{t,q}$ is a measure of the average output gap between period t and $t+q$. E is the expectation operator, and Ω_t is the information set at the time the interest rate is set. r^* is the desired nominal rate when both inflation and output are at their target levels. CGG highlight that this equation represents a good description of how central banks actually operate. The implied forward-looking real rate rule is given by

$$rr^*_t = rr^* + (\beta - 1)\,(E[\pi_{t,k} \mid \Omega_t] - \pi^*) + \gamma E[x_{t,q} \mid \Omega_t] \qquad (24)$$

where $rr^*_t = r_t - E[\pi_{t,k} \mid \Omega_t]$ and $rr^*_t = r_t - \pi^*$ is the long-run equilibrium real rate. This equation shows that the sign of the response of the real rate target to changes in expected inflation depends on whether is greater or less than one. Therefore, rules with $\beta > 1$ will tend to be stabilizing (target real interest rate will be increased in response to inflation) and $\beta \leq 1$ will be destabilizing. If the central bank increases the real interest rate at less than one by one with expected inflation, consumers will demand more today creating further inflationary pressures. CGG (2000) support this argument empirically by estimating the Federal Reserve's policy reaction function; the details are provided below.

In order to obtain a more realistic reaction function, CGG expand equation (23) to incorporate interest rate smoothing (adding lags of the interest rate to the rule), to allow also for randomness in policy reaction (central banks do not use policy rules mechanically) and also relaxing the implied assumption that the central bank has perfect control over the federal funds rate. The result is the following augmented reaction function

$$r_t = (1 - \rho)[rr^* - (\beta - 1)\pi^* + \beta\, \pi_{t,k} + \gamma x_{t,q}] + \rho(L) r_{t-1} + \epsilon_t \qquad (25)$$

where $\rho(L) = \rho_1 + \rho_2 L + ... + \rho_n L^{n-1}$ and $\rho \equiv \rho(1)$. Therefore ρ constitutes an indicator of the degree of smoothing of interest rate changes and where $\epsilon_t \equiv -(1 - \rho)\{\beta(\pi_{t,k} - E[\pi_{t,k} \mid \Omega_t] + \gamma(x_{t,q} - E[x_{t,q} \mid \Omega_t])\}$. The term in curly brackets is a linear combination of forecast errors and is orthogonal to any variable in the information set Ω_t. If z_t constitutes a vector of instruments known when r_t is set, equation (26) implies the set of orthogonality conditions,

$$E\{[r_t - (1 - \rho)(rr^* - (\beta - 1)\pi^* + \beta\, \pi_{t,k} + \gamma x_{t,q}) + \rho(L) r_{t-1}] z_t\} = 0 \qquad (26)$$

which provides the basis for the estimation of the parameter vector (α, β, γ, ρ), using the Generalized Method of Moments. CGG find that the Federal Reserve did not raise the real interest rate sufficiently to face inflationary pressures in the pre-Volker period, at least by the Taylor criterion, hence failing to stabilize inflation. On the other hand, under the Volcker-Greenspan regime, the interest rate was increased on a roughly two-for-one basis to meet anticipated inflation. These two different type of response can potentially explain the macroeconomic volatility of the pre-Volcker spell and the relative stability of the early 1980's onwards. They are supportive of the hypothesis that monetary policy played a key role in the oil crises of 1973 and 1979, deepening and prolonging the period of stagflation, as also argued by Blanchard and Galí (2008).

CGG proceed to evaluate the macroeconomic consequences of the two estimated rules in a neo-Keynesian DGSE model, consisting of an expectations augmented Phillips curve, an IS curve and a policy rule. They found that a monetary policy rule with $\beta < 1$, which applies to the pre-Volcker spell, is in itself a source of instability. It leads to indeterminacy of the model equilibrium and raises the possibility of fluctuations in output and inflation around their steady state values that result from self-fulfilling revisions in expectations. The initial expected inflation becomes self fulfilling. Therefore, persistent fluctuations in output and inflation arise, despite the absence of any fundamental shocks. When the estimated policy rule that corresponds to Volcker and Greenspan tenures is used instead, with values of β well above one, macroeconomic fluctuations arise only in the presence of shocks to fundamentals, and self-fulfilling fluctuations cannot arise.

CGG conclude that the policy rule of the second period is superior. A supply shock can indeed induce persistent inflation under the estimated pre-Volcker rule (inflation coefficient smaller than 1), but not under the estimated Volcker-Greenspan rule (inflation coefficient bigger than 1).

2.3.3 Monetary policy and oil shocks

In this context then, how exactly should monetary policy react to oil-price shocks in order to minimize their adverse macroeconomic effects? To answer this question De Fiore, Lombardo and Stebunovs (2006) (DLS) build an open-economy DSGE model to evaluate the welfare consequences of oil-price shocks when the central bank commits to a policy rule of the Taylor type. They argue that the macroeconomic effects of the surge in oil prices observed since 2003 might be different from those experienced in the past. They point out that the industrialized countries have reduced significantly their oil dependence. In addition oil supply and demand pressures played an important role in this episode, whereas in the 70's the oil-price shocks were mainly driven by supply events. Consequently, they build a medium scale model with a number of frictions and economic disturbances in order to replicate these and other stylized facts and perform a welfare analysis. In particular, the model can simulate oil-price shocks that are either endogenous or exogenous to the world economy. Oil in oil-importing countries enters consumption and production, thus demand and supply shocks in those countries generate endogenous volatility in the price of oil. On the other hand, a productivity shock in the oil-exporting country works as an exogenous supply shock in the world economy. The effects of fiscal policy asymmetries on the propagation of oil-price shocks are also taken into account by imposing taxes on labor, consumption and energy. Finally, due to the relevance of international markets, policy rules are evaluated for the oil importing countries, the European Union (EU) and the United States (US), under two alternative specifications concerning the international financial market: a complete market structure conducive to consumption-risk sharing across countries, and a non-contingent bonds structure. The model contains the following main components:

a) Two oil-importing countries, the European Union (EU) and the United States (US), and one oil-exporting country. The two oil-importing countries are identical in structure and are inhabited by infinitely-lived households consuming a basket of domestic goods, imported goods and oil.

b) There are wage rigidities, i.e. nominal wage contracts which can be renegotiated only at random intervals of time and in staggered fashion, as in the standard Calvo (1983) pricing model.

c) Firms produce differentiated goods using labor and capital and prices are set according to Calvo pricing.

d) Oil enters production in two ways: capital can only be used in production if it is combined with oil, and it is needed to vary capital utilization.

e) Government can finance public expenditures by issuing debt certificates and by levying taxes.

f) The central banks commit to a Taylor type monetary policy rule.

g) The oil-exporting country is inhabited by a representative household consuming a basket of goods that can only be imported from the rest of the world. Firms produce oil, which is exported and not used for internal consumption, and set prices optimally at each point in time. The exchange rate is pegged to the US dollar.

The authors assume a feedback interest rate rule that responds to lagged interest rate, inflation, output, growth, oil prices and oil inflation. The explicit reaction to oil price movements in (27) constitutes a new development in policy rules.

$$R_t = \lambda_R R_{t-1} + (1-\lambda_R)[\lambda_\pi(\frac{\pi_t}{\pi} -1) + \lambda_Y(\frac{Y_t}{Y} -1) + \lambda_{\Delta Y}(\frac{Y_t}{Y_{t-1}} -1) + \lambda_{\Delta Pe}(\frac{P_{e,t}}{P_{e,t-1}} -1) + \lambda_{pe}(\frac{P_{e,t}}{P_e} -1) + R_0] + \varepsilon^R_t \quad (27)$$

R_t is the interest rate, π_t is inflation, Y_t is nomial GDP, $P_{e,t}$ is oil prices and variables without a subscript denote steady-state values. This formulation is new in that it advocates a specific and direct response to oil prices. Policy rules are evaluated according to the effects of oil price shocks on welfare. The optimal rule should: 1) be simple, 2) maximize welfare to a second order of approximation, 3) satisfy the zero-lower-bound for the nominal interest rate and 4) produce either a Nash or a cooperative equilibrium. DLS justify the inclusion of this last criterion; "...(it) is dictated by the fact that the choice of policy parameters by a given central bank is influenced by the choice made by the other central bank. We assume that each central bank responds optimally to the choice made by the other. Under cooperation we assume that international transfers are made between EU and US in order to compensate the country that is worse off under the chosen policies."

The model was calibrated for the EU and US seeking to match three criteria: replicate the volatility and correlations of relevant macroeconomic variables, reproduce the oil intensity in production and consumption observed in the data and generate a contribution of the oil-price shocks to the overall variance of GDP as the one obtained in related empirical work.

The calibrated model was then simulated with three type of shocks, searching for the optimal parameters of the monetary policy rule (27) that maximize welfare. That is, oil-price shocks, technology shocks (in the oil importing countries) and government spending shocks. Due to the intense computational requirements of the procedure, the authors considered two cases and restricted some of the parameter values. Specifically two cases were considered:

1) The unconstrained case: in this case the central bank does react to oil shocks It is tested whether it is optimal to respond to the oil price level or oil inflation (oil price level parameter = $\lambda_{Pe,}$ oil inflation parameter =$\lambda_{\Delta Pe}$) and the optimal response to headline inflation (λ_π). The tests include three different degrees of inertia (λ_R = 0, 0.5, 0.95) and three different responses to output (λ_Y = 0, 0.5, 1.98). The response to output growth is set to zero ($\lambda_{\Delta Y}$ = 0) in all the exercises.

2) The constrained case: This implies no policy response to oil shocks. The response to both the oil price level and its change (oil inflation) are set to zero ($\lambda_{Pe} = \lambda_{\Delta Pe} = 0$).

The resultant policy-rule parameters that maximize welfare for the EU and the US are shown in Table 4.5 and 4.6[3].

[3] The different results for the EU and the US are due to the different calibration values. The size of the EU relative to the US is 75%. The elasticity of labor supply is set at 0.4 for both. The consumption habit parameter is 0.7 for the EU and 0.45 for the US. The elasticity of inter-temporal substitution in consumption is 2.5 in the EU and 2 in the US. The shares of oil in consumption and production are 6.03% and 1.56% respectively in the EU and 6.89% and 1.96% in the US. The labor in production is set to 0.64 for both countries. The elasticity of capital utilization to energy is 28 in the EU and 20 in the US. The elasticity of the demand for final goods is assumed to be the same in both countries. The probability of not adjusting the price in a particular quarter is 0.8 for the EU and 0.6 for the US. The probability of not readjusting wages is 0.83 for the EU and 0.73 for the US. The adjustment cost of investment is 7 for the EU and 5 for the US. An equal degree of price and wage indexation is assumed in both countries. The excise tax on oil is set at 20% for the US and 70% for the EU. The elasticity of substitution between imported goods and domestically produced goods is set at 0.7 for both the EU and the US.

Table 4.5. Optimal monetary policy parameters for the unconstrained model

Country	λ_R	λ_π	$\lambda_{\Delta Y}$	λ_Y	λ_{Pe}	$\lambda_{\Delta Pe}$	$\frac{\lambda_{\Delta Pe}}{\lambda_\pi}$
EU	0.95	27.2	0	1.98	0	-2.4	-0.088
US	0.95	20.8	0	1.98	0	-2.6	-0.125

DLS report the main findings are:

1) The results advocate a high degree of inertia ($\lambda_R = 0.95$)

2) The optimal response to oil inflation is negative and it is optimal to respond to oil inflation ($\lambda_{\Delta P e}$) rather than to oil price level. This negative response to oil inflation allows for a stronger response to headline inflation.

3) The response to headline inflation in fact constitutes core inflation, since oil prices are being considered separately.

4) The optimal responses to inflation are large. This suggests that the marginal cost of reducing inflation in the model is not particularly high relatively to the marginal benefit, indicates the optimal weight to be given to oil-price inflation. This means that for the EU, the optimal weight to oil inflation is 8.8% of the response to headline (core) inflation, and for the US the 12.5%, both in negative terms.

Table 4.6 Optimal monetary policy parameters for the constrained model

Country	λ_R	λ_π	$\lambda_{\Delta Y}$	λ_Y	λ_{Pe}	$\lambda_{\Delta Pe}$	$\frac{\lambda_{\Delta Pe}}{\lambda_\pi}$
EU	0.95	16.8	0	1.5	0	0	0
US	0.95	18.8	0	2.5	0	0	0

DLS also report that, in terms of welfare loss, the optimal rule under the constraint of zero response to oil-prices is about .008 and .006% of GDP worse than the optimal unconstrained rule, for the EU and the US respectively. This means that in the US the constrained optimum costs around $2.45 per person more per year than the unconstrained optimum, while the cost of the unconstrained optimum relative to the flexible price equilibrium is abou $24.05.

Finally, to test whether the optimal rule is qualitatively affected by the presence of the exogenous oil-price shocks, optimal rules were estimated for two extreme scenarios: when oil-price shocks are absent (technology and government spending shocks only) and when oil-prices are the only source of stochastic volatility in the economy (the other two shocks are switched off)[4]. Based on the results, shown in Tables 7 and 8 respectively, the authors conclude that in the first case the central bank should respond even more strongly to headline inflation but should also react *positively* to oil-price inflation. In the second case, the central bank should react less aggressively to headline inflation but partially accommodate increases in oil-price inflation by cutting interest rates. That is, the *negative* response found in Table 5 is restored.

Why should the monetary authority increase interest rates in response to oil prices when oil-price shocks are absent, and decrease them when they are the only source of volatility in the economy? It is well known that to stabilize inflation, a central bank would normally increase the interest rate in response to higher inflation originated from a positive oil-price shock. However, this increase in the interest rate will also have a negative impact on output. Therefore, the authors argue, that the presence of exogenous oil-price shocks introduces a higher cost of reducing inflation and that a reduction of interest rates can ameliorate the negative impact on welfare.

The optimal ratios of the optimal response to oil shocks to headline (core) inflation in Tables 4.7 and 4.8 suggest that the negative response to exogenous oil shocks should be stronger than the positive reaction to endogenous oil inflation, for both the EU and the US. Moreover, the response in both cases (positive and negative) should be stronger in the US than in the EU.

[4] This model can simulate oil-price shocks that are either exogenous or endogenous to the world economy. Since oil enters both consumption and production in the oil-importing countries, demand and supply shocks in those countries generate endogenous volatility in the price of oil. On the contrary, a productivity shock in the oil-exporting country acts as an exogenous supply shock. Here the experiment is about such exogenous oil-price shocks.

Table 4.7 Optimal monetary policy parameters. Oil endogenous inflation but no exogenous oil shocks

Country	λ_R	λ_π	$\lambda_{\Delta Y}$	λ_Y	λ_{Pe}	$\lambda_{\Delta Pe}$	$\frac{\lambda_{\Delta Pe}}{\lambda_\pi}$
EU	0.95	29.7	0	1.98	0	1.23	0.0414
US	0.95	27.2	0	1.98	0	2.72	0.1

Table 4.8 Optimal monetary policy parameters. Exogenous oil price shocks

Country	λ_R	λ_π	$\lambda_{\Delta Y}$	λ_Y	λ_{Pe}	$\lambda_{\Delta Pe}$	$\frac{\lambda_{\Delta Pe}}{\lambda_\pi}$
EU	0.95	12.4	0	1.98	0	-0.99	-0.08
US	0.95	12.4	0	1.98	0	-1.73	-0.14

De Fiore et.al. (2006) conclude: "When the economy is not hit by exogenous oil-price shocks, the central bank should strongly respond to headline inflation but also positively react to oil-price inflation. On the other hand, when exogenous oil-price shocks are the only source of volatility in the economy, the central bank should react less aggressively to headline inflation but partially accommodate increases in oil-price inflation."

Dhawan and Jeske (2007) also investigate whether, in the context of energy shocks, it is better to employ headline inflation or separate measures for core inflation and energy prices in the reaction function. Should a central bank accommodate energy prices? (with low or even negative weights on the energy price inflation). Or should the central bank raise interest rates so as to bring down inflation? To answer these questions, the authors build a DSGE model with energy price shocks in the presence of money, nominal rigidities and durable goods investment. The key theoretical innovation is the distinction between durables investment and fixed investment.

In the model the representative household gets utility from consuming three types of consumption goods: consumption of nondurables and services excluding energy, the flow of services from the stock of durables goods (like autos) and energy use. On the other hand, firms produce output by combining three inputs: labor, capital and energy. It is assumed that all the energy inputs need to be imported. Hence total investment is given by adding nondurable goods and capital.

The authors argue that the drop in GDP after an energy price hike is smaller in an economy with durables goods than in one without them. This is because the representative consumer lowers durables investment more than fixed investment (this is observed in real data), which cushions the drop in output. In a model without durable goods, the total drop in investment (as a result of consumers postponing investment decisions) falls completely on fixed capital and therefore directly in the production function. Moreover, Dhawan and Jeske show that a Taylor rule with headline inflation impedes this rebalancing and thus causes larger output drops. On the other hand if the central bank puts a low (even negative) weight on energy inflation it enhances the rebalancing and thus cushions the drop in output.

To evaluate policy rules, they modify CGG's reaction function incorporating headline and core inflation. That is, headline inflation is expressed as core inflation (π) plus energy inflation (π^e):

$$\pi_t^{HL} = \pi_t + \chi^e \pi^e_t \qquad (28)$$

χ^e is the steady state share of energy expenditures for consumers. At the steady state only the nominal price grows at a positive rate, not the relative energy price. They use a generalized Taylor rule with the additional energy term:

$$R_t - \bar{R} = \rho_\tau (R_{t-1} - \bar{R}) + (1 - \rho_\tau)[\tau_\pi^{core}(\pi_t - \bar{\pi}) + \tau_\pi^e \pi_t^e + \tau_y (Y_t - \bar{Y})] \qquad (29)$$

R_t is interest rate, π_t is core inflation, Y_t is output, π^e_t is energy inflation, variables with bar indicate steady state values and ρ_τ, τ_π^{core}, τ^e_π, τ_y are weights.

The model was calibrated and estimated. Energy is assumed to follow an ARMA(1,1) process and total productivity an AR(1) process. Instead of searching for the optimal rule, as in De Fiore et.al., the authors tested a benchmark monetary policy rule and four variants.

The values of the parameters in the benchmark rule were taken from Leduc and Sill (2004), which are based on Orphanides (2001). The model was simulated with a doubling in value of oil prices. The alternative rules are summarized in table 4.9.

Table 4.9 Alternative Policy Rules, Dhawan and Jeske (2007)

		τ_{π}^{core}	τ_{π}^{e}	τ_{y}
Rule 1	Benchmark	1.8	0.0000	0.27
Rule 2	Use headline inflation	1.8	0.1002	0.27
Rule 3	Accommodates energy inflation	1.8	-0.1002	0.27
Rule 4	Lower weight on core inflation	1.5	0.0000	0.27
Rule 5	Higher weight on the output gap	1.8	0.0000	0.35

First of all, the authors report that they did not encounter any indeterminacy problem in the simulations, which shows the robustness of the Taylor principle ($\tau_{\pi}^{core} > 1$). It is true even for rule 3, which responds negatively to energy prices. The model was simulated with each of the policy rules and the impulse response functions for output, inflation and the federal funds rate were plotted. Comparing the impulse response functions for each rule, the following findings are reported:

1) A central bank that uses rule 2 causes a large drop in output, almost 9 percent in the first quarter. Furthermore, over the whole transition (back to steady state level), output is the lowest among the five policy rules considered. Regarding inflation, in the first period, inflation is slightly lower than in the benchmark rule, 1.5 and 1.7 percent respectively, but then it stays persistently above the benchmark level (rule 1). Besides, the response of the Fed funds rate is above that under the benchmark Taylor rule (1.5 versus 1.3 percent in the first quarter).

2) A bank that follows rule 3, responding negatively to energy price shocks, would cause output to increase around 9 percent above the steady state level in the first quarter, and around 1 percent in the second, before falling into negative values around -4 and -5 percent. Along the transition path back to the steady state, output never gets below that of any other rule. With respect to core inflation, this jumps at about 2 percent above steady state, but only for one period. After that, inflation is the lowest among the five policy rules. Regarding the Federal funds rate, this barely increases (less than 1 percent) due to the negative weight on energy inflation. Finally, the response of the Federal funds rate to an energy price shock is the lowest among the 5 rules, due in part to the low increase in core inflation.

3) Rules 4 and 5 are successful in ameliorating the response of output (3 and 1 percent growth in period 1 before falling into negative figures) to the energy shocks but also create the highest responses in inflation (2.7 and 2.3 percent) and interest rates (1.7 and 1.4 percent).

Rule 3 therefore turns out to be preferred, it cushions both inflation and the output loss. This means that the energy-price shock can be accommodated without trading off higher inflation for it. Dhawan and Jeske argue that this is made possible by rule 3 because it encourages rebalancing of durables and fixed capital in response to energy price shocks. On the contrary the Taylor rule with headline inflation discourages rebalancing. They plot the impulse response functions of the two investment series to an oil shock under three alternative specifications for the Taylor rule: The benchmark (Rule 1), using headline inflation (Rule 2) and accommodating energy inflation with a negative response (Rule 3). The results show that under Rule 1 durable investment falls 50 percent in the first quarter and fixed investment increases 11 percent. Under rule 2, both durables investment and fixed investment fall in 63 and 29 percent respectively. Finally, under Rule 3 durable investment falls 39 percent and fixed investment increases 51 percent. Therefore fixed investment is much higher under Rule 3 and even durables investment drop less than under the other rules.

2.3.4 Summary

Dhawan and Jeske (2007) and De Fiore, Lombardo and Stebunovs (2006) both evaluated monetary policy in the framework of a DSGE model. Both employed a contemporaneous Taylor type monetary policy rule with core inflation and oil/energy prices. However, DLS's model is more complex, apart from households and firms, it includes an external sector, financial markets and fiscal policy; but does not take into account the channel of consumption of durable goods, nondurable goods and investment as in Dhawan and Jeske (2007). DLS evaluate different reaction functions with welfare optimization when the economy faces different shocks (oil, productivity and fiscal), while DJ evaluate the ability of alternative rules to cushion the responses of output, inflation and interest rate to energy shocks only. Both optimal rules agree in that the response to inflation should be bigger than one by one. Lastly, DLS find that it is optimal to respond negatively to the change in oil prices in the event of oil shocks (about -2.5), but in the absence of oil shocks the central bank should respond positively to oil prices (variations in oil prices that do not constitute shocks). The negative response to oil shocks is consistent with DJ's optimal rule, which also reacts negatively to energy shocks (-0.1002), although with an smaller coefficient. Briefly, both reach similar conclusions in the sense that the optimal policy rule should react strongly to core inflation, relatively weakly to output and negatively to oil/energy shocks.

2.4 Conclusion

Oil shocks have historically played a role in economic downturns. The way monetary policy reacts to oil shocks is relevant, it can magnify or cushion their effects. Hamilton (1983) found that oil prices "Granger cause" output, employment, inflation and money aggregates using samples from 1948-1972 and 1973-1980. Although he recognizes that the response of output to oil prices is smaller in the second sample. In contrast, Hooker (1996) tested this relationship in a sample from 1973 to 1994, and concluded that the link between oil prices and macroeconomic variables in the US is not statistically significant in this period. Hamilton (1996) responded arguing that many of the oil price increases in the sample (1973-1994) are recoveries from previous price drops. He goes on reasoning that this type of price corrections is unlikely to affect spending decisions on key goods, which is the transmission mechanism through which oil prices impact on output. Hamilton then constructs an oil-price shocks series with, what he calls, net price increases and re-establishes a statistically significant relation between oil prices and output in the 1973-1994 sample. This does not prove that oil prices cause economic downturns, but it certainly shows that they play an important role in the duration and magnitude of the recessions. It also shows that the way in which the oil-shocks series is constructed is relevant in empirical work. In this respect, oil-shock series that account for exogenous political/war events, are plausibly better.

BGW (1997) found empirical evidence that it is in fact the response of monetary policy which has caused economic downturns and not the oil shocks themselves. They suggest that if the Federal Reserve had not risen the interest rate in response to the oil shocks, then the effects would have been less severe. These findings have been challenged (Hamilton and Herrera, 2001) on the grounds of econometric misspecification of BGW's regressions.

However, these two works rely on VAR and Granger causality analysis, which is theoretically questionable according to the Lucas critique. Leduc and Sill (2004) find, using a DSGE model, that the monetary policy contribution to recessions might be around 75% in the pre-1979 sample, and up to 40% in the post 1979 era.

Concerning the question of what is the best way for monetary policy to respond to oil shocks, Taylor (1993) suggests informally that monetary policy should not respond to transitory oil shocks. CGG (2000) suggest that the inflation weight in the policy rule should be bigger than one to avoid destabilizing monetary policy, i.e. the central bank has to respond strongly to inflation. In this respect, they assert that the pre Volcker-Greenspan era was characterized by an accommodative policy and hence the high macroeconomic volatility of the time. Moreover, in a medium scale model with oil-exporting and oil importing countries, complete financial markets, government and oil as an input in consumption and production, DLS (2006) find that the optimal monetary policy should react strongly to headline inflation and negatively to oil inflation. This also has the implication that it is optimal to use core inflation in the rule, as opposed to headline inflation. Dhawan and Jeske (2007) also tested the wisdom of using core over headline inflation in the rule and whether it is a good idea to accommodate energy prices, hence decreasing the interest rate in response to positive oil price inflation. In an smaller model compared to DLS's and with a much smaller range of parameters tested, they concur with a strong response to core inflation. Additionally, they also agree in a weaker response to output. Both optimal reaction functions are consistent in reacting negatively to oil/energy shocks.

The economic literature provide some evidence that oil shocks have historically been linked to economic recessions, that this role has declined over time, that the central bank should respond weakly negatively to such shocks and that it might be optimal to use core inflation (as opposed to headline inflation) in the policy rule.

3. Policy rules with oil prices in a New Keynesian Model

3.1 Introduction

In this section, the best policy response to oil shocks is evaluated in the framework of a New Keynesian model. Dynamic stochastic general equilibrium models have become the standard tool to evaluate monetary policy. Optimal response to oil shocks depending on the degree of oil intensity in the production process, price stickiness and the relative importance of output in the loss function are appraised. The theoretical model, developed in the second chapter of this dissertation, incorporates imported commodities as an additional input to labor in the production function. In this chapter input commodities is composed of oil only. The model then lends itself to incorporate a monetary policy rule with oil inflation and to be simulated with oil-price shocks. This model is simpler than other formulations and therefore can allow investigation of a simple mechanism. The optimal oil-price parameter is found with the minimization of the loss function, which is composed of output and inflation variances. Subsequently, this parameter is contrasted with the findings in previous literature.

In addition, the ARMA process that characterizes oil shocks is analyzed. It is found that it can actually have an impact on the duration and magnitude of the shock. Consequently, the type of process can also influence the optimal response.

3.2 Theoretical model

The model in Pickering and Valle (2008) embodies an extended New Keynesian framework with oil (or any other exogenously priced import commodity) in the production function. It differs from previous theoretical approaches to oil shocks in that it focuses on oil in the production process. This therefore allows to isolate the production cost effect on output and inflation.

The Phillips (30) and IS (31) curves are taken from Pickering and Valle (2008). Furthermore, in order to carry out exercises of monetary policy, the above model needs to be completed with a policy function. Hence a Taylor type reaction function with oil prices is incorporated (32).

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa \tilde{y}_t + \varsigma u_t \qquad (30)$$

where π_t is inflation, $\tilde{y}_t$ represents deviation of output from potential output, κ and ς are composite parameters, and $u_t =(p^o_t - p_t) - r^o$, where r^o are long-run real oil prices. The term u_t acts as a cost-push shock and comprises oil shocks. The economy's response to these shocks is given by the structural parameters in ς.

$$y_t = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{t+1}\} - \rho) \qquad (31)$$

where y_t is output, i_t is the nominal interest rate and ρ is the discount rate.

$$i_t = \tau^\pi \pi + \tau^o u_t + \tau^y y_t \qquad (32)$$

where τ^π, τ^o and τ^y are the policy reaction parameters to inflation, oil inflation and output, respectively.

Only simple rules like (32) are considered in this exercise. The objective here is to obtain optimal values for τ^π, τ^o and τ^y, with special interest on the oil prices parameter, and compare with previous literature.

To solve and simulate the model a function that describes how the oil shock (u_t) evolves through time is needed. In order to be more realistic, instead of assuming a given process the next subsection identifies one for different samples of the actual oil price series.

3.3 The oil prices process

In this section the ARMA process that best fits the oil price series is identified, so that it can be employed in the solution and simulation of the model described above. Since the impact of oil shocks and the corresponding policy reaction has evolved through time, as stated above, ARMA processes are identified for different time periods. It could be that the oil price process has also played a role in this evolution. Hence, we ask the question whether different oil price processes can impact the economy differently and what the optimal policy response should be.

With this purpose the standard Box and Jenkins methodology is applied to the West Texas Intermediate oil price series. That is identification, estimation and verification. Identification is based on the autocorrelation (ACF) and partial autocorrelation functions (PCF). In particular, when the ACF decays exponentially and there is some identifiable structure in the PACF (statistically significant PACF lags), an autoregressive (AR) process is identified and its order is given by the significant lags in the PACF. The opposite relationship identifies a moving average process (MA), i.e. exponentially decaying PACF and significant structure in the ACF. Additionally, an ARMA process is identified when there is statistically significant structure in both the ACF and the PCF.

The model is estimated and in order to verify whether it was properly identified, the residuals are tested for serial correlation. If there is any structure left in the series that was not identified it will show in the ACF and PACF of the residuals and it would be needed to return to the identification stage. The verification phase is performed with the help of the Ljung-Box *Q-statistic* for residual serial correlation.

In practice, the ACF and PACF rarely exhibit the exact theoretical identification criteria. The practitioner has to use a bit of creativity/imagination in the identification process. In the end, the selection criteria is down to the examination of the residuals and the forecasting properties of the model, when forecasting is the objective of the model.

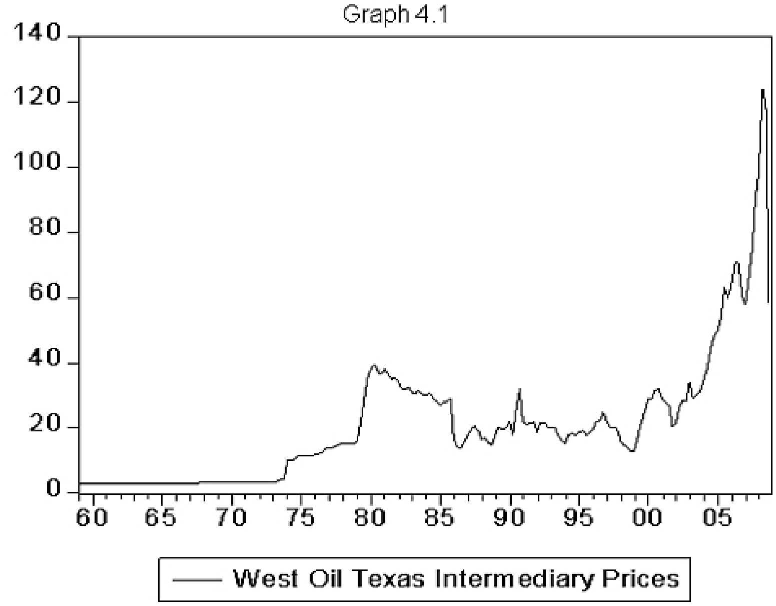
The samples chosen are quarterly from 1959 to 1984 and 1985 to 2008. The first period is characterized for high macroeconomic volatility. The second sample encompasses both the "great moderation" and the two major shocks (1999 and 2002) that affect the economy differently from the shocks in the 1970s, as identified by Blanchard and Galí (2008) and discussed above. This second sample thus might represent better the current oil price process.

The ARIMA modeling requires the series to be stationary. Therefore the first step here is to carry out stationarity tests on the oil price series. In this sense graphic analysis of the series does not constitute a formal test, but it helps the intuition of what to expect, especially with the well known low power of the unit root tests. Graph 4.1 in the appendix shows the whole series from 1959:1 to 2007:4 and it can be seen that there are spells where the series seems stationary, then spells where the series exhibits very sharp trends and above all several structural brakes. In brief, it seems to be periods when the series is stationary and periods when it is not. The question then is a matter of stationarity in a particular sample and not in the whole series. Consequently the unit root tests are carried out separately for each sample.

Graph 4.2 (in the appendix) encompasses the sample 1959:1-1984:4 and it clearly shows structural breaks in the 70s and the 80s. Hence the Phillips-Perron unit root test, especially designed for series with structural brakes is more appropriate. The results of the test are presented in tables 4.10 and 4.11. The null hypothesis "the series has a unit root" cannot be rejected at any of the conventional significance levels for the series in levels, but it can in first difference. As a result it can be concluded that the series is integrated of order one I(1), which means that it is not stationary in levels but it is in first difference.

The sample 1985:1-2007:4 is presented in graph 4.3, it does not exhibit structural breaks but it does show a steep trend by the end of the sample. The standard Augmented Dickey-Fuller was performed (Table 4.12), and again the unit root hypothesis cannot be rejected in levels. It was also concluded that the series is I(1).

Graph 4.1



Since the series is not stationary it is therefore transformed in logarithms and first difference. The logarithmic transformation not only helps to stabilize the variance but also facilitates the interpretation of the series as percentage change. Consequently, this transformation results in the rate of change of oil prices, i.e. oil inflation. The ACF and the PACF of the 1959:1-1984:4 sample suggests an AR(1) process. For comparison purposes, MA(1) and an ARMA(1,1) models were also estimated. The results in Table 4.13 clearly show that oil prices in this period follow an AR(1) process. The term is highly significant whereas the MA(1) term is just nearly significant. The constant term was dropped because it was not significant and dropping it improved the significance of the other terms in the regression.

Furthermore, the correlogram of the residuals do not indicate the need of additional terms with longer lags, as in the next case.

Graph 4.2

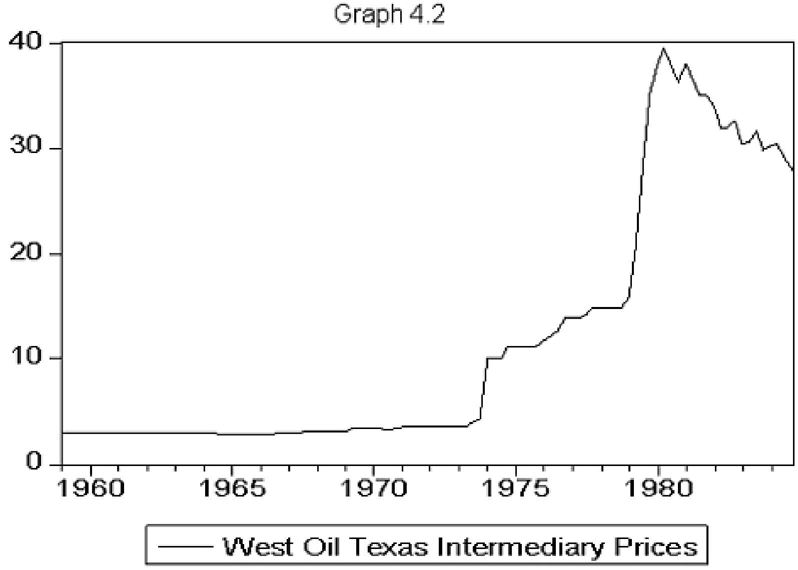


Table 4.10

Null Hypothesis: OIL has a unit root
Exogenous: Constant
Bandwidth: 5 (Newey-West using Bartlett kernel)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-0.558638	0.8739
Test critical values:	1% level	-3.495021	
	5% level	-2.889753	
	10% level	-2.581890	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.985958
HAC corrected variance (Bartlett kernel)	4.720668

Phillips-Perron Test Equation
Dependent Variable: D(OIL)
Method: Least Squares
Date: 07/29/09 Time: 17:06
Sample(adjusted): 1959:2 1984:4
Included observations: 103 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OIL(-1)	-0.000444	0.011726	-0.037854	0.9699
C	0.246841	0.194331	1.270208	0.2069

R-squared	0.000014	Mean dependent var	0.241748
Adjusted R-squared	-0.009887	S.D. dependent var	1.416142
S.E. of regression	1.423125	Akaike info criterion	3.562814
Sum squared resid	204.5537	Schwarz criterion	3.613973
Log likelihood	-181.4849	F-statistic	0.001433
Durbin-Watson stat	0.906356	Prob(F-statistic)	0.969879

Table 4.11

Null Hypothesis: D(OIL) has a unit root
Exogenous: Constant
Bandwidth: 2 (Newey-West using Bartlett kernel)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-5.330805	0.0000
Test critical values:	1% level	-3.495677	
	5% level	-2.890037	
	10% level	-2.582041	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	1.410893
HAC corrected variance (Bartlett kernel)	1.372495

Phillips-Perron Test Equation
Dependent Variable: D(OIL,2)
Method: Least Squares
Date: 07/29/09 Time: 17:08
Sample(adjusted): 1959:3 1984:4
Included observations: 102 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(OIL(-1))	-0.453030	0.084306	-5.373628	0.0000
C	0.104390	0.120723	0.864703	0.3893

R-squared	0.224060	Mean dependent var	-0.011503
Adjusted R-squared	0.216300	S.D. dependent var	1.355103
S.E. of regression	1.199629	Akaike info criterion	3.221315
Sum squared resid	143.9111	Schwarz criterion	3.272786
Log likelihood	-162.2871	F-statistic	28.87587
Durbin-Watson stat	1.958748	Prob(F-statistic)	0.000001

Graph 4.3

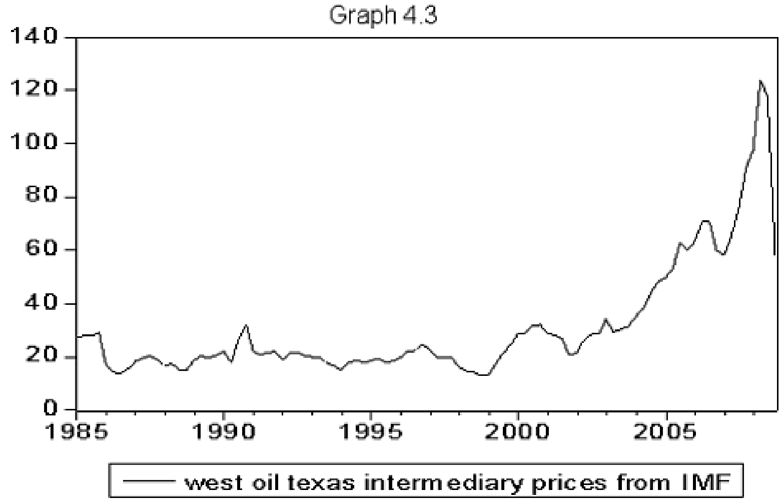

140
120
100
80
60
40
20
0
1985
1990
1995
2000
2005
west oil texas intermediary prices from IMF

Table 4.12

Null Hypothesis: OIL has a unit root
Exogenous: Constant
Lag Length: 5 (Automatic based on SIC, MAXLAG=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.919285	0.9954
Test critical values:	1% level	-3.499910	
	5% level	-2.891871	
	10% level	-2.583017	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OIL)
Method: Least Squares
Date: 07/29/09 Time: 16:45
Sample: 1985:1 2008:4
Included observations: 96

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OIL(-1)	0.050279	0.054694	0.919285	0.3604
D(OIL(-1))	0.449046	0.168059	2.671951	0.0090
D(OIL(-2))	-0.669923	0.181093	-3.699341	0.0004
D(OIL(-3))	0.070904	0.201683	0.351563	0.7260
D(OIL(-4))	-0.542375	0.196343	-2.762382	0.0070
D(OIL(-5))	-0.545101	0.205711	-2.649846	0.0095
C	-0.444302	1.541321	-0.288261	0.7738

R-squared	0.355701	Mean dependent var	0.318299
Adjusted R-squared	0.312265	S.D. dependent var	7.809288
S.E. of regression	6.476227	Akaike info criterion	6.644275
Sum squared resid	3732.795	Schwarz criterion	6.831258
Log likelihood	-311.9252	F-statistic	8.189092
Durbin-Watson stat	1.820616	Prob(F-statistic)	0.000000

Table 4.13. Oil price inflation process 1959:1-1984:4

	1	2	3
Constant	0.0218	0.0216*	
	(0.0122)	(0.0112)	
AR (1)	0.2091***		0.6655***
	(0.0979)		(0.2369)
MA (1)		0.1685*	-0.4428
		(0.0982)	(0.2844)
Q-Stat (24)	12.556	15.217	11.871
p-value	0.961	0.887	0.96

*** Significant at 1%, ** Significant at 5%, * Significant at 10%

The autocorrelation and partial autocorrelation functions in the second sample do not exhibit an identifiable ARMA pattern. In fact, it looks more like a white noise process. Therefore, a "try and error" strategy was adopted, running regressions with different AR and MA terms. The results were judged according to the significance of the regressors, the ACF and PACF of the residuals and the Ljung-Box Q-statistic.

The most relevant results of the try and error process are summarized in Table 4.14. Regression 1 constitutes the purely autoregressive process, however the AR term is significant only at 12%. The value of the estimated AR(1) coefficient is not very different from the one in the previous sample but its significance is, which is relevant for identification purposes. Regressions 2 and 3 incorporate the MA term and not only it is highly significant but also improves the significance of the AR term. The ACF and PACF of the residuals in regressions 1-3 persistently showed significant structure at lag 5. Therefore, lag 5 was taken into account in the model selection process. The best fit is achieved by regression 4, where both terms are highly significant. However this result was not taken into account to carry out simulations in the next section because the theoretical model is limited to two time periods (*t* and *t+1*), whereas regression 4 contains one term at lag 5. Nonetheless, it helps to decide to use an ARIMA (1,1,1) process for the simulations of the 1985:1-2008 sample.

Table 4.14. Oil price process 1985:1-2008:

	1	2	3	4
AR(1)	0.1880		-0.3966*	
	(1.6428)		(0.2385)	
MA(1)		0.3519***	0.6803***	0.3177***
		(0.1046)	(0.1802)	(0.1074)
AR(5)				-0.3173***
				(0.1145)
Q-Stat(24)	22.832	21.413	18.514	19.890
p-value	0.471	0.556	0.675	0.590

*** Significant at 1%, ** Significant at 5%, * Significant at 10%

In the next section, the model will be solved with an ARIMA(1,1,0) oil price process to mimic the response to the shocks of the 1959-1984, and ARIMA (1,1,1) to simulate the 1985-2008 period.

3.4 Solution of the model

The system of the IS and Phillips curves plus the policy rule represent a system of linear difference equations. The solution represents the time series behavior of the variables (output and inflation) as a function of exogenous innovations (oil shocks). This solution must be written in terms of variables expressed as deviations from steady state values. The method employed to solve the model was developed by Blanchard and Kahn (1980). A detailed exposition of the method can be found in appendix 4.1.

To carry out simulations with the solved model, the parameters were given the following values: the discount factor, β= 0.99; the intertemporal elasticity of substitution, $\sigma = 1$; $\phi = 1.55$; the price stickiness parameter, $\theta = 0.5$; Elasticity of demand, $\varepsilon = 1$; the headline/core inflation coefficient in the policy rule $\tau^h = 1.5$; the coefficient of the output gap in the policy rule $\tau^y = 0.5$.

Moreover, the benchmark case is an economy in which the participation of labor in the production process is more important than oil. That is, $\alpha = 0.75$ and $\gamma = 0.25$ in the production function.

The parameters Θ, λ, κ and ζ, are calculated according to chapter 2 of this dissertation, as follows:

$$\Theta = (1 - \alpha)/(1 - \alpha + \varepsilon(\alpha - (1 - \gamma))$$
$$\lambda = \Theta(1 - \theta)(1 - \beta\,\theta)/\theta$$
$$\kappa = \lambda(\varphi + \sigma(1 - \alpha) + \alpha - (1 + \varphi)(1 - \gamma)$$
$$\zeta = \lambda(1 + \varphi)(1 - \gamma)/(1 - \alpha)$$

Finally an oil price process needs to be incorporated to simulate the evolution of the shock. For this purpose, the different ARIMA models identified in the previous section are alternatively used in the exercises below.

This set up, as in previous literature, represents an inflation targeting regime. The central bank reacts strongly to inflation deviations from target and also reacts to output gaps. In this framework, oil prices are added to the policy rule to determine the optimal response to oil inflation and shocks. This constitutes the main research objective in this section, to find the appropriate value for τ^o, i.e. how a central bank should react when facing oil shocks, in the context of a model where oil enters the production process.

3.5 Simulations

The purpose of this section is to identify how the different types of oil price processes, in combination with the policy response, might affect the way an oil shock impacts the economy.

With this purpose, a shock of one standard deviation increase to oil prices is simulated. In this sense, the exercises are performed with the different ARIMA models estimated above, and varying the oil inflation coefficient in the policy reaction function.

In the concepts and notation of the solution method (see the appendix), the nonpredetermined variables ($E_t y_{t+1}$) encompass output and inflation, whereas the predetermined variable (w_{t+1}) is the oil shock. In all simulations, the Blanchard-Kahn stability conditions are tested for the given parameters plus a range of coefficients of oil prices (τ^o) from -10 to +10 in 0.1 increments. The conditions were met in all cases, i.e. there are two eigenvalues bigger than 1 and one smaller in matrix A. This ensures that there is a unique and stable solution, that is a unique optimal value of τ^o in each simulation.

3.5.1 Oil shocks with different oil price processes

Having satisfied the stability conditions, the model is solved and simulated. The simulations contemplate the following policy responses: negative and less than proportional as has been suggested in the literature (τ^c = -0.5), positive and less than proportional (τ^o = 0.5), proportional (τ^o = 1), more than proportional (τ^o = 3) and a very strong reaction (τ^o = 10).

In addition, each policy response, is simulated with different oil shock processes, i.e. AR(1), MA(1) and ARMA(1,1). The parameters for these processes employed in the simulations are those in Table 4.11. The graphs that correspond to the results discussed below are in Appendix 4.2.

Effects on output. As can be seen in Graphs 4.4 to 4.8, the AR(1) process always generates the biggest initial impact but then it is the quickest in returning back to steady state. By the second period it already registers the lowest effect. In general, the MA(1) process shows the lowest initial impact except with a one to one policy response (τ^o=1). In this case the ARMA(1,1) shows the lowest initial effect. It hints that with this type of process a proportional or relatively small response is optimal, at least with the set of values tested and for output only. Furthermore, this response is even superior to the one achieved with the negative response (τ^o = -0.5). For the other two processes, AR(1) and MA(1), the negative response generates the lowest effect on output.

It is also important to highlight that output reductions are always the lowest when τ^o = -0.5, so recessions are reduced when oil price shocks are accommodated.

Effect on inflation. Graphs 4.9 to 4.13 show the effect on inflation. The lowest rates of inflation for all the processes are obtained with a strong response to oil prices in (Graph 4.13). Additionally, as with output, the biggest effect at period one comes with an AR(1) process and then it decays faster than either of the other two cases. The exception is when there is a very strong reaction to oil shocks (τ^o = 10); there the impact is the lowest from the beginning. At the other end of spectrum, a negative response does not favor the inflation response (graph 4.9), as expected. Finally, the lowest initial effect comes from an MA process, except when $\tau^o = 1$. In this case the ARMA process show the lowest response to the shock in period 1.

Effects on the interest rate. As expected, the higher the reaction to oil prices the higher the impact on the interest rate (Graphs 4.14 to 4.18). When the central bank reacts very strongly to an oil shock ($\tau^o = 10$), the increase in the interest rate that follows is lower with an AR(1) process than with any other process. On the contrary, with any other τ^o value the jump in the interest rate with an AR(1) process is the highest. Also, when oil prices are governed by an ARMA process, the increase in the interest rate is lower than with any other process when $\tau^o = 1$.

The AR(1) process. Since oil shocks were governed by an AR(1) process during an important spell (1959:1-1984:4), it is important to determine the optimal response to such type of shock according to its level of persistence. The level of persistence is given by the coefficient of the AR(1) term. Consequently, the model was simulated with coefficients from 0.1 to 0.9 in 0.1 increments. The optimal response to an oil shock is the one that minimizes the central bank loss function. This function is defined as:

$$loss = \varphi_{\hat{y}} var(\hat{y}_t) + \varphi_{\hat{\pi}} var(\hat{\pi}_t) \qquad (33)$$

where $var(\hat{y}_t)$ is the variance of output, $var(\hat{\pi}_t)$ is the variance of inflation and $\varphi_{\hat{y}}$.and $\varphi_{\hat{\pi}}$ are the corresponding weights.

The results are summarized in Graph 4.19 in appendix 4.2. The optimal response is negative for AR(1) coefficients from 0.1 to 0.6. Nonetheless, as the level of persistence goes from 0.7 to 0.9 the optimal policy response becomes positive. Hence, the optimal policy response is sensitive to the level of persistence of the oil sock. This implies that relatively low levels of persistence can be faced by policy makers with an accommodative policy.

It was also found that the optimal response is sensitive to the relative weight of output in the loss function. The exercise was repeated with the extreme case of a very low weight of output variance in (33), i.e. 0.10, and the resultant optimal responses are all positive.

3.5.2 Oil intensity, price flexibility, output importance and optimal rule

The degree of oil intensity in the production process and the degree of price flexibility can in fact determine the impact of an oil shock on the economy. Moreover, the relative importance of output in the central bank loss function has relevant implications for the conduct of monetary policy. The first two parameters in fact have evolved over time. In general, the world has evolved from the 1960's to the 21st century towards less oil intensity and more price flexibility. The purpose of this section is therefore to find out what happens with the optimal response to oil shocks with the change in these variables.

The model is simulated with one thousand normally distributed random oil-price shocks (ε_t^u), with zero mean and standard deviation one. The variance of output ($\hat{y}_t$) and inflation ($\hat{\pi}_t$) for simulations 100 to 1000 are calculated to get the loss function (33).

The simulations were carried out with a wide range of oil price weights ($\hat{\pi}_t$) in the Taylor rule, from -10 to 10 in 0.1 increments. The value of τ^o that minimizes the loss function is considered to be the optimal. The experiments included optimal rule with different degrees of oil intensity, price stickiness and the weight of the output gap in the loss function. results are summarized in table 4.15.

Table 4.15. Optimal policy reaction to oil shocks

Oil intensity	Price Flexibility	Output weight	AR(1) coeff	Optimal τ^o
25%	50%	1	0.2	-3.3
50%	50%	1	0.2	-0.3
75%	50%	1	0.2	0.1
25%	50%	1	0.7	0.1
50%	50%	1	0.7	0.7
75%	50%	1	0.7	0.2
25%	25%	1	0.2	-1
25%	25%	1	0.7	-1.4
25%	25%	1	0.9	-1.5
25%	75%	1	0.2	5.1
25%	50%	0.50	0.2	4.6
25%	50%	0.75	0.2	3.2

Oil intensity refers to the participation of oil as an input in the production function. The more oil intense an economy is, the higher the optimal response of the central bank to an oil shock. In fact the optimum response is negative except when the economy is highly intensive in oil. The reasoning is that when oil price increases, it becomes costlier to produce and firms cut production. If the central bank reacts by increasing the interest rate it would force firms to cut production even further. On the contrary, if the central bank cuts interest rates instead it would ameliorate the impact of the oil shock on production costs and therefore on output. However, the central bank can get away accommodating oil shocks without affecting inflation much only when the economy is not highly oil intensive. When the production process rely heavily on oil as an input the benefits of the accommodative policy are offset by the cost of the rise in inflation. Hence, a positive response is optimum to face oil shocks in the framework of high oil intensity.

Nonetheless, this is true when the oil shock process does not exhibit a high degree of persistence. It can be seen in table 4.15 that when the AR(1) coefficient in the oil shock process is 0.7 the optimal response regarding the level of oil intensity is *always* positive.

Price flexibility in table 4.15 is given by the proportion of firms allowed to change prices in the model in each period ($1 - \theta$). Price rigidity is one of the key element that enables monetary policy to affect the real sector of the economy. Hence with relatively low price flexibility (25% and 50%) the optimal response is negative. On the other hand, the higher the degree of price flexibility the higher the optimal response of monetary policy to oil shocks.

This means that under larger price flexibility the real negative effect of rising the interest rate is less severe. Consequently, the central bank has more freedom to respond positively to the rise in oil prices without punishing economic growth too much. Therefore, with a 75% of price flexibility the optimal response is positive.

Interestingly, this result is not sensitive to the persistence of the oil shock. When the coefficient of the oil shock in the AR(1) process was increased to 0.7 and 0.9 it did not change the sign of the optimal response under 25% of price flexibility (see Table 4.15).

Output weight in table 4.15 is the coefficient of the variance of output in the loss function.

Due to the negative effect on output of increasing the interest rate, the more a central bank cares about growth the smaller the optimal central bank feedback to oil shocks. Nonetheless the optimal reaction is always positive. Although it may turn negative if the relative weight of output becomes bigger than the weight of inflation.

In conclusion, the optimal response to oil shocks can indeed be negative, as previous literature has suggested (De Fiore, Lombardo and Stebunovs, 2006, and Dhawan and Jeske, 200&), but here it has been shown that only under certain circumstances and this constitutes one of the contribution of this chapter. The sign of the optimal reaction to oil shocks is conditional on the level of oil intensity in the production process, the degree of oil-price flexibility, the persistence of the oil shock and the relative degree of importance of output to inflation in the loss function. In particular under low oil intensity, low price rigidity, low shock persistence and low inflation weight in the loss function the optimal response to oil shocks is negative. On the contrary, high oil intensity, high price rigidity, high oil shock persistence render the optimal response positive.

These findings might be the results of the more involved propagation mechanisms in the paper. Finally, it is important to point out that the optimal response to oil prices exhibit quite a bit of variance. It is not the case of a single optimal response but a relatively wide range.

4. Empirical results

The objective of this section is to ask what the Federal Reserve's response to oil prices/shocks has been in practice, and to contrast it with the theoretical results above and the previous literature. With this purpose monetary policy rules of the Taylor type are estimated with core inflation and oil prices, employing the different oil price shock definitions discussed above. The systematic response to oil shocks by the Federal Reserve is something that has not been done before and represents another contribution of this chapter.

4.1 Taylor rule estimations

The strategy followed here is first to replicate the Clarida, Galí and Gertler (2000) estimation of monetary policy rules for the United States. Then the rules will be reestimated and updated incorporating oil prices and core inflation.

Clarida, Galí and Gertler (2000) based their econometric estimation on equations (23) to (26). Here, the reaction function augmented with lags of the interest rate and a disturbance term (equation 25) is expanded with oil prices,

$$r_t=(1-\rho)[rr^* -(\beta -1)\pi^* +\beta E\pi_{t-1}^{core} +\psi E\pi_{t-1}^{oil} +\gamma Ex_{t+1}]+\rho\lambda(L) r_{t-1} +\rho(1-\lambda)r_{t-2} +\epsilon_t \quad (34)$$

where π^{core} is core inflation, π^{oil} is oil inflation, E is an expectation operator and $\rho, \beta, \psi, \gamma$ and λ are parameters.

Equation (34) was estimated with the generalized method of moments with the data described below. Here the key parameter is ψ.

4.1.1 The data

The sample is quarterly data from 1960 to 2007. This is divided in three subsamples: 1960:1- 1979:2, 1979:3-1996:4 and 1997:1-2007:4. The first two subsamples conform with CGG's work, which constitutes the benchmark of our estimations. Dividing the sample in this way not only allows for comparison but also correspond to the pre and Volcker-Greenspan eras.

The third period represents an update of the rule, and gives some additional insights about how monetary policy has reacted to oil shocks in the last ten years.

All the data, with the exception of core inflation, that comes from the Bureau of Labor Statistics, are from the International Financial Statistics of the International Monetary Fund. The policy rate (r_t) is the Federal funds rate (FFR) and, as in CGG (2000), the observed sample average is taken as a measure of the equilibrium real rate (rr^*). Core inflation (π^{core}) is consumer price index inflation less food and energy prices. These two items are excluded from core inflation on the basis of their high volatility which, in general, is not attributable to monetary factors. Oil prices can be driven by political events (wars for instance) and food prices can depend on seasonal or climate factors. Oil prices are West Texas Intermediate U.S. dollars per barrel. Output is seasonally adjusted quarterly GDP in billions of chained 2000 dollars. Potential output is the estimated by the Congressional Budget Office of the U.S. Congress, in billions of chained 2000 dollars.

Following CGG, the set of instrumental variables (Ω) to carry out the GMM estimation of (25) comprises: commodity price inflation (oil and food), M2 growth, and the "spread" between the long-term bond rate (ten-years Treasury bill) and the three-month Treasury Bill rate, and lags of the FFR, inflation, and the output gap.

4.1.2 Estimation

Replication of Clarida, Gali and Gertler estimates. The reproduction of the CGG's estimation results are presented in table 4.16. The estimates are based on equation (25) with two lags of the interest rate and four lags of the instruments. The equation was estimated with the two alternative measures of potential output described above, one from the Budget Office of the Congress and the other based on the Hodrick-Prescott filter. In general the estimations with the potential output from the United States Congress must be regarded as the benchmark, as used in CGG. The results with the alternative measure are for the sake of robustness and because of the widespread use the Hodrick-Prescott filter to estimate potential output.

Replication 1 was estimated with potential output from the Congressional Budget Office, and Replication 2 with the HP filter. The minor differences in the results can be attributed to primary data revisions and the use of different sources; we use mainly the IMF and the Federal Reserve data bases whereas CGG's data is from CITIBASE. The compared CGG results correspond to the baseline estimations, with GDP deflator changes as the inflation measure (Table II in CGG).

The replication estimates are consistent with CGG in both samples. The differences in the target inflation rate, π^*, show the decreasing inflation trend in the second period.
Regarding the inflation coefficient (β), the new estimates also exhibit values less than one in the first sample, and greater than one in the second. The first case, as explained

above, would lead to indeterminacy of the equilibrium, raising the possibility of fluctuations in output and inflation around their steady state values that result from self-fulfilling revisions in expectations. The value of ρ in the replications also show that the Federal Reserve Bank smooths changes in the interest rate, with a trend towards greater smoothing in the second period.

The most relevant difference between the replications and the original estimates, is that the output gap coefficient (γ) is bigger than one when using the Hodrick-Prescott output gap in the period 1979:3-1996:4. In general, the policy response to the output gap tend to be bigger and more significant (at least in the second period) in the replications. It is important to point out that in CGG (2000) the significance and value of the output coefficient proved to be not very robust to different specifications of output, potential output and inflation (see Table III in CGG, 2000). Although it is also important to take into account that the Hodrick-Prescott results obtained today can be quite a bit different to those estimated in 2000, due to data revisions.

The estimates with the expanded sample, 1979:3-2007:4, show the continued commitment of the Federal Reserve to fight inflation. That is, the inflation coefficients are very significant and higher than in any other estimation. Moreover, the central bank appears to have responded strongly to deviations from potential output as well. This response is smaller than the response to inflation when using the estimation of the output gap from the U.S. Congress, however it is the other way around with the alternative measure of potential output. Overall, it can be said that the estimation of this sample is also consistent with low and stable levels of inflation.

Table 4.16 Replication of CGG

	1960: 1 - 1979: 2			1979: 3 - 1996: 4			1979: 3 - 2007: 4	
	CGG	**Rep. 1**	**Rep. 2**	**CGG**	**Rep. 1**	**Rep. 2**	**Est.1**	**Est. 2**
π^*	4.24***	2.659***	4.385***	3.58***	1.200***	1.663***	1.508***	1.90***
	(1.09)	(1.123)	(0.469)	(0.50)	(0.407)	(0.456)	(0.412)	(0.477)
β	0.83***	0.863***	0.712***	2.15***	2.004***	1.676***	2.835***	2.284***
	(0.07)	(0.044)	(0.043)	(0.40)	(0.220)	(0.168)	(0.412)	(0.358)
γ	0.27***	0.365***	0.744***	0.93***	0.945***	1.493***	1.271***	2.866***
	(0.08)	(0.059)	(0.104)	(0.42)	(0.222)	(0.269)	(0.315)	(0.534)
ρ	0.68***	0.647***	0.675***	0.79***	0.714***	0.717***	0.851***	0.865***
	(0.05)	(0.027)	(0.043)	(0.04)	(0.041)	(0.036)	(0.028)	(0.022)
J - test	0.834	0.998	0.998	0.138	0.99	0.990	0.99	0.994

Estimations of the response to oil prices.

This section discuses the estimates of the Federal Reserve reaction function with oil prices included, i.e. estimating equation (34). Oil prices are introduced with three different definitions: changes in West Texas Intermediate oil prices (TOP), net oil prices as defined by Hamilton (NOP), oil price increases only (OPIO) and negative oil price changes only (OPDO), considered separately as in Mork (1989). Also, in this estimation core inflation is used instead of changes in the GDP deflator to avoid duplicity of oil/energy prices in the equation, and the potential GDP measure is from the U.S. Congress.

In order to contrast the empirical results with the analysis of the oil prices process in 4.3.2 , the ARMA process of the oil price series for each specific sample is identified. As it was found above, the magnitude and duration of the price shock can be influenced by the type of ARMA process that characterizes it. As a consequence, the optimal response varies accordingly. Here the oil process that governs oil price in each sample is identified to contrast it with the estimated policy response. The questions asked are: Did the Federal Reserve reacted optimally according to the oil price process? Could the Federal Reserve have responded differently to minimize the negative effects of the shock?

How should the Fed react next time the economy faces a surge in oil prices?

The models were identified following the Box and Jenkins methodology described above. Table 4.17 shows that the 1960:1-1979:2 follow an AR(1) process, the second sample (1979:3-1996:4) is governed by an ARMA(1,1) process, and a third period from 1997:1 to 2007:4 can be described by an MA(1) model. This last period was included to account for the most recent development of the oil price series.

Table 4.17. Oil price process

	1960:1 1979:2	1979:3 1996:4	1997:1 2007:4
Constant	0.2607	3.1608***	0.0303
	(1.3279)	(0.1156)	(0.0235)
AR(1)	1.020***	0.8167***	
	(0.018)	(0.0758)	
MA(1)		0.3995***	0.3541***
		(0.1205)	(0.1455)
Q-Stat(24) *p-value*	8.7018 0.997	20.091 0.577	18.514 0.503

*** Significant at 1%, ** Significant at 5%, * Significant at 10%

The results of the first sample (1960:1-1979:2) in Table 4.18 show that the target inflation rate does not vary importantly across the different estimations with the different oil price measures, and is coherent with the relatively higher inflation rates experienced in this period compared to the other two samples (see below). The magnitude and the value of the inflation coefficient (β) is homogeneous over the estimations and, importantly, it is smaller than one which is accordant with CGG (2000). The policy response to oil prices is mostly small but significant and positive. The magnitude varies from the response to NOP, the highest, followed by OPIO and TOP. This hints that meaningful oil price increases are more important. In particular, according to the rule in column 1, the Federal Reserve responds to a 10% increase in the oil price rising the interest rate in 0.03%. If oil prices double interest rates increase by 0.3%. If there is a doubling of the net oil price (column 2) interest rates increase by 2.3%. These are quite big responses to a big oil price jump, especially considering that doubling (i.e. 100% increase) is fairly common with oil prices. The response to the same shock in rules 2 and 3, is 0.23% and 0.05% respectively. The OPDO coefficient (rule 4) is not significant, which might indicate either asymmetry in the policy response to oil shocks or the absence of large and sustained oil price reductions in this period, as Hamilton (1996) points out. The output coefficient is smaller than one and significant in all cases, as in CGG's benchmark estimation. Finally the estimates for ρ and λ, are both significant and show that the Federal Reserve smooths changes in the interest rate.

Considering that in this period oil prices followed an AR(1) process, according to the identification presented in table 4.17, the Federal Reserve should arguably have responded more strongly to them. As it was found in our theoretical model (section 4.3.5.1), the AR(1) process is potentially the most harmful type for the economy and it is optimal to react strongly to ameliorate its impact.

The results also show that the response was always positive, which is congruent with the optimal rule given the high level of persistence that characterized oil shocks in that period (see Table 4.15). Specifically, the coefficient of the AR(1) term is well above 0.7 which, according to the discussion in 4.3.4.2, turns the optimal negative response into positive for any level of oil intensity. Moreover the share of oil was bigger in the 1970's (Blanchard and Galí, 2008), something that also makes the optimal response positive.

Finally, the results do not hint any negative response to oil shocks with any of the shock measures employed in the exercise, contrary to the optimal negative response suggested in the literature (De Fiore, Lombardo and Stebunovs, 2006, and Dhawan and Jeske, 2007) and under some specific circumstances in this chapter.

Table 4.18. Core and oil inflation 1960:1-1979:2

	1	2	3	4
	Texas Oil prices (TOP)	**Net Oil prices (NOP)**	**Oil price increases (OPIO)**	**Oil price decreases (OPDO)**
π^*	2.91***	3.085***	3.086***	3.286***
	(0.364)	(0.389)	(0.388)	(0.383)
β	0.740***	0.742***	0.741***	0.736***
	(0.026)	(0.032)	(0.033)	(0.032)
ψ	0.003***	0.023***	0.005***	-0.327
	(0.009)	(0.009)	(0.002)	(0.250)
γ	0.272***	0.298***	0.298***	0.274***
	(0.057)	(0.055)	(0.055)	(0.052)
ρ	0.65***	0.593***	0.594***	0.644***
	(0.03)	(0.029)	(0.029)	(0.021)
λ	1.581***	1.588***	1.587***	1.626***
	(0.062	(0.057)	(0.057)	(0.069)
J - test *p - value*	 0.99	 0.99	7.980 0.997	8.18 0.996

Estimation of (34) for the second period (1979:3-1996:4) (Table 4.19) produce inflation and output coefficients that also can be considered congruent with CGG (2000). The core inflation parameter is bigger than one and highly significant in all cases. The parameter γ is significant and bigger than the corresponding estimate in the preceding period. With respect to oil prices, the corresponding coefficient is positive and significant in all cases except for NOP. The rule in column 1 dictates that when the price of oil increases in 10%, the Federal Reserve reacts increasing the interest rate in 0.46%. A doubling of oil prices leads to an increase in interest rates of 4.6%. The reaction in column 3 (regression with OPIO as oil-price shock definition), following the same 10% increase in oil prices, is 0.6%. Interestingly, in this period the ψ coefficient (with OPDO as oil-price shock definition) is significant and with the expected sign. That is, a 10% negative variation results in a 1.09% reduction of the interest, according to the rule in column 4. This suggests that in this period the Federal Reserve did react significantly to oil price decreases relaxing its monetary policy, arguably to support economic growth. Here it is important to point out that Hamilton (1996) argues that the period between 1986 and 1992 was characterized by large oil price decreases, something that did not occur in the previous sample (1960:1-1979:2). These results reveal some symmetry in the response of the Federal Reserve to oil shocks in this particular period, despite the asymmetry of the effects of oil shock on the economy. In general, the magnitude of the estimators display a stronger response to oil shocks in this period than previously, although it is still less than proportional (smaller than one) and most importantly, positive. As in the previous sample, the sign of the oil price coefficients, in all cases, conform with the resultant optimal response in this paper; contrary to the optimal reaction suggested previously in the literature.

The reaction of the Federal Reserve is consistent with the ARMA(1,1) process that governed oil prices in this period. The optimal response to such process was found to be small or proportional. It might be one of the reasons of why monetary policy was more successful in this period than in the one that preceded. Not only an ARMA(1,1) process seems to be less harmful but also the policy response was more appropriate.

The policy response is always positive which is also consistent with the optimal response discussed in 4.3.4.2. Oil-price shocks are again governed by a very persistent AR(1) process, the autoregressive coefficient is above 0.7 (Table 4.17). Therefore the optimal response to any degree of oil intensity should be positive.

Additionally, the resultant inflation targets are not statistically different from zero, except in the OPIO case. This might be the reflection of very low inflation targets or an outcome from using core inflation instead of headline inflation (the inflation target is normally set for headline inflation). Finally the estimated values of ρ and λ indicate a higher degree of interest rate smoothing by the Federal Reserve.

Table 4.19 Core inflation and oil prices 1979:3-1996:4

	1	**2**	**3**	**4**
	Texas Oil prices (TOP)	**Net Oil prices (NOP)**	**Oil price increases (OPIO)**	**Oil price decreases (OPDO)**
π^*	1.679	2.604	5.610**	-2.613
	(1.262)	(2.272)	(2.412)	(2.599)
β	1.357***	1.366***	1.368***	1.456***
	(0.173)	(0.210)	(0.185)	(0.213)
ψ	0.046***	0.113	0.060**	0.109***
	(0.016)	(0.090)	(0.024)	(0.037)
γ	0.889***	1.092**	0.92**	1.316***
	(0.373)	(0.440)	(0.386)	(0.052)
ρ	0.821***	0.839***	0.837***	0.835***
	(0.03)	(0.023)	(0.023)	(0.031)
λ	0.755***	0.738***	0.738***	0.733***
	(0.055)	(0.045)	(0.053)	(0.053)
J - test *p - value*	7.51 0.998	10.80 0.990	10.627 0.987	11.361 0.979

The estimation of the policy rule is updated expanding the sample from 1979 up to the most recent data available outside the current financial crisis (2007:4), (Table 4.20). Again, the response to deviations from the inflation target is more than proportional, i.e. bigger than one and highly significant in all cases. This reinforces the long term commitment of the Federal Reserve to price stability. As for the response to oil prices, the coefficient is overall not significant (it is significant at 10% for TOP only). The NOP coefficient has negative sign which is consistent with the optimal response under some circumstances, but it is not statistically different from zero. The lack of any meaningful response can be interpreted as a decline in the response to oil shocks over time. That the response to oil shocks was found to be positive and significant in the 1979:3-1996:4 sample but not significant in the 1979:3-2007:4 spell suggests an structural brake in the regression. This indicates that the response in the 1997:1-2007:4 spell was either mute or even negative. The direct estimation of the rule for the 1997:1-2007:4 sample did not produce satisfactory results, maybe due to the shortness of the sample.

That the Federal Reserve can get away with not responding to oil shocks (or perhaps responding negatively) without causing a major macroeconomic crisis might be, in part, due to the oil price process. A pure MA process proved in general to generate the lowest initial impact on output and inflation, and to require the lowest increase in the interest rate as policy response. Therefore, if in fact oil prices are currently governed by an MA process, then the central bank does not need to react as strongly as it had in the past.

Furthermore, the trend towards less oil intensity in the twenty first century together with the low persistence of the oil-price process indicate a negative optimal policy response to oil shocks, according to the discussion in 4.3.4.2.

On the other hand, the feedback to deviations from potential output is strong and highly significant. In fact, this is even greater than the reaction to inflation. It might be that, due to the lack of inflationary pressures in the last years the central bank has had more room to maneuver to stabilize output. In fact the standard deviation of core inflation is 2.8, 2.67 and 0.38 respectively for the periods 1960:1-1979:2, 1979:3-1996:4 and 1997:1-2007:4.

The estimated inflation target is again not different from zero, as discussed above. Finally, the smoothing coefficients ρ are the largest across the three sample, which indicates a trend towards greater interest rate smoothing.

Table 4.20 Core inflation and oil prices 1979:3-2007:4

	1	**2**	**3**	**4**
	Texas Oil prices (TOP)	**Net Oil prices (NOP)**	**Oil price increases (OPIO)**	**Oil price decreases (OPDO)**
π^*	1.359	-2.989	-1.325	-2.292
	(1.544)	(5.627)	(13.746)	(2.391)
β	1.423***	1.217***	1.107***	1.447***
	(0.173)	(0.167)	(0.194)	(0.208)
ψ	0.033*	-0.090	0.021	0.071
	(0.017)	(0.128)	(0.032)	(0.033)
γ	0.282	2.785***	2.850***	0.866***
	(0.278)	(0.717)	(0.386)	(0.260)
ρ	0.855***	0.875***	0.886***	0.861***
	(0.024)	(0.016)	(0.016)	(0.018)
λ	0.863***	0.738***	0.742***	0.809***
	(0.060)	(0.048)	(0.042)	(0.056)
j - test *p - value*	24.137 0.396	15.24 0.885	13.642 0.937	15.913 0.859

4.4.2 Summary and conclusions

In conclusion, the empirical evidence suggests that the Federal Reserve has indeed responded to oil prices in the 1960:1-1979:1 and 1979:2-1996:4 samples. This reaction has been in general small but positive, and statistically significant. Oil prices followed an AR(1) in the first period, which suggest that the Federal Reserve could have been more successful by reacting more strongly. The positive response in this period is in line with the optimal policy response given the high persistence of the oil-price shocks and the relatively high oil intensity that characterized this period.

The highest degree of feedback occurred in the period 1979:2-1996:4. This is more in line with the ARMA(1,1) process of oil prices in this period, which suggest a small or proportional response. There is also evidence of symmetrical response in this particular period. The response is again positively signed, with all the different definitions of oil shock, which again is optimal due to the highly persistent process of the oil shocks of the period.

However, the policy response to oil prices has tended to decline in the last ten years, until recently becoming insignificant. There is indication of structural brake in this period that suggests that the policy response has been either mute or negative. This type of response might be partially explained by the MA(1) process that governs oil prices in this period. A pure MA process is the least harmful and the one that requires, in general, the least degree of intervention by the central bank. Furthermore, under low oil intensity and low oil-price shocks persistence, the optimal response is negative.

Finally, previous literature has argued that a negative policy response to oil shocks is optimal in terms of welfare (De Fiore, Lombardo and Stebunovs, 2006), or in cushioning the effects of an oil shock (Dhawan and Jeske, 2007). Instead, the rules show a positive feedback to oil shocks, which can also be optimal according to the theoretical simulations performed in 3.3.4.2.

5. Conclusions

The contribution of this paper is to show that, under some circumstances, a positive monetary policy response to oil shocks can be optimal. This constitutes a new result since previous literature has suggested that it is optimal for the central bank to accommodate oil shocks responding negatively (cutting interest rates). Employing a New Keynesian model expanded with oil in the production function, it was found that in fact, a negative response can be optimal under low oil intensity and high price rigidity. However, when the production process is highly oil intensive or prices are highly flexible then it is optimal not to accommodate inflation but to react positively. Furthermore, some of this results are sensitive to the persistence of the oil shock. In particular, it was found that under low oil intensity if the oil shock is highly persistent it is optimal to respond positively and not negatively as stated above. Finally, a low weight of output relative to inflation also implies a positive optimal response.

Additionally this chapter presents new evidence on the response of the Federal Reserve to oil prices and shocks. There is indication that the response has been significant but less than one to one in both, the period before and during the Volcker-Greenspan era. The Federal Reserve has somehow accommodated oil shocks by reacting less than proportionally to minimize the negative effect on output. Moreover, it appears that in fact the Federal Reserve was more active responding to oil shocks in the 1979-1996 period than in 1960-1979.

The significance of the response however has almost disappeared in more recent years. It could be that, due to the decrease of the effects of oil shocks on the macroeconomy as Blanchard and Galí (2008) have documented, the Federal Reserve has not needed to intervene (or perhaps even to react negatively). If in fact the trend towards better monetary policy, more wage flexibility and less oil dependency has diminished the effect of oil shocks, all these factors might as well have contributed in reducing the need for central bank interventions.

The ARMA process that governs oil prices might, in part, also explain their impact on the economy and the optimal policy response. An AR process has the biggest initial impact but then dies away quicker than the other processes. It also requires a very strong policy response. On the other hand a pure MA process makes the lowest initial impact and requires the lowest policy reaction. Also, the optimal response to an ARMA process is positive and small or proportional. It was identified that the period before 1985, oil prices followed an AR(1) process, for which a strong policy response is optimal. On the other hand, the "Great Moderation" spell (195-2007), is better described by an ARMA (1,1) process, for which a small or proportional response is optimal.

In this sense and given that oil prices were characterized by an AR(1) process, the Federal Reserve arguably should have reacted more strongly increasing interest rates in the 1960:1- 1979:2 period. The positive, significant and relatively small response of the Fed in the 1979:3-1996:4 period is a more appropriate policy for the ARMA(1,1) process that oil prices followed in this period. This might be one of the reasons why monetary policy was more successful in this spell. Finally if oil prices have indeed followed an MA(1) process in the last ten years, it might help the Federal Reserve to reduce its degree of intervention when oil shocks occur.

It is also important to point out that there is no evidence of any negative feedback, as some researchers have argued to be optimal, in contrast to the theory presented here.

Appendix 4.1 Blanchard and Kahn Solution Method

The exposition of the Blanchard and Kahn solution method here follows Dejong and Dave (2007) and Barnett and Ellison (2005).

The system of equations expressed as deviations from steady state is given by (35)

$$\hat{y}_t = E_t\,\hat{y}_{t+1} - \hat{\imath}_t + E_t\,\hat{\pi}_{t+1} \tag{35}$$

$$\hat{\pi}_t = \beta E_t\,\hat{\pi}_{t+1} + K\hat{y}_t + \zeta u_t \tag{36}$$

$$\hat{\imath}_t = \tau^{\pi}\,\hat{\pi}_t + \tau^{o}\,\hat{u}_t + \tau^{y}\,\hat{y}_t$$

where ^ means deviations from steady state. Substituting $\hat{\imath}_t$ into the IS equation yields

$$\hat{y}_t = E_t\,\hat{y}_{t+1} - \tau^{\pi}\,\hat{\pi}_t - \tau^{o}\,\hat{u}_t - \tau^{y}\,\hat{y}_t + E_t\,\hat{\pi}_{t+1}$$

The system of equations has now been reduced to two equations. Rearranging terms so that the *t+1* terms are function of the terms in *t*, and adding the oil prices ARMA process, the system becomes:

$$E_t\,\hat{y}_{t+1} + E_t\,\hat{\pi}_{t+1} = \hat{y}_t\,(1 + \tau^{y}) + \tau^{H}\,\hat{\pi}_t + \tau^{o}\,\hat{u}_t$$

$$\beta\,E_t\,\hat{\pi}_{t+1} = \hat{\pi}_t - K\hat{y}_t - \zeta\,u_t$$

$$u_t = \eta + \psi\,\varepsilon^{u}_{t-1} + \rho_u\,u_{t-1} + \varepsilon^{u}_t$$

The oil price ARMA process was identified using the West Texas Intermediate prices series, and following the standard Box and Jenkins method.

The system of equations can also be represented in matrix notation, which is the state space representation/form.

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & \beta \end{bmatrix}\begin{bmatrix} u_{t+1} \\ \hat{y}_{t+1} \\ \hat{\pi}_{t+1} \end{bmatrix} = \begin{bmatrix} \rho_u & 0 & 0 \\ \tau^{0} & (1+\tau^{y}) & \tau^{H} \\ -\zeta & -k & 1 \end{bmatrix}\begin{bmatrix} u_t \\ \hat{y}_t \\ \hat{\pi} \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}\begin{bmatrix} \varepsilon^{u}_t \end{bmatrix} \tag{37}$$

The model is now ready to be solved, as described below.

Having linearized the model around steady state (??), now the objective is to obtain a recursive solution where all the variables are function of predetermined variables and structural shocks. The departing point is the state-space representations,

$$A_0 X_{t+1} = A_1 X_t + B_0 \upsilon_{t+1} \tag{38}$$

$$E_t X_{t+1} = A_0^{-1} A_1 X_t + A_0^{-1} B_0 \upsilon_{t+1} \tag{39}$$

where X_t represent the transformed time series, υ_t is a vector of exogenous innovations or structural shocks, and A_0, A_1 and B are matrices or parameters. Blanchard and Kahn's method is applied to models expressed as

$$\begin{bmatrix} w_{t+1} \\ E_t\,y_{t+1} \end{bmatrix} = A\begin{bmatrix} w_t \\ y_t \end{bmatrix} + B\upsilon_{t+1} \tag{40}$$

where the model variables have been divided into an n_2 X 1 vector of endogenous predetermined variables w_t (defined as variables for which $E_t(w_{t+1}) = w_{t+1}$), and an n_2X1 vector of endogenous nonpredetermined variables y_t (for which $y_{t+1} = E_t(y_{t+1}) + \eta_{t+1}$, with η_{t+1} representing an expectational error). The *k* X 1 vector υ_t contains exogenous forcing variables. Also, $A = A_0^{-1}A_1$ and $B = A_0^{-1}B_0$.

The method begins with a Jordan decomposition of *A*,

$$A = P\,\Lambda P^{-1} \tag{41}$$

the diagonal elements of Λ consist of the eigenvalues of *A* and are ordered in increasing absolute value from left to right. It can be written as

$$\Lambda = \begin{bmatrix} \Lambda_1 & 0 \\ 0 & \Lambda_2 \end{bmatrix}$$

The solution of the model is unique if the number of unstable eigenvectors of the system is exactly equal to the number of forward-looking (control) variables. That is, the eigenvalues in Λ_2 lie outside of the unit circle and consequently, Λ_2 is said to be explosive or unstable because it diverges as *n* increases. If the number of explosive eigenvalues is equal to the number of nonpredetermined variables, the system is said to be saddle-path stable and a unique solution to the model exists. Furthermore, if the number of explosive eigenvalues exceeds the number of nonpredetermined variables, no solution exists (the system is said to be a source); in the opposite case an infinity of solutions exist (the system is said to be a sink). On the other hand, the eigenvalues in Λ_1 lie on or within the unit circle (are smaller than one)

The matrices Λ and B are partitioned conformably as

$$P = \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix}, \quad B = \begin{bmatrix} B_1 \\ B_2 \end{bmatrix}$$

Assuming saddle-path stability, (41) is substituted in (40),

$$\begin{bmatrix} w_{t+1} \\ E_t y_{t+1} \end{bmatrix} = P \Lambda P^{-1} \begin{bmatrix} w_t \\ y_t \end{bmatrix} + B\upsilon_{t+1}$$

The system is then premultiplied by P^{-1} , yielding

$$P^{-1} \begin{bmatrix} W_{t+1} \\ E_t y_{t+1} \end{bmatrix} = \mathbf{\Lambda} P^{-1} \begin{bmatrix} W_t \\ Y_t \end{bmatrix} + R\upsilon_{t+1}$$

where $R = P^{-1} B$ and defining

$$P^{-1} = \begin{bmatrix} P^*_{11} & P^*_{12} \\ P^*_{21} & P^*_{22} \end{bmatrix}$$

$$P^*_{11} w_t + P^*_{12} = \tilde{w}_t$$

$$P^*_{21} w_t + P^*_{22} = \tilde{y}_t$$

The decoupled system can be re-written as,

$$\begin{bmatrix} \tilde{w}_{t+1} \\ E_t \tilde{y}_{t+1} \end{bmatrix} = \begin{bmatrix} \Lambda_1 & 0 \\ 0 & \Lambda_2 \end{bmatrix} \begin{bmatrix} \tilde{w}_t \\ \tilde{y}_t \end{bmatrix} + \begin{bmatrix} R_1 \\ R_2 \end{bmatrix} \upsilon_{t+1} \qquad (42)$$

This transformation decouples the system, so that the non-predetermined variables depend upon only the unstable eigenvalues of A contained in Λ_2 (lower part of 42), and the predetermined variables upon the stable portion of the model (upper part of 42).

From here, the solution strategy is to solve separately the unstable and stable transformed equations, and subsequently translate back into the original problem. The resultant solution is given by

$$y_t = -P^{*-1}_{22} \; P^*_{21} \; w_t$$

$$w_{t+1} = (P^*_{11} - P^*_{12} \; P^{*-1}_{22} P^*_{21})^{-1} \Lambda_1 (P^*_{11} - P^*_{12} P^{*-1}_{22} P^*_{21}) \, w_t +$$

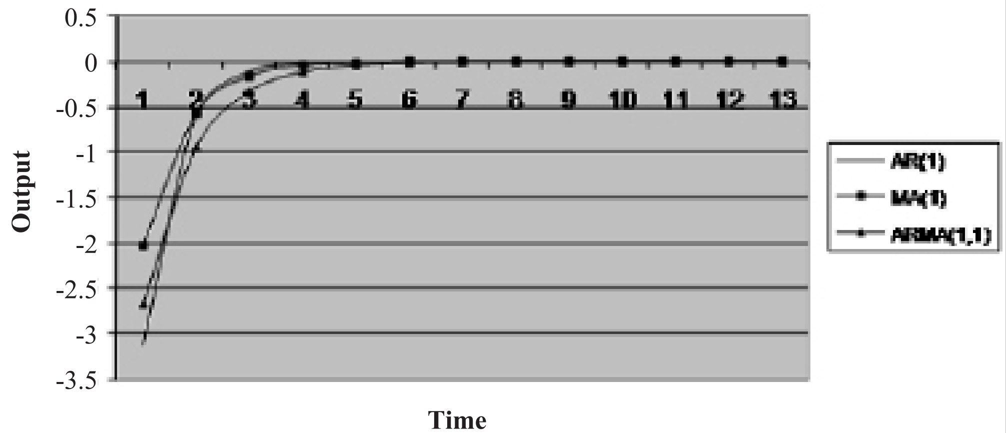
$$(P^*_{11} - P^*_{12} P^{*-1}_{12} P^*_{21})^{-1} R_1 \upsilon_{t+1}$$

where all variables are function of backward-looking variables and therefore represents a recursive structure.

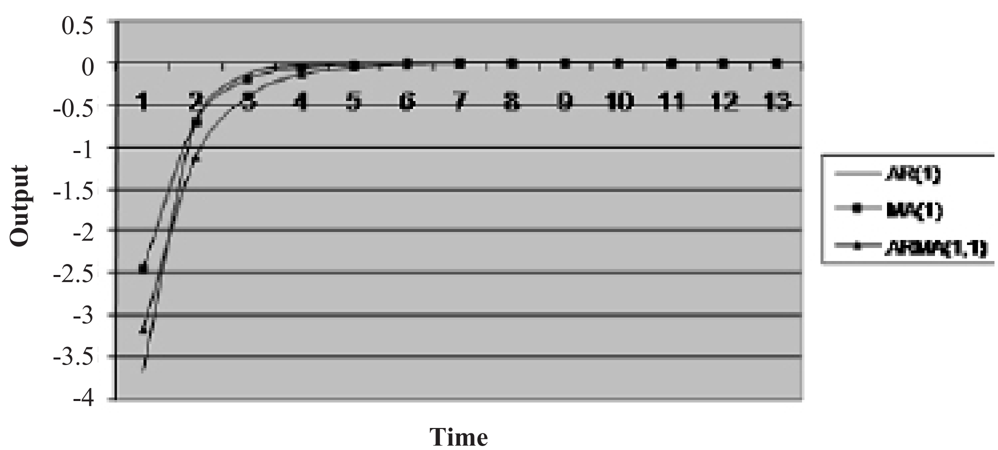
Appendix 4.2

A. Output response

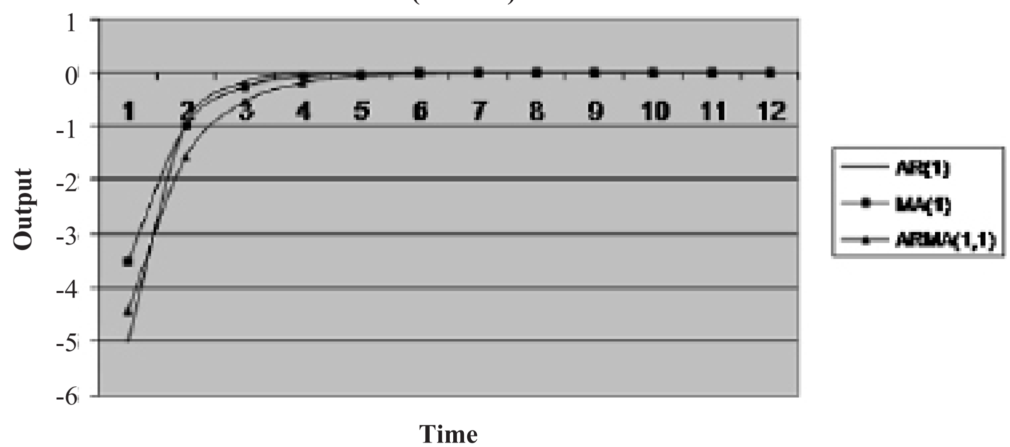
Graph 4.4
Output impulse-response function to an oil shock
(Tauo=0.5)



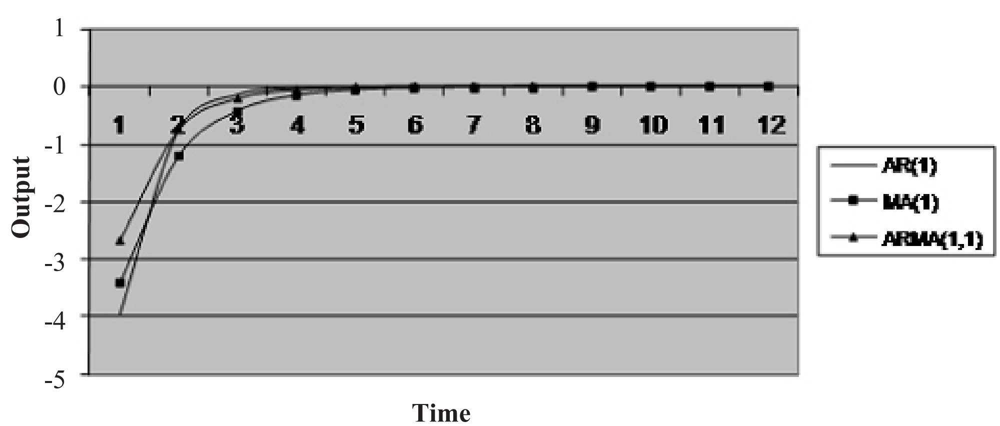
Graph 4.5
Output impulse-response function to an oil shock
(Tauo=0.5)



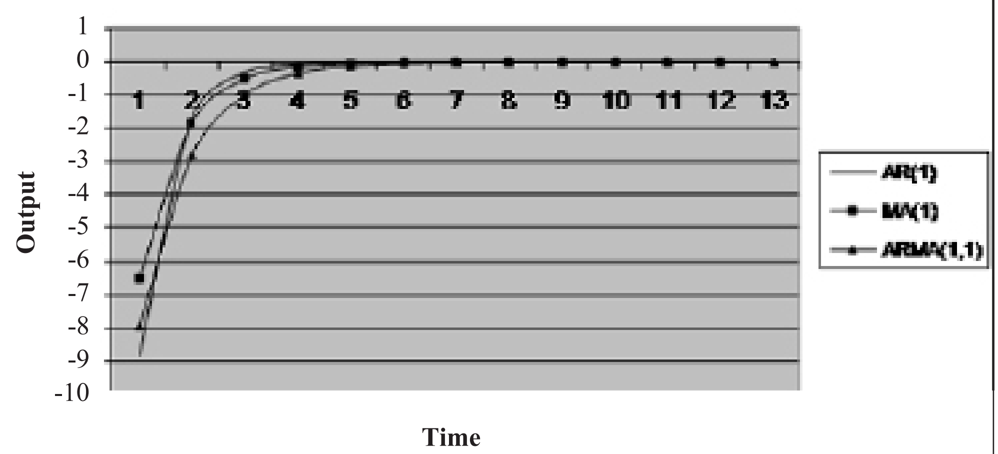
Graph 4.6
Output impulse-response function to an oil shock
(Tauo=1)



Graph 4.7
Output impulse-response function to an oil shock
(Tauo=3)

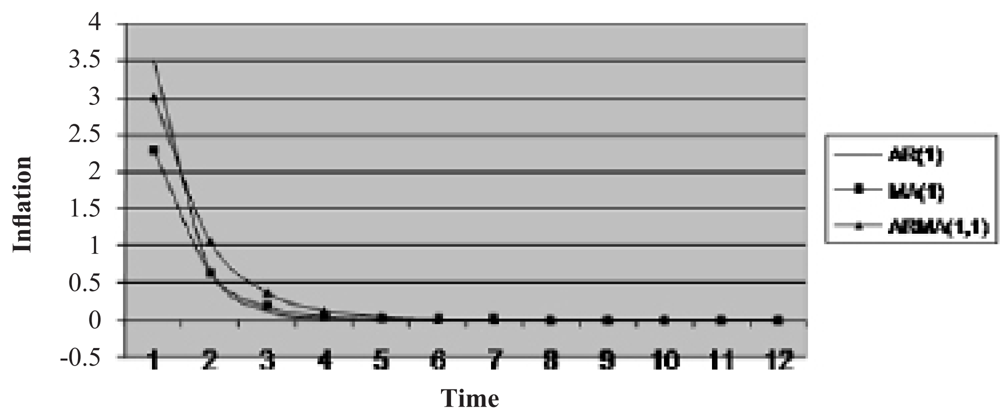


Graph 4.8
Output impulse-response function to an oil shock
(Tauo=10)

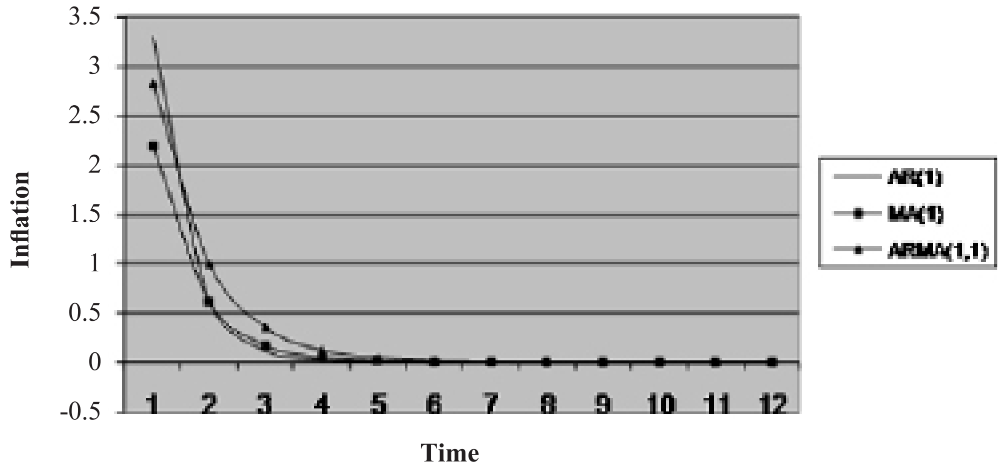


B. Inflation response

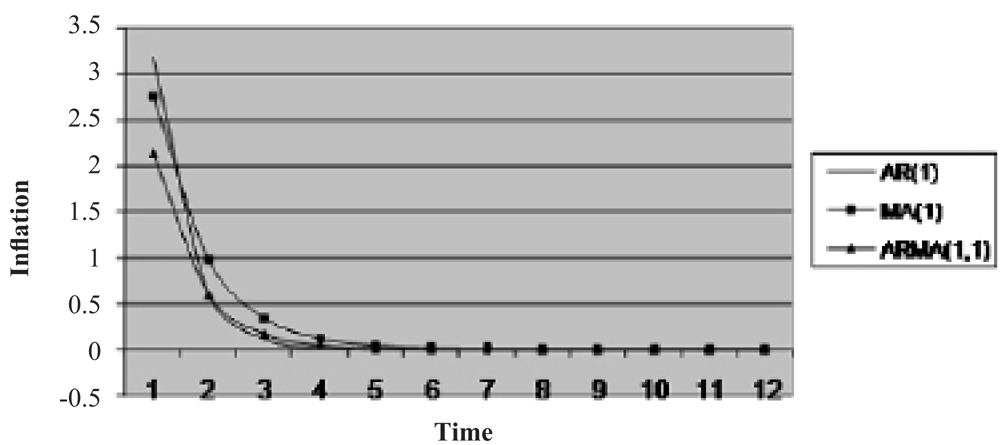
Graph 4.9
Inflation impulse-response function to an oil shock
(Tauo=0.5)



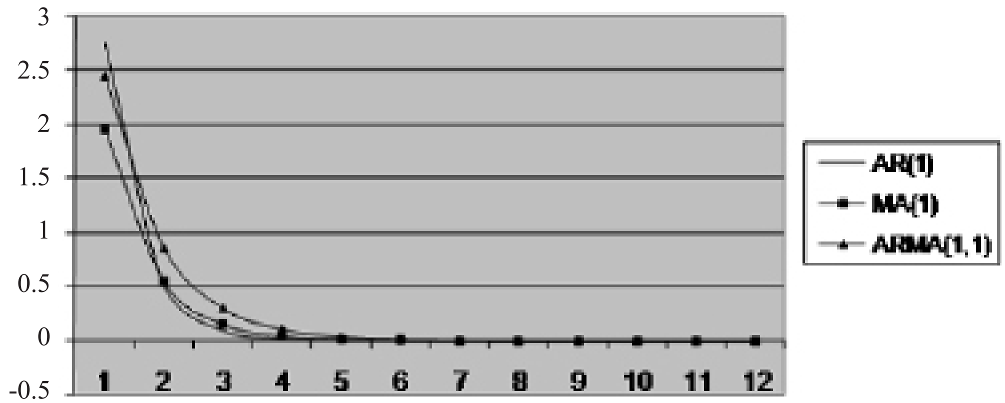
Graph 4.10
Inflation impulse-response function to an oil shock
(Tauo=0.5)



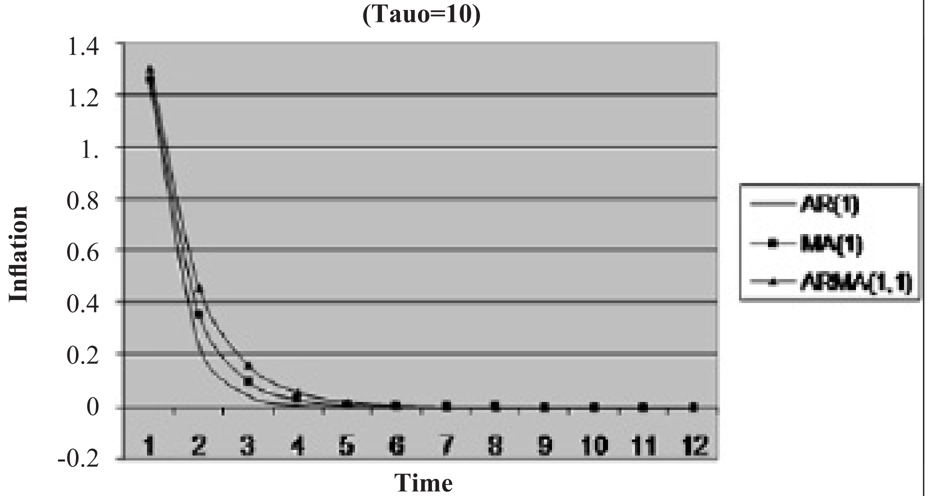
Graph 4.11
Inflation impulse-response function to an oil shock
(Tauo=1)



Graph 4.12
Inflation impulse-response function to an oil shock
(Tauo=3)

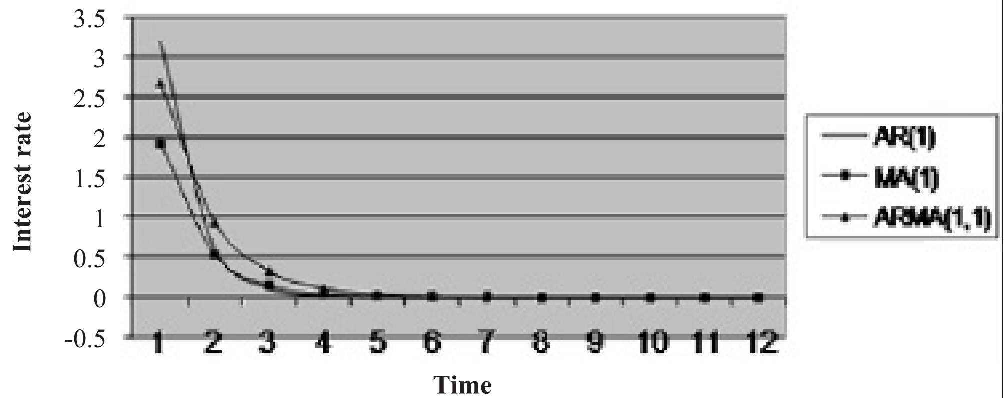


Graph 4.13
Inflation impulse-response function to an oil shock
(Tauo=10)

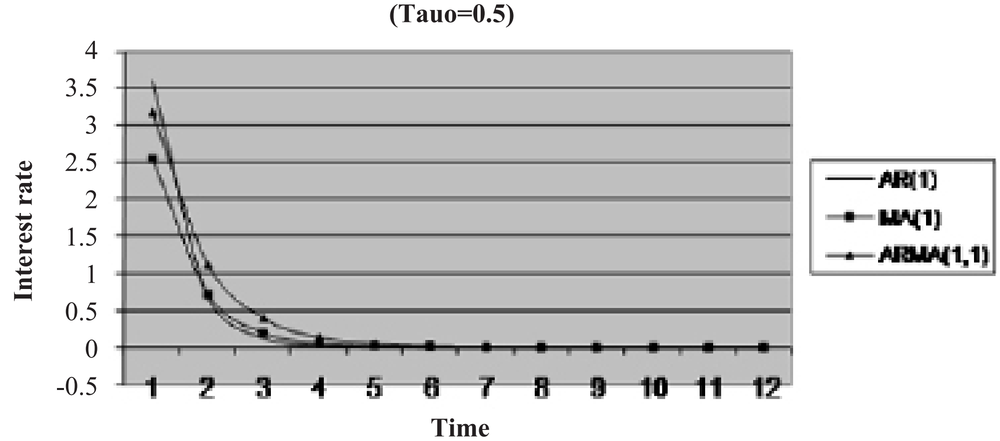


C. **Interest rate response**

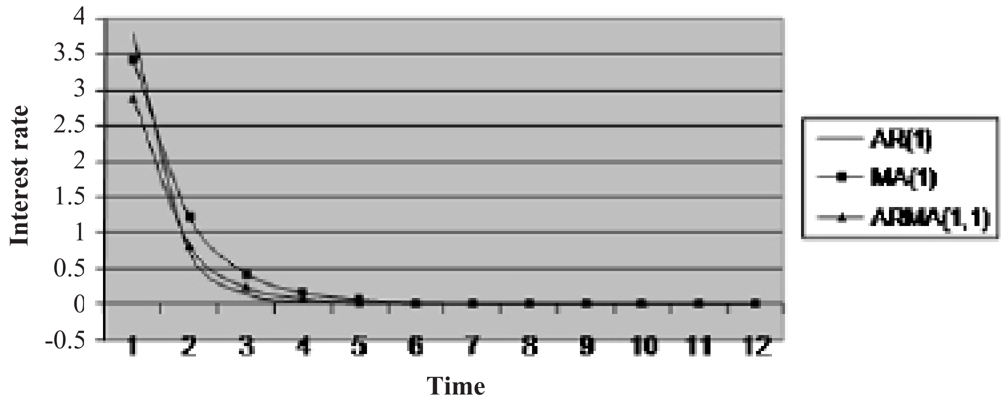
Graph 4.14
Interest rate impulse-response function to an oil shock
(Tauo=0.5)



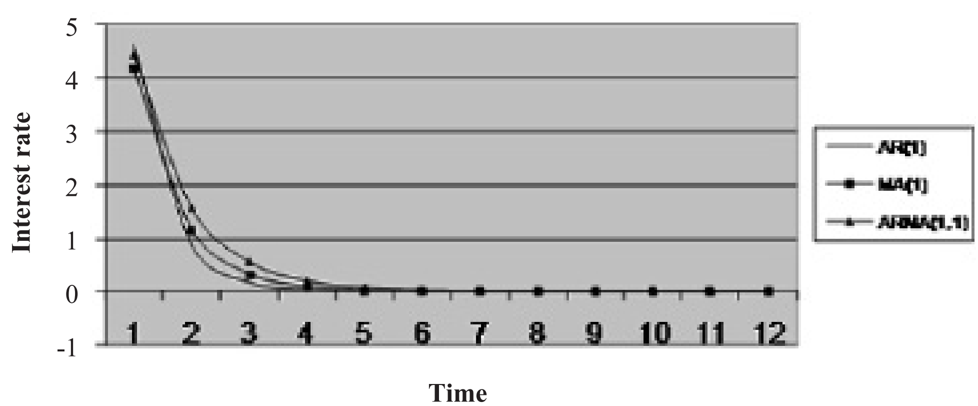
Graph 4.15
Interest rate impulse-response function to an oil shock
(Tauo=0.5)



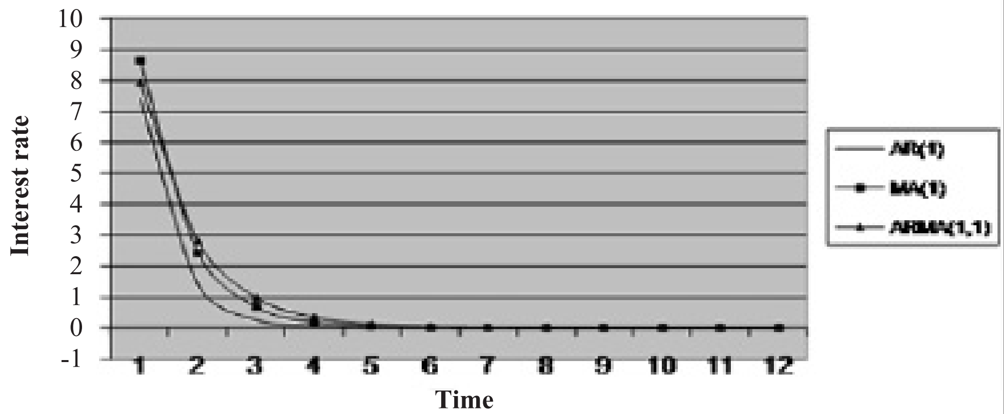
Graph 4.16
Interest rate impulse-response function to an oil shock
(Tauo=1)



Graph 4.17
Interest rate impulse-response function to an oil shock
(Tauo=3)

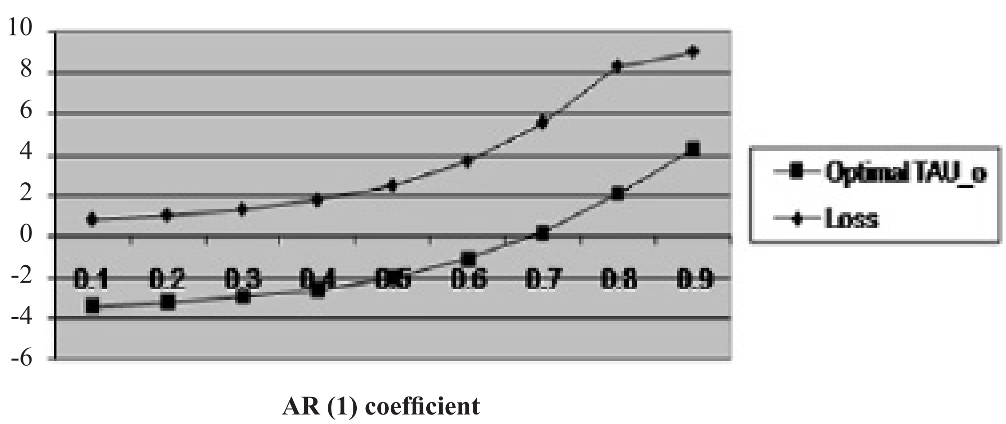


Graph 4.18
Interest rate impulse-response function to an oil shock
(Tauo=10)



D. Optimal response to oil shocks

Graph 4.19
Optimal response to oil shock



Guatemala: estimation of bank efficiency with a production approach through a panel data methodology

Óscar L. Herrera V.,
Héctor A. Valle S.[1]

Abstract

The purpose of this research is to assess the efficiency of the Guatemalan banking system from 1997 to 2007, period that comprises changes in the financial legal framework. We use the methodology denominated "production approach" that involves the analysis of inputs and outputs in the production process. Bank efficiency provides relevant information to monetary and financial authorities about economic growth and the degree of development of a country. These two variables are subject to the overall degree of efficiency of the financial system in general and of the banking services in particular. In this sense banks do not only affect the behavior of savings and investment, facilitating the payments system, but also influence the global competitive dynamics. The distinction of efficiency in terms of outputs and inputs in a production process is important because it allows us to infer economies of scale. With this purpose, panel data econometrics is employed in the paper to estimate and identify economies of scale based on the analysis of trans-logarithmic functions. For this analysis, the banks are classified into three groups according to their market share.

I. Introduction

Banking technology can be studied in order to measure efficiency by examining the existence of scale economies in the banking sector. As a firm expands its scale of operations, economies of scale occur if the firm is able to reduce costs per unit of output. There is extensive literature on the estimation of banks' costs and their production functions. This literature identifies basically three estimation approaches: the production approach, the intermediation approach, and the modern approach. The first two approaches apply the classical microeconomic theory of the firm to the banking system; they differ only in the specification of banks' activities. The third approach modifies the classical theory of the firm by including some specific banks' activities, namely risk management and information processing. One important issue choosing one approach or the other is the availability of information. In fact, many countries do not have enough data to implement any approach. Many other countries focus in the first two approaches because the data required is usually available.

In this work we use the "production approach". This approach describes banking activities as the production of services for depositors and borrowers. The outputs of banks are typically named services for depositors and borrowers, and the inputs are labor and capital. A major difficulty associated to the analysis of banking technology, is the definition of output. Many empirical studies have attempted to measure banking activity by broadly categorizing output in terms of deposits and loans. Deposits are classified as demand deposits, saving deposits and time deposits. Outputs are measured in terms of nominal monetary units. Over the last decade,

[1] Analysis, comments and conclusions contained in this document are of total responsibility of the authors and they do not necessarily represent the opinion of the staff and authorities of Bank of Guatemala. October 2011

the Guatemalan banking system has undergone a series of changes, which include a reduction in number of institutions, a new regulatory framework and increased mergers and takeovers. In that sense, the motivation of this paper is to examine the Guatemalan banking technology before and after these important changes during de period 1996-2007, in order to provide some evidence about changes in economies of scale and therefore in efficiency. The model specification under the production approach consists of a conventional "translog" function in which operative costs are the dependent variable. To this effect banks are classified in three groups according to their market shares in terms of deposits size. Additionally, panel data techniques are applied, using both fixed effect and random effect models.

The paper is divided into six parts as follows: a summary of the conceptual framework, a description of the costs of the Guatemalan banking system, a complete model specification, an explanation about the econometric techniques, the empirical results and finally the conclusions.

II. Theoretical framework

2.1 Previous studies

There is a broad literature on banking costs around the world to study bank technology and bank efficiency; however the most formal studies are about the United States. The first empirical studies were limited to examine the banks' output to costs ratios for banks of different sizes, without using any econometrics of costs functions. Subsequent research in the area of banking costs is characterized by the introduction of relatively sophisticated econometric methods. These methods have their roots in the production theory and are based on the modeling of cost functions. Formal studies, starting with Benston (1965), introduced the analysis of two important variables in the study of bank efficiency: (a) detailed costs, obtained from the Functional Cost Analysis (FCA) program of the Federal Reserve System in the United States, and (b) marginal costs, calculated for specific bank output. Benston concludes that larger banks may offset small cost inefficiencies by making large loans. Bell and Murphy (1967) followed finding evidence of scale economies. Studies made in the 1970's, mainly from Murphy, Schweitzer, Longbrake's and others, observed scale economies studying bank costs in the same line.[2]

The work by Benston, Berger, Hanweck and Humphrey (1982), hereafter BBHH, on economies of scale in the U. S. banking is recognized as one of the main contributions to the topic. The authors test the joint effect of different outputs on costs in the production of bank services using a "translog model" for the following outputs: demand deposits, time and saving deposits, real estate loans, commercial loans, and installment loans. They observed that economies of scale prevailed for all sizes of banks except the largest. This methodology has been widely applied; furthermore, recent studies have changed econometric methods to allow for multiple product output and potential jointness cost. There are studies about economies of scale in other parts of the world. Burdisso (1997), using a translog cost function and panel data econometrics methods, finds evidence of important economies of scale in banking in Argentina. Scale economies in Chilean banking system were measured recently by Dagnino and Zúñiga (2001) and Budnevich, Franken and Paredes (2001), hereafter BFP. Both included two variants of translog function. Dagnino and Zúñiga's work includes a conventional translog function while BFP's work adopted a Fourier-Flexible functional form that contains two components: a translog functional and a Fourier truncated component. Both works found scale economies in all banks except for big ones (Dagnino and Zúñiga) and for foreign banks (BFP). In addition, Aguirre, Herrera and Bravo (2004) found constant scale economies for all the banks groups in Chile. There is also previous work for Guatemala. Herrera (2002) found important scale economies for the group of big banks, constant economies of scale for medium banks and diseconomies of scale for small banks.

2.2 Banking technology

A bank is an institution whose typical activities consist in granting loans and receiving deposits from the public. In this sense banks play an important role in the process of capital allocation. However, these operations imply risks that justify banking regulations. Banking theory classifies banking functions into four main categories: (1) payment system, (2) assets transformation, (3) risk management and (4) processing information and monitoring borrowers. Universal banks do all these functions, but specialized

[2] See Kollari and Zardkoohi (1987).

banks do not. According to Kim (1986) "...a fundamental difficulty associated to the study of banking technology and its characteristics (e. g. scale and scope economies) is the specification of an appropriate measure of output". Since banks produce several and different services (outputs) it is also very difficult to allocate banking costs to all those services. As a result, researchers have identified three basic approaches: (a) production approach, (b) intermediation approach, and (c) modern approach. Each one targets a specific segment of the banks' activities. The first approach relates to the role played by the banks as asset transformers (production approach). The second approach refers to the nature of the liabilities issued and their central function in a monetary economy (intermediation approach). Finally, the third approach views banks like risk takers and their costs are in function of it. In this context, the cost function must be estimated to study banking technology. When a firm is maximizing its benefits it must at the same time be efficiently related with costs; it means, a firm should operate with minimum average costs and an optimal combination of products.[3]

2.3 Costs and scale economies

The assumption of cost minimizing behavior sets the framework to characterize the underlying production structure through the estimation of the cost structure. The short run multi-product variable cost function can be written as follows:

$$C = C(z,w,f)$$

where C is a minimal short run variable cost, z is a vector of outputs, w is a vector of variable input, and f is a vector of fixed input, exemplified by capital.[4]

In banking, the operative costs are very important since the objective is to minimize costs and, at the same time, maximize benefits. Additionally, it is convenient to show that operative costs are related to banks as producers of different services, while financial costs are related to the analysis of profitability and credit allocation policies. In this sense, the operative costs are important for the banking activity from the perspective of producers of several services. It is important to distinguish the nature of inputs and outputs in the banking industry. According to the production approach, inputs like labor (number of employees) and capital (size of the plant), are necessary to produce banking products (outputs). In this context, the distinction between flow and stock variables is very important. Capital is a stock variable while labor is a flow variable. In the short-run labor varies and capital is fixed however in the long run both variables vary. Because of this, when a banking firm is expanding its plant size and increasing production, cost average must fall. This is directly associated with economies of scale.

Economies of scale in production theory imply that the average cost falls as output and/or size of the plant is increased. On the other hand, short-term average costs are at least as high as average long-term costs. Scale economies are attributable to technological efficiencies resulting from increasing the plant size and are associated to greater specialization and labor division.[5] The objective for scale economies is to achieve the lower minimum point in the short-run average cost curve (SRAC) as the firms expand the range of their operating capacities, and trace out a tangential minimum long-run average cost curve (LRAC).

III. Average costs in Guatemalan banking system

This section describes the average costs of the Guatemalan banking system. The information is classified according to the banks size in order to be consistent with the rest of the paper, where economies of scale are tested according to the bank's size. Large banks are defined as those whose market share in deposits is greater than 10%, medium banks between 2% and 10%, and small banks less than 2%.

3.1 Market share

Figure 1 shows the average size of market that small, medium and large banks absorb in the 2000-2005 and 2006-2010 periods, according to the bank size definition given above. Large banks increased their average market share from the first to the second period, while medium and small banks decreased its share. This is the result of a process of banking consolidation, mainly through mergers

3 See Burdisso (1997).
4 See Hancock D. (1991).

5 See Standford (2001).

and acquisitions that took place during these years. Despite the high share on large banks, it is considered moderate compared to the rest of the Central American region. This reveals the relatively low participation of foreign banks and the conservative bank's strategy.

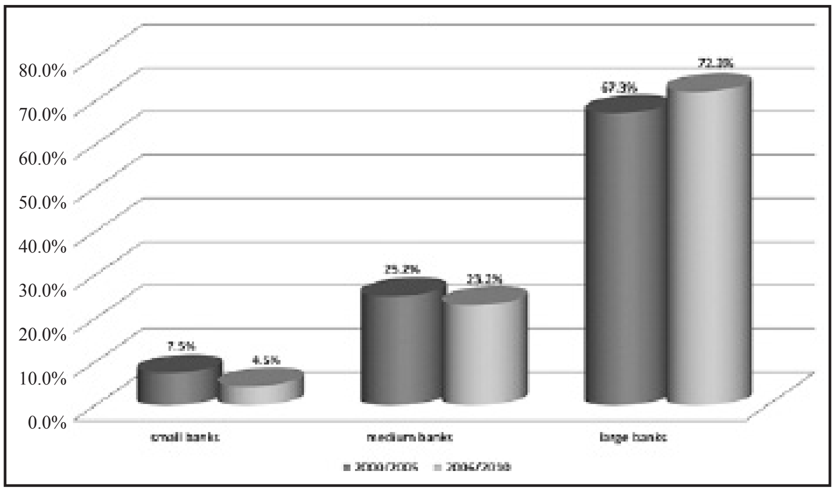


Figure 1: Market share of banks in Guatemala

3.2 Evolution of costs through time

Figure 2 shows a marked difference between small and medium banks with respect to large ones.

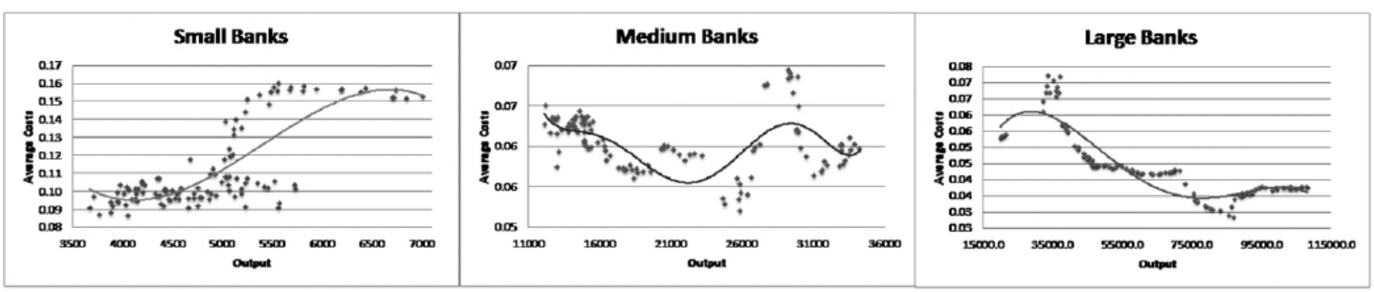


Figure 2: Average cost per output (Deposits). Jan 2001-Apr 2011

It can be observed in the period of analysis that unit cost of large banks have been substantially smaller than unit cost of small and medium banks. Furthermore, unit cost in large banks shows a declining trend, contrary to the observed trend in small and medium banks, where unitary cost goes upwards.

3.3 Operating costs

Operation costs are those costs associated with managing, operating and running a business. They are also known as administrative expenses. The evolution of operating costs, by bank size, is presented in Figure 3. It can be seen that there are significant differences between small, medium and large banks. This gap widened further since 2007, when operating costs for small banks begin to show a marked increasing trend. This is due, among other things, by the absorption of bad debt losses, which to some extent involves the cleaning of spreadsheets. Despite the increase in liabilities, the growth of operating costs was more than proportional. The average increase in this period was 11.3% and the highest 16%. Medium-sized banks showed on average operating costs equivalent to 6.05% of total of liabilities, with the highest level at 6.95%. The big banks show lower operating costs, with an average of 3.71% over the past two years. These results reflect the increasing diversification of funding sources for medium and large banks and the large installed capacity that allows the increase of sight deposits at no cost. Another aspect that makes small banks to have higher administrative expenses is that, in general, banks maintain their structure and governance oriented to provide universal banking, which implies providing a wider range of products and services that cause higher costs.

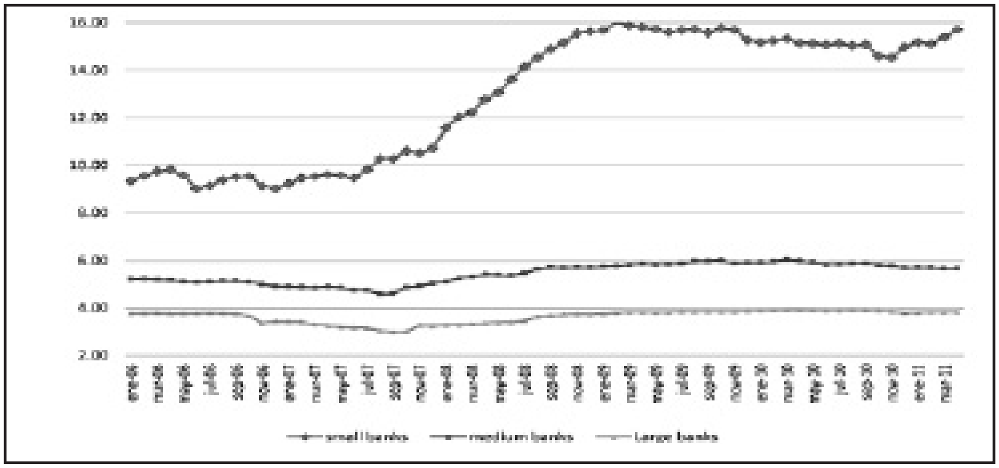


Figure 3: Operative costs as percentage of liabilities. By groups of banks.

3.4 Costs for bad loans

During most of the period analyzed, the bad loan cost component was substantially higher in the case of small and midsize banks, and much lower for large banks, whose difference from the first is quite significant for the reasons mentioned above. For large banks such component represented only 0.29% in average over the past year, while for medium and small banks this percentage was 2.18% and 2.3%, respectively (see Figure 4).

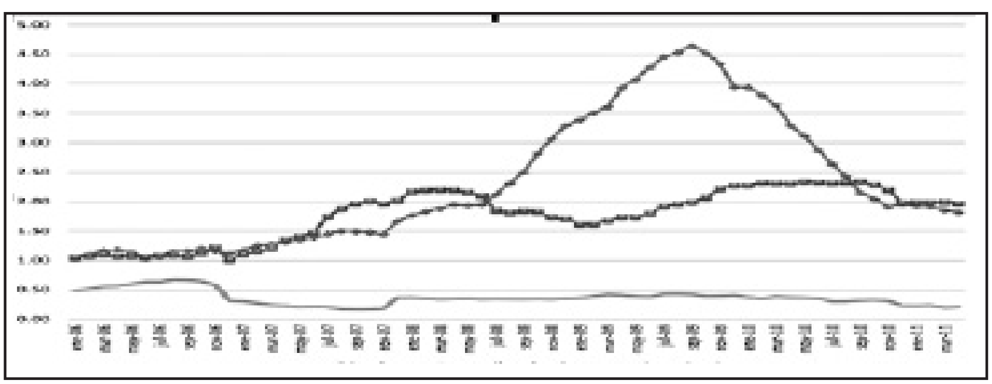


Figure 4: Costs for bad loans as percentage of liabilities. By groups of banks.

Since October 2009, this indicator has been falling substantially for the group of small banks, having peaked at 4.64% in September of that year, reaching even lower levels than the group of medium-sized banks for the past eight months. In general, given the market segment they serve, small banks have a higher risk, measured by nonperforming loans, increased focus on consumption and keep more liquidity, in part, by funding structure. In general small banks take greater risks because they serve an important share of the consumer credit, unlike large banks, which face a lower credit risk, mostly serving the corporate and mortgage segment.

3.5 Banking spread

Banking spread constitutes a measure of efficiency which reflects economies of scale. The banking spread of Guatemalan banks was calculated for the period of January 2006 to April 2011, employing Camacho y Mesalles' (1994) methodology. This measures banking spread by its components (implicit banking spread, IBS), and the results clearly reflect a substantial difference between the group of small banks and the other two groups (Figure 5), with a marked increasing gap until January 2009. The measure is very stable for the medium and large banks, averaging 10% and 6%, respectively.

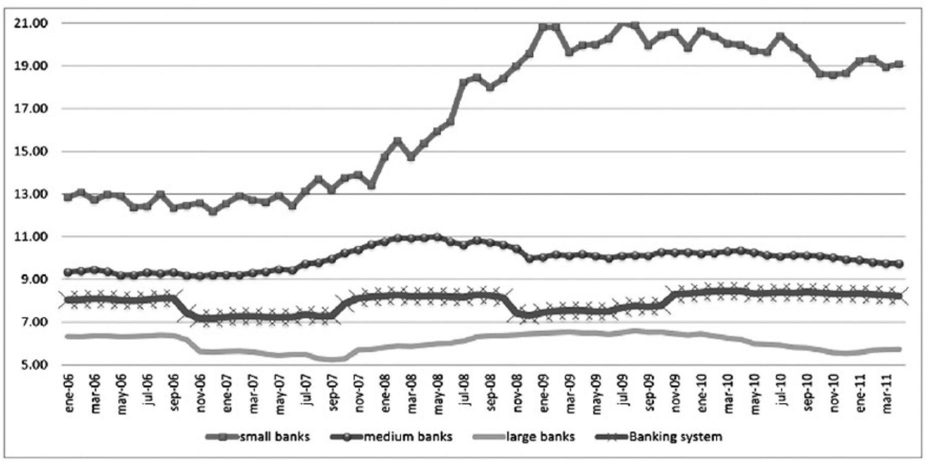
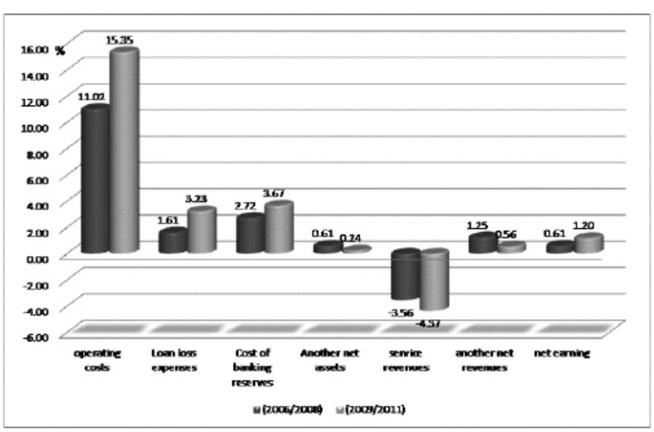


Figure 5: Implicit banking spread. By groups of banks.

The results described above are consistent with the relative weight of operating costs (OC) in the IBS structure for small banks in Guatemala. These costs on average accounted for 11% from 2006 to 2008 (see Figure 6), while from January 2009 to April 2011 these costs represented 15.4%. Also, the relative weight of OC throughout the period represented, on average, 77.3% of IBS.



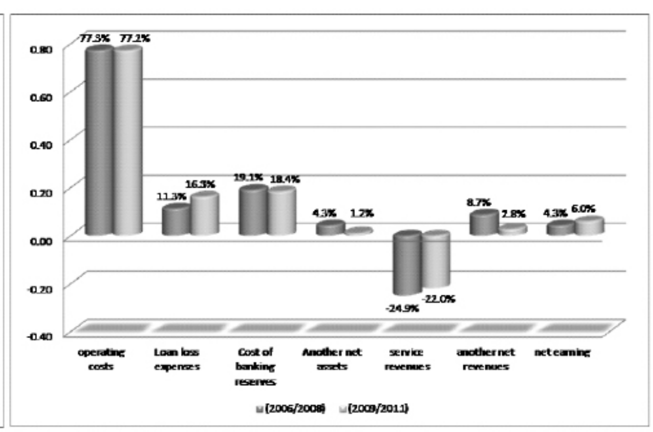
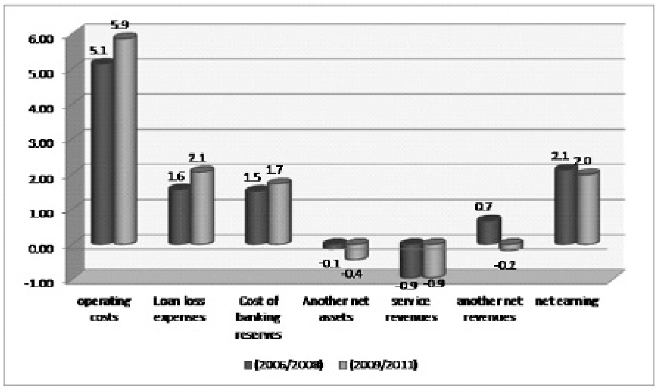
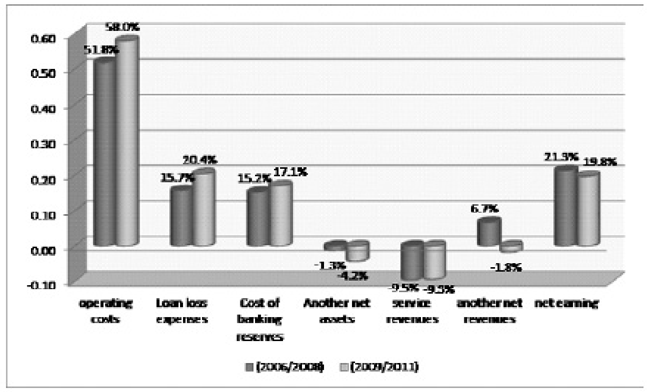


Figure 6: (left) and Figure 7 (right): Structure (left) and relative weight (right) of IBS, for small group of banks.

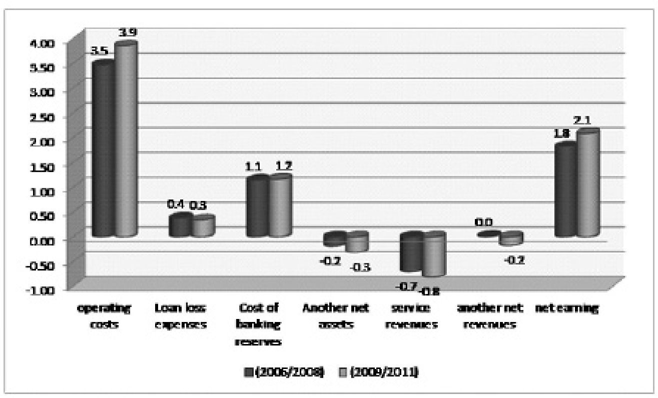
The observed trend of IBS for medium and large banks during the different time samples is explained primarily by the proportion of the OC's (see Figure 7). Indeed, the OC's were lower in both sub-periods for big banks, compared to those of medium banks; however these costs, for both groups, increased from one sub-period to another. Furthermore, the relative weight of OCs for each of these two groups shows to be slightly higher for large banks than for medium banks, in both sub-periods.

Medium banks





Large banks



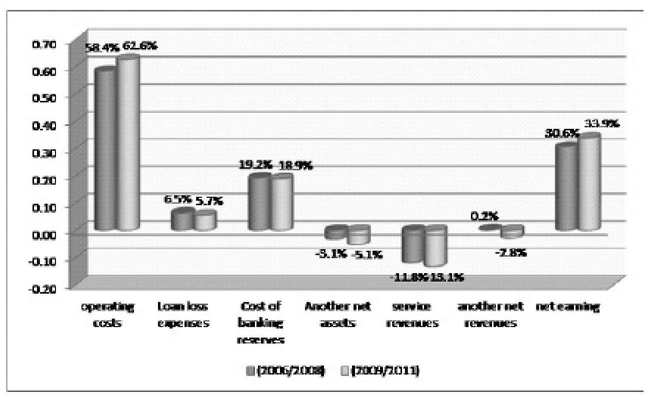


Figure 8 (up) and Figure 9 (down): Structure (left) and relative weight (right) of IBS, for small and large groups of banks.

The evidence above suggests that there are some characteristics that distinguish banks according to their size. First, while cost of reserves for small banks is the second most important component, both as part of their structure and their relative weight, for medium banks the reserves are the fourth largest component influencing the margin upward, after operating costs, bad debt costs and net income and whereas, for large banks, the reserve becomes the third important component in the composition of the margin, after operating costs and net income. Second, net income represents a more significant component for medium and large banks than for small banks; however, the relative weight within the total range is much greater for large banks than for medium banks. Finally, notice that the influence of bad loans cost within the range is quite similar between the groups of small and midsize banks, while for large banks the influence of this kind of cost on IBS is very low.

IV. Model specification

4.1 Production approach

The approach adopted in this document is known in the banking literature as the "production approach". This approach is a response to contributions by Benston (1965) and Bell and Murphy (1968). It describes basically the activity of banking as the production process of services for depositors and borrowers with labor and physical capital as inputs. In this context, the production approach recognizes the multi-product nature of banking activities. According to different authors the appropriate measure for output in this approach is amounts of money.[6] A natural extension of this approach is, therefore, the use of a multi-product cost function, which will be developed later, in order to test the measures of scale and scopes economies.

4.2 Defining output

A fundamental aspect in the use of the production approach is the definition of a good measure of output. According to Kolari and Zardkoohi (1987), there are theoretical requirements to select this measure: first, the cost of an additional monetary unit of both, small and large accounts should be the same. In this sense, the use of number of accounts could present some degree of confusion to interpret the results; second, the use of number of accounts instead of amounts of money may well lead to a biased estimation of model coefficients (because of multicolinearity); third, bankers prefer larger amounts per account because it is more easily handled than very small accounts; fourth, bank costs could be overestimated or underestimated by using the number of accounts only (see appendix 1); fifth, banks compete to increase their market share, as opposed to the number of accounts. As it is suggested above, using the number of accounts presents a problem, because it implies the existence of equal cost per account across different types of accounts. The problem is that some accounts, according to their nature, are more active than others (demand deposit accounts for instance) and therefore are more costly to maintain. Taking the above considerations into account, in this work we use values in quetzales (Guatemalan currency) as the measure of output.

[6] See Benston, Hunweck, and Humprey (1982).

4.3 Translog approximation model

Recent research has adopted econometric methods that allow the estimation of a multi-product output and a potential joint cost function. A significant advance over the constant elasticity of substitution production function (CES) is the "translog" production function developed by Christiansen, Jorgensen, and Lau (1973). The "translog" production and cost functions overcome all the problems associated with Cobb-Douglas and CES models.[7] "Translog" function allows estimation of production (or cost) with more than one output and more than two inputs. More important, "translog" models allow estimation of U-shaped cost curves. Applying the dual properties, "translog" cost functions are obtained by a Taylor series expansion around a specific point of a generalized log-linear cost function of the form:

$$Ln\ C = f(LnQ1, LnQ2, LnP1, LnP2) \qquad (3.3.1)$$

where $Qi\ (i=1,2)$ are the number of products produced by the firm and $Pi\ (i=1,2)$ are the prices of the two input factors.

Based on Kolari and Zardkoohi (1987), the "translog" cost function employed in this research is a log-linear quadratic local approximation to the arbitrary multi-product cost function specified in equation (3.3.1) around the point of expansion:

$$LnC = \propto_o + \propto_1 LnMD + \propto_2 LnTD + \propto_3 LnSD + \propto_4 LnOD + \propto_5 LnLO + \tfrac{1}{2}\phi_{11}(LnMD)^2 + \tfrac{1}{2}\phi_{22}(LnTD)^2 + \tfrac{1}{2}\phi_{33}(LnSD)^2 + \tfrac{1}{2}\phi_{44}(LnOD)^2 + \tfrac{1}{2}\phi_{55}(LnLO)^2 + \phi_{12}(LnMD)(LnTD) + \phi_{13}(LnMD)(LnSD) + \phi_{14}(LnMD)(LnOD) + \phi_{15}(LnMD)(LnLO) + \phi 21(LnTD)(LnSD) + \phi 23(LnTD)(LnOD) + \phi_{24}(LnTD)(LnLO) + \phi_{25}(LnSD)(LnOD) + \phi_{26}(LnSD)(LnLO) + \phi_{27}(LnOD)(LnLO) + \beta_1 LnP_k + \beta_2 LnP_L + \tfrac{1}{2}\gamma_{11}(LnP_k)^2 + \tfrac{1}{2}\gamma_{22}(LnPL)^2 + \gamma_{12}(LnP_k)(LnP_L) + \rho_{11}(LnP_k)(LnMD) + \rho_{12}(LnP_k)(LnTD) + \rho_{13}(LnP_k)(LnSD) + \rho_{14}(LnP_k)(LnOD) + \rho_{15}(LnP_k)(LnLO) + \rho_{21}(LnP_L)(LnMD) + \rho_{22}(LnP_L)(LnTD) + \rho_{23}(LnP_L)(LnSD) + \rho_{24}(LnP_L)(LnOD) + \rho_{25}(LnP_L)(LnLO). \qquad (3.3.2)$$

[7] For details about it, see L. R. Christiansen, D. W. Jorgensen, L. J. Lau, "Transcendental Logarithmic Production Frontiers". Review of Economics and Statistics. 5.5 (February 1973): 28-45.

where,
Ln = natural logarithm
C = Operative costs
MD = Money Deposits
TD = Time Deposits
SD = Saving Deposits
OD = Other Deposits
LO = Loans
PK = Capital price
PL = Labor price

By symmetry $\gamma 12 = \gamma\, 21$ and $\phi 12 = \phi 21$

Duality conditions require that the cost function be linearly homogeneous in prices, or,

$$\frac{\partial LnC}{\partial LnP_K} + \frac{\partial LnC}{\partial LnP_L} = 1 \qquad (3.3.3)$$

This, in turn, requires the following restrictions on the parameters of function (3.3.2)

$$\beta_1 + \beta_2 = 1 \qquad (3.3.4a)$$

$$\gamma 11 + \gamma 12 = 0 \text{ and } \gamma 22 + \gamma 21 = 0 \qquad (3.3.4b)$$

$$\rho 11 + \rho 21 = 0, \text{ and } \rho 22 + \rho 12 = 0 \qquad (3.3.4c)$$

Some works[8] have suggested that an appropriate measure of economies of scale (SE), in a multi-product case, is the sum of the individual output elasticities, as follows:

$$SE = \sum_{i=1}^{n} \frac{\partial LnC}{\partial LnQ_i}, \quad \text{for n = 5 products} \qquad (3.3.5)$$

[8] See for example Dagnino and Zuñiga (2001) and Burdisso (1997).

where, Qi is the product i and

SE < 1 => evidence of scale economies
SE = 1 => constant returns to scale prevail
SE > 1 => evidence of scale diseconomies

For this research SE come given by:

$$SE = \frac{\partial LnC}{\partial LnMD} + \frac{\partial LnC}{\partial LnTD} + \frac{\partial LnC}{\partial LnSD}\ \frac{\partial LnC}{\partial LnOD} + \frac{\partial LnC}{\partial LnLO}$$

$$= S1 + S2 + S3 + S4 + S5 \qquad (3.3.6)$$

Developing S1, S2, S3, S4 y S5 respectively, we have,

$$S1 = \propto_1 + \phi_{11} LnMD + \phi_{12} LnTD + \phi_{13} LnSD + \phi_{14} LnOD + \phi_{15} LnLO + \rho_{11} LnP_k + \rho_{21} LnP_L \qquad (3.3.7)$$

$$S2 = \propto_3 + \phi_{22} LnTD + \phi_{12} LnMD + \phi_{21} LnSD + \phi_{23} LnOD + \phi_{24} LnLO + \rho_{12} LnP_k + \rho_{22} LnP_L \qquad (3.3.8)$$

$$S3 = \propto_3 + \phi_{33} LnSD + \phi_{13} LnMD + \phi_{21} LnTD + \phi_{25} LnOD + \phi_{26} LnLO + \phi_{13} LnP_k + \rho_{23} LnP_L \qquad (3.3.9)$$

$$S4 = \propto_4 + \phi_{44} LnOD + \phi_{14} LnMD + \phi_{23} LnTD + \phi_{25} LnSD + \phi_{27} LnLO + \rho_{14} LnP_k + \rho_{24} LnP_L \qquad (3.3.10)$$

$$S5 = \propto_5 + \phi_{55} LnLO + \phi_{15} LnMD + \phi_{24} LnTD + \phi_{26} LnSD + \phi_{27} LnOD + \rho_{15} LnP_k + \rho_{25} LnP_L \qquad (3.3.11)$$

Respect to scope economies, following Zúñiga and Dagnino (2001),

$$\frac{\partial^2 LnC}{\partial LnMD \partial LnTD} = \emptyset_{12} < 0; \frac{\partial^2 LnC}{\partial LnMD \partial LnSD} = \emptyset_{13} < 0; \frac{\partial^2 LnC}{\partial LnMD \partial LnOD} = \emptyset_{14} < 0; \frac{\partial^2 LnC}{\partial LnMD \partial LnLO} = \emptyset_{15} < 0;$$

$$\frac{\partial^2 LnC}{\partial LnTD \partial LnSD} = \emptyset_{21} < 0; \frac{\partial^2 LnC}{\partial LnTD \partial LnOD} = \emptyset_{23} < 0; \frac{\partial^2 LnC}{\partial LnTD \partial LnLO} = \emptyset_{24} < 0; \frac{\partial^2 LnC}{\partial LnSD \partial LnOD} = \emptyset_{25} < 0;$$

$$\frac{\partial^2 LnC}{\partial LnSD \partial LnLO} = \emptyset_{26} < 0; \frac{\partial^2 LnC}{\partial LnOD \partial LnLO} = \emptyset_{27} < 0; \qquad (3.3.12)$$

For convenience we rename $\phi 12, \phi 13, \ldots, \phi 27 = \phi 1, \phi 2, \ldots, \phi 10$.

It means that coefficients $\phi 1, \phi 2, \ldots, \phi 10$, each one less than cero, are the first order condition. However this condition is not enough, therefore it is required that,

$$\left[\sum_{n=1}^{9} \phi n + \prod_{k=1}^{5} \alpha_k\right] < 0 \quad \text{(Sufficient condition)} \qquad (3.3.13)$$

where,

ϕn = parameter of two products combination
αk = parameter for each individual product

4.4 Data and data construction

Data come mainly from the supervisory agency monthly statistical bulletins. Data belong to thirty-one banks organized into three groups of banks (small, medium and large banks) from 1995 to 2001.[9] The sample includes only banks that were created before 1995. It is important to point out that there are four banks of recent creation that are not included in the sample. These banks are relatively of small size and the reason for not including them in the sample is incomplete data. Regarding the variables, total operative costs (OC) are the sum of salaries, benefits, occupancy expenses and other expenses. Deposits are the sum of amount of demand deposits, saving deposits, and time deposits. Loans are the amount of different types of loans, according to the balance sheet of each bank. The price of capital, PK, is defined as the ratio of occupancy expense to total of branches (the measure of plant size) like the opportunity cost of the capital. The labor price, PL, is the amount of salaries plus benefits divided by number of employees. All variables are normalized by total liabilities, except Pk that is the amount of rentals related to amount of physical capital.

V. Econometric technique

The econometric technique used in this research is known in the literature as "panel data" or "longitudinal group". With this technique we are able to analyze statistical data that combine time series with cross section data. It allows researchers to classify economic effects that cannot be captured with the use of cross section or time series separately. According to Pindyck and Rubinfeld (2001) the use of panel data has two important advantages: (1) the groups of panel data, in general, provide an increased number of data, which generate additional degrees of freedom, and (2) combining cross section and time series data can diminish, in a considerable way, situations that arise when a problem of omitted variables exists.

5.1 Simple OLS technique: pooled data regression

The first technique with the use of panel data simply combines all data of time series with that of cross section, and then the underlying pattern is estimated using OLS.

Now, it is possible to considerate a model with two variables:

$$Y_{it} = \alpha + \beta X_{it} + \varepsilon_{it}\ ,\ i = 1,2,\ldots,N \text{ and } t = 1,2,\ldots,T \qquad (4.1.1)$$

where, N is the number of units of cross sectional data (individuals) and T is the number of periods.

Separated regressions with cross sectional data can be considered, with regression implying N observations. For example, for period t = 1 the following regression can be estimated:

$$Y_{i1} = \alpha + \beta X_{i1} + \varepsilon_{i1} \quad i = 1,2,\ldots,N \qquad (4.1.2)$$

Therefore we have N number of equations of this type. In the same way, it can be estimated N time-series regressions with T observations each. An advantage is that the combination of NT observations can lead to obtain efficient parameters. Panel data econometrics comprises two different models, which can be estimated according to the heterogeneity of the units of analysis in the sample and, also, to the correlation of the independent variables with the error term. These models are denominated "fixed effects" and "random effects". These two models are described briefly in the next two sections.

5.2 Fixed effects model

The model of "fixed effects" arises of the idea that the intercept of each of the individuals is not fixed, neither in the cross section nor in the time series. To correct this

[9] The criteria for bank classification by groups is the size of market according with deposit amounts in quetzales reported by SB.

problem the literature of panel data introduces indicative variables that lead intercept term changes across time and individuals. The fixed effects model can be written as follows:

$$Y_{i1} = \alpha + \beta X_{i1} + \gamma_2 \; W_{2t} + ... + \gamma_N \; W_{NT} + \; \delta_2 Z_{i2} + \delta_3 Z_{i3} + ... + \delta_T Z_{iT} + \varepsilon_{i1} \qquad (4.2.1)$$

where,

$$W_{it} = \begin{cases} 1 \text{ for an i-individual, i=2,...,N} \\ 0 \text{ in any other case lk} \end{cases}$$

$$Z_{it} = \begin{cases} 1 \text{ for a t-period, t=2,...,T} \\ 0 \text{ in any other case} \end{cases}$$

5.3 Random effects model

Another variant is known in the panel data literature as "random effects". It improves the OLS estimates, explaining the interference of cross sectional and time series. It represents a variant of generalized least squares. A particular characteristic of this model is that the independent variables can be correlated with the error term It can be written as follows:

$$Y_{it} = \alpha + \beta X_{i1} + \varepsilon_{it} \qquad (4.3.1a)$$

$$\varepsilon_{it} + u_i + V_i \quad \omega_{it} \qquad (4.3.2b)$$

where,

$ui \sim N(0, \sigma^2_u)$ = error component of cross section
vi $\sim N(0, \sigma^2_v)$ = error component of time series
$\omega it \sim N(0, \sigma^2_\omega)$ = combined error component

VI. Results

The results presented in this section are based on a sample of 33 banks in the first period (1997-2002) and 27 in the second (2003-2007). Estimates were obtained using a translog function with panel data techniques and all the tables are in the appendix. Estimates of overall economies of scale (SE) and scope economies (SCE) are constructed from the estimated parameters.[10] According to the results using fixed effects models, important economies of scale and few economies of scope were found for small banks in the first period, while for the second period these banks showed important diseconomies of scale and no change in economies of scope. These results are consistent with the relative high operating costs, the relative importance of bad loan costs and the fewer gains showed through this time period by these banks. With regard to medium-sized banks, this group showed important diseconomies of scale through both periods and no economies of scope in first period, however, this kind of economies were positives in second period. This is consistent with Figure 2, where we cannot see a clear intuitive trend of economies of scale. Also, it is consistent with a sustained level of bad loan costs and a banking spread over the corresponding average of the system as a whole. For large banks, the results showed important scale and scope economies during the first period. Surprisingly, there is a strong evidence of diseconomies of scale in the second period but evidence of scope economies. According with Figure 2, we can observe certain area with no reductions in average cost as output increases. In terms of efficiency changes in the context of the current legal framework, we can infer from the evidence found that small banks were competitive in terms of the old financial laws regarding the limited competition that they allowed. However, we can assume that with the new set of financial laws, that encourage more competition, smaller banks have failed to be market efficient, and consequently their costs have increased. We can observe that small banks changed their market segment towards a riskier one (consumer credit), this has resulted in higher operating costs and more bad loan costs.

With respect to medium-sized banks, it seems that the new legal financial framework don't allow increasing efficiency. According to the results, there is evidence that this type of banks took advantage of the production of diversified services, in particularly with regard to changes in treatment of financial groups and new products generated from changes in legislation. However their level of efficiency has not improved. Finally, although the banking spread of large banks is small compared with small and medium banks, the level of operative costs remains increasing through time. However, since they do not face competition by more efficient banks in the system their oligopoly power has increased, which is reflected in their market share. The net result is less competition as a result of less market competition required.

[10] See appendixes.

VII. Conclusions

Derived from the use of the methodology and the econometric technic, it has been found that small banks have become less competitive after the adoption of the new financial legal framework; medium banks have not changed their low record of competitiveness and large banks are less competitive because their oligopoly power has increased. The results in this paper suggest that banks of all sizes in Guatemala are operating, in average, in the increasing area of their long-term average cost curve, although each bank-size group for different reasons. The current legal framework has not helped to increase the level of bank efficiency in the Guatemala's banking system, however, the results are partials and further research can expand the period of analysis. It might be that the new laws have not reached yet their full effect.

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Appendix 1
Results of estimation with random effects for 1997-2002
Large Banks

Variable	Random Effects coefficients		S1	
ldv_p	2.4029511		ALPHA 1	2.4029511
ldp_p	-3.6438975		PHI 11	0.23419936
lod_p	-2.3181199		PHI 12	-0.20106958
lda_p	2.3449042		PHI 13	0.53994632
lcred_p	-17.648186		PHI 14	0.43261875
ldv_p22	0.23419936		PHI 15	-2.6562225
ldp_p22	-0.49498025		RHO 11	-0.22433132
lod_p22	-0.19544487		RHO 21	0.4331266
lcred_p22	4.8745329			
lda_p22	0.48760435		S2	
dvxdp	-0.20106958		ALPHA 2	-3.6438975
dvxod	0.43261875		PHI 22	-0.49498025
dvxcred	-2.6562225		PHI 12	-0.20106958
dpxod	-0.02877548		PHI 21	-0.1677244
dpxcred	-1.5358837		PHI 23	-0.02877548
odxcred	-0.26569673		PHI 24	-1.5358837
daxcred	-1.8253364		RHO 12	-0.17269646
daxod	0.30767424		RHO 22	0.01993784
daxdp	-0.1677244			
daxdv	0.53994632		S3	
lr_k	-3.3261603		ALPHA 3	2.3449042
lw_p	2.5446375		PHI 33	0.48760435
lr_k22	-0.18966088		PHI 13	0.53994632
lw_p22	1.1205637		PHI 21	-0.1677244
rxw	-0.35671416		PHI 25	0.30767424
rxdv	-0.22433132		PHI 26	-1.8253364
rxdp	-0.17269646		RHO 13	0.00176514
rxdod	0.06661651		RHO 23	0.06592969
rxcred	0.29093429			
rxda	0.00176514		S4	
wxdv	0.4331266		ALPHA 4	-2.3181199
wxdp	0.01993784		PHI 44	-0.19544487
wxod	-0.34703004		PHI 14	0.43261875
wxcred	-2.000844		PHI 23	-0.02877548
wxda	0.06592969		PHI 25	0.30767424
_cons	-17.763663		PHI 27	-0.26569673
			RHO 14	0.06661651
			RHO 24	-0.34703004
			S5	
			ALPHA 5	-17.648186
			PHI 55	4.8745329
			PHI 15	-2.6562225
			PHI 24	-1.5358837
			PHI 26	-1.8253364
			PHI 27	-0.26569673
			RHO 15	0.29093429
			RHO 25	-2.000844

Appendix 2
Calculus of se for 1997-2002
Large Banks

SCALE ECONOMIES = S1+S2+S3+S4+S5									
S1	ALPHA 1	PHI 11 *LN DV	PHI 12 * LN DP	PHI 13 * LN DA	PHI 14 * LN OD	PHI 15 * LN CRED	RHO 11 * LN r	RHO 21 * LN w	S1
1997	2.4029511	1.95	(1.54)	4.51	2.79	(23.01)	(1.44)	3.01	-11.34502194
1998	2.4029511	1.93	(1.59)	4.31	2.83	(22.75)	(1.43)	2.96	-11.56210825
1999	2.4029511	1.90	(1.56)	4.19	2.85	(22.91)	(1.41)	2.96	-11.91512636
2000	2.4029511	1.94	(1.62)	4.27	2.64	(23.15)	(1.39)	2.98	-12.14089268
2001	2.4029511	1.96	(1.66)	4.39	2.76	(23.62)	(1.40)	3.02	-12.23541002
2002	2.4029511	1.96	(1.66)	4.40	2.83	(23.81)	(1.36)	3.02	-12.23541002
S2	ALPHA 2	PHI 22 * LN DP	PHI 12 *LN DV	PHI 21 * LN DA	PHI 23 * LN OD	PHI 24 * LN CRED	RHO 12 * LN r	RHO 22 * LN w	S2
1997	-3.6438975	(3.80)	(1.67)	(1.40)	(0.19)	(13.30)	(1.11)	0.14	-24.85929804
1998	-3.6438975	(3.92)	(1.65)	(1.34)	(0.19)	(13.15)	(1.10)	0.14	-24.80220425
1999	-3.6438975	(3.84)	(1.63)	(1.30)	(0.19)	(13.25)	(1.09)	0.14	-25.1049018
2000	-3.6438975	(3.98)	(1.67)	(1.33)	(0.18)	(13.38)	(1.07)	0.14	-25.54783096
2001	-3.6438975	(4.08)	(1.68)	(1.36)	(0.18)	(13.66)	(1.08)	0.14	-25.65056897
2002	-3.6438975	(4.09)	(1.68)	(1.37)	(0.19)	(13.77)	(1.05)	0.14	-25.65056897
S3	ALPHA 3	PHI 33 *LN DA	PHI 13 * LN DV	PHI 21 * LN DP	PHI 25 * LN OD	PHI 26* LN CRED	RHO 13 * LN r	RHO 23 * LN w	S3
1997	2.3449042	4.07	4.49	(1.29)	1.99	(15.81)	0.01	0.46	-3.809889086
1998	2.3449042	3.89	4.44	(1.33)	2.02	(15.63)	0.01	0.45	-4.032784207
1999	2.3449042	3.79	4.39	(1.30)	2.03	(15.74)	0.01	0.45	-4.23949979
2000	2.3449042	3.86	4.47	(1.35)	1.88	(15.91)	0.01	0.45	-4.348960989
2001	2.3449042	3.97	4.52	(1.38)	1.96	(16.23)	0.01	0.46	-4.436358027
2002	2.3449042	3.97	4.52	(1.39)	2.01	(16.36)	0.01	0.46	-4.436358027
S4	ALPHA 4	PHI 44 *LN OD	PHI 14 * LN DV	PHI 23 * LN DP	PHI 25 * LN DA	PHI 27 * LN CRED	RHO 14 * LN r	RHO 24 * LN w	S4
1997	-2.3181199	(1.26)	3.60	(0.22)	2.57	(2.30)	0.43	(2.41)	-2.035720437
1998	-2.3181199	(1.28)	3.56	(0.23)	2.45	(2.28)	0.43	(2.37)	-2.174146287
1999	-2.3181199	(1.29)	3.51	(0.22)	2.39	(2.29)	0.42	(2.37)	-2.019433721
2000	-2.3181199	(1.19)	3.58	(0.23)	2.43	(2.32)	0.41	(2.39)	-2.0437179
2001	-2.3181199	(1.25)	3.62	(0.24)	2.50	(2.36)	0.42	(2.42)	-2.100134426
2002	-2.3181199	(1.28)	3.62	(0.24)	2.50	(2.38)	0.40	(2.42)	-2.100134426
S5	ALPHA 5	PHI 55*LN CRED	PHI 15 * LN DV	PHI 24 * LN DP	PHI 26 * LN DA	PHI 27 * LN OD	RHO 15 * LN r	RHO 26 * LN w	S5
1997	-17.648186	42.23	(22.08)	(11.78)	(15.24)	(1.71)	1.87	(13.92)	-37.99697287
1998	-17.648186	41.75	(21.84)	(12.15)	(14.56)	(1.74)	1.86	(13.66)	-36.88012852
1999	-17.648186	42.04	(21.58)	(11.91)	(14.17)	(1.75)	1.83	(13.69)	-37.5591471
2000	-17.648186	42.48	(22.00)	(12.35)	(14.44)	(1.62)	1.80	(13.79)	-37.87179232
2001	-17.648186	43.34	(22.23)	(12.65)	(14.85)	(1.69)	1.82	(13.95)	-37.64538876
2002	-17.648186	43.69	(22.23)	(12.70)	(14.86)	(1.74)	1.77	(13.93)	-37.64538876
SE									SE
1997									-80.04690237
1998									-79.45137151
1999									-80.83810876
2000									-81.95319485
2001									-82.0678602
2002									-82.0678602

Appendix 3
Calculus of scope economies for 1997-2002
Large Banks

ECONOMÍAS DE ALCANCE		
	CONDITIONS	
	NECESARY	SUFFICIENT
PHI 12	-0.20100958	
PHI 13	0.53994632	
PHI 14	0.43261875	
PHI 15	-2.6562225	
PHI 21	-0.1677244	
PHI 23	-0.02877548	
PHI 24	-1.5358837	
PHI 25	0.30767424	
PHI 26	-1.8253364	
PHI 27	-0.26569673	
SUM		-5.40046948
ALPHA 1		2.4029511
ALPHA 2		-3.6438975
ALPHA 3		2.3449042
ALPHA 4		-2.3181199
ALPHA 5		-17.648186
PITATORY		(839.98621)
TOTAL		(846.38)

Appendix 4
Result of estimations with random effects for 2003-2007
Large Banks

Variable	Random Effects coefficients		S1	
ldv_p	44.560041		ALPHA 1	44.560041
ldp_p	68.442646		PHI 11	-22.542212
lod_p	6.3224525		PHI 12	-2.9583792
lda_p	30.211271		PHI 13	-1.4190898
lcred_p	-12.498271		PHI 14	7.8702133
ldv_p22	-22.542212		PHI 15	-6.9750651
ldp_p22	18.715915		RHO 11	3.7336533
lod_p22	-0.80621441		RHO 21	2.7429012
lcred_p22	-0.99054735			
lda_p22	2.7297123		S2	
dvxdp	-2.9583792		ALPHA 2	68.442646
dvxod	7.8702133		PHI 22	18.715915
dvxcred	-6.9750651		PHI 12	-2.9583792
dpxod	5.9873626		PHI 21	8.552693
dpxcred	4.5275485		PHI 23	5.9873626
odxcred	0.22247387		PHI 24	4.5275485
daxcred	2.2790082		RHO 12	-4.5459955
daxod	1.8832924		RHO 22	2.5608928
daxdp	8.552693			
daxdv	-1.4190898		S3	
lr_k	-12.109208		ALPHA 3	30.211271
lw_p	-2.3003203		PHI 33	2.7297123
lr_k22	-0.54371619		PHI 13	-1.4190898
lw_p22	-0.26576471		PHI 21	8.552693
rxw	-0.28728363		PHI 25	1.8832924
rxdv	3.7336533		PHI 26	2.2790082
rxdp	-4.5459955		RHO 13	-1.2492854
rxdod	-0.41062357		RHO 23	1.2233968
rxcred	0.31793865			
rxda	-1.2492854		S4	
wxdv	2.7429012		ALPHA 4	6.3224525
wxdp	2.5608928		PHI 44	-0.80621441
wxod	-1.1705117		PHI 14	7.8702133
wxcred	-2.8588158		PHI 23	5.9873626
wxda	1.2233968		PHI 25	1.8832924
_cons	71.206324		PHI 27	0.22247387
			RHO 14	-0.41062357
			RHO 24	-1.1705117
			S5	
			ALPHA 5	-12.498271
			PHI 55	-0.99054735
			PHI 15	-6.9750651
			PHI 24	4.5275485
			PHI 26	2.2790082
			PHI 27	0.22247387
			RHO 15	0.31793865
			RHO 25	-2.8588158

Appendix 5
Calculus of se for 2003-2007
Large Banks

ECONOMÍAS DE ESCALA = S1+S2+S3+S4+S5

S1	ALPHA 1	PHI 11 *LN DV	PHI 12 * LN DP	PHI 13 * LN DA	PHI 14 * LN OD	PHI 15 * LN CRED	RHO 11 * LN r	RHO 21 * LN w	S1
2003	44.560041	(189.76)	(24.50)	(11.63)	51.84	(62.58)	22.77	19.33	-149.9860958
2004	44.560041	(194.30)	(25.33)	(11.92)	51.85	(63.55)	23.49	19.77	-155.4358191
2005	44.560041	(196.63)	(25.67)	(12.02)	52.21	(64.27)	23.68	20.05	-158.0957768
2006	44.560041	(198.36)	(26.05)	(12.04)	52.86	(64.83)	23.93	20.18	-159.737052
2007	44.560041	(200.88)	(26.44)	(12.19)	54.00	(65.74)	24.36	20.50	-161.8269542

S2	ALPHA 2	PHI 22 * LN DP	PHI 12 *LN DV	PHI 21 * LN DA	PHI 23 * LN OD	PHI 24 * LN CRED	RHO 12 * LN r	RHO 22 * LN w	S2
2003	68.442646	154.99	(24.90)	70.12	39.44	40.62	(27.72)	18.04	339.0253652
2004	68.442646	160.24	(25.50)	71.85	39.45	41.25	(28.60)	18.46	345.5853908
2005	68.442646	162.42	(25.81)	72.42	39.72	41.72	(28.83)	18.72	348.8024243
2006	68.442646	164.80	(26.03)	72.53	40.21	42.08	(29.14)	18.84	351.7367661
2007	68.442646	167.27	(26.36)	73.45	41.08	42.67	(29.65)	19.14	356.0389517

S3	ALPHA 3	PHI 33 *LN DA	PHI 13 * LN DV	PHI 21 * LN DP	PHI 25 * LN OD	PHI 26* LN CRED	RHO 13 * LN r	RHO 23 * LN w	S3
2003	30.211271	22.38	(11.95)	70.82	12.40	20.45	(7.62)	8.62	145.3234052
2004	30.211271	22.93	(12.23)	73.22	12.41	20.77	(7.86)	8.82	148.2658732
2005	30.211271	23.11	(12.38)	74.22	12.49	21.00	(7.92)	8.94	149.68083
2006	30.211271	23.15	(12.49)	75.31	12.65	21.18	(8.01)	9.00	151.0053626
2007	30.211271	23.44	(12.65)	76.44	12.92	21.48	(8.15)	9.14	152.8413474

S4	ALPHA 4	PHI 44 *LN OD	PHI 14 * LN DV	PHI 23 * LN DP	PHI 25 * LN DA	PHI 27 * LN CRED	RHO 14 * LN r	RHO 24 * LN w	S4
2003	6.3224525	(5.31)	66.25	49.58	15.44	2.00	(2.50)	(8.25)	123.5312677
2004	6.3224525	(5.31)	67.84	51.26	15.82	2.03	(2.58)	(8.44)	126.9380106
2005	6.3224525	(5.35)	68.65	51.96	15.95	2.05	(2.60)	(8.56)	128.4188573
2006	6.3224525	(5.42)	69.25	52.72	15.97	2.07	(2.63)	(8.61)	129.6763801
2007	6.3224525	(5.53)	70.13	53.51	16.17	2.10	(2.68)	(8.75)	131.2780634

S5	ALPHA 5	PHI 55*LN CRED	PHI 15 * LN DV	PHI 24 * LN DP	PHI 26 * LN DA	PHI 27 * LN OD	RHO 15 * LN r	RHO 26 * LN w	S5
2003	-12.498271	(8.89)	(58.72)	37.49	18.68	1.47	1.94	(20.14)	-40.66514706
2004	-12.498271	(9.08)	(60.12)	38.76	19.15	1.47	2.00	(20.60)	-40.87488106
2005	-12.498271	(9.13)	(60.84)	39.29	19.30	1.48	2.02	(20.90)	-41.2883706
2006	-12.498271	(9.21)	(61.38)	39.87	19.33	1.49	2.04	(21.03)	-41.38551003
2007	-12.498271	(9.34)	(62.16)	40.46	19.57	1.53	2.07	(21.37)	-41.71857472

SE	SE
2003	417.2287953
2004	424.4785743
2005	427.5179642
2006	431.2959469
2007	436.6128335

Appendix 6
Calculus of scope economies for 2003-2007
Large Banks

	CONDITIONS	
	NECESARY	SUFFICIENT
PHI 12	-2.9583792	
PHI 13	-1.4190898	
PHI 14	7.8702133	
PHI 15	-6.9750651	
PHI 21	8.552693	
PHI 23	5.9873626	
PHI 24	4.5275485	
PHI 25	1.8832924	
PHI 26	2.2790082	
PHI 27	0.22247387	
SUM		19.97005777
ALPHA 1		44.560041
ALPHA 2		68.442646
ALPHA 3		30.211271
ALPHA 4		6.3224525
ALPHA 5		-12.498271
PITATORY		(7,280,762.79126)
TOTAL		(7,280,742.83)

Appendix 7
Results of estimation with random effects for 1997-2002
Medium Banks

Variable	Random Effects coefficients		S1	
ldv_p	0.65603916		ALPHA 1	0.65603916
ldp_p	0.73740193		PHI 11	0.1027412
lod_p	-0.27679788		PHI 12	-0.01396401
lda_p	1.141793		PHI 13	0.03441617
lcred_p	5.4330534		PHI 14	-0.01119409
ldv_p22	0.1027412		PHI 15	0.87830518
ldp_p22	0.03961974		RHO 11	-0.0407927
lod_p22	-0.04977821		RHO 21	0.01328968
lcred_p22	-1.9622579			
lda_p22	0.09720752		S2	
dvxdp	-0.01396401		ALPHA 2	0.73740193
dvxod	-0.01119409		PHI 22	0.03961974
dvxcred	0.87830518		PHI 12	-0.01396401
dpxod	0.00451404		PHI 21	0.09755069
dpxcred	0.30948997		PHI 23	0.00451404
odxcred	-0.17139608		PHI 24	0.30948997
daxcred	0.2458813		RHO 12	-0.0437886
daxod	0.04312543		RHO 22	0.07337819
daxdp	0.09755069			
daxdv	0.03441617		S3	
lr_k	-0.75730513		ALPHA 3	1.141793
lw_p	2.1437892		PHI 33	0.09720752
lr_k22	-0.0863933		PHI 13	0.03441617
lw_p22	0.22143908		PHI 21	0.09755069
rxw	-0.0525718		PHI 25	0.04312543
rxdv	-0.0407927		PHI 26	0.2458813
rxdp	-0.0437886		RHO 13	0.00816707
rxdod	0.00405847		RHO 23	0.03312414
rxcred	0.21010259			
rxda	0.00816707		S4	
wxdv	0.01328968		ALPHA 4	-0.27679788
wxdp	0.07337819		PHI 44	-0.04977821
wxod	-0.00274323		PHI 14	-0.01119409
wxcred	0.65202205		PHI 23	0.00451404
wxda	0.03312414		PHI 25	0.04312543
_cons	5.8588848		PHI 27	-0.17139608
			RHO 14	0.00405847
			RHO 24	-0.00274323
			S5	
			ALPHA 5	5.4330534
			PHI 55	-1.9622579
			PHI 15	0.87830518
			PHI 24	0.30948997
			PHI 26	0.2458813
			PHI 27	-0.17139608
			RHO 15	0.21010259
			RHO 25	0.65202205

Appendix 8
Calculus of se for 1997-2002
Medium Banks

SCALE ECONOMIES = S1+S2+S3+S4+S5

S1	ALPHA 1	PHI 11 *LN DV	PHI 12 * LN DP	PHI 13 * LN DA	PHI 14 * LN OD	PHI 15 * LN CRED	RHO 11 * LN r	RHO 21 * LN w	S1
1997	0.65603916	0.85	(0.11)	0.29	(0.07)	7.61	(0.26)	0.09	8.944029845
1998	0.65603916	0.84	(0.11)	0.27	(0.07)	7.52	(0.26)	0.09	8.984996237
1999	0.65603916	0.83	(0.11)	0.27	(0.07)	7.57	(0.26)	0.09	9.090972733
2000	0.65603916	0.85	(0.11)	0.27	(0.07)	7.65	(0.25)	0.09	9.256772797
2001	0.65603916	0.86	(0.12)	0.28	(0.07)	7.81	(0.25)	0.09	9.324252894
2002	0.65603916	0.86	(0.12)	0.28	(0.07)	7.87	(0.25)	0.09	9.324252894

S2	ALPHA 2	PHI 22 * LN DP	PHI 12 *LN DV	PHI 21 * LN DA	PHI 23 * LN OD	PHI 24 * LN CRED	RHO 12 * LN r	RHO 22 * LN w	S2
1997	0.73740193	0.30	(0.12)	0.81	0.03	2.68	(0.28)	0.51	4.615763066
1998	0.73740193	0.31	(0.11)	0.78	0.03	2.65	(0.28)	0.50	4.613967044
1999	0.73740193	0.31	(0.11)	0.76	0.03	2.67	(0.28)	0.50	4.670698503
2000	0.73740193	0.32	(0.12)	0.77	0.03	2.70	(0.27)	0.51	4.759452777
2001	0.73740193	0.33	(0.12)	0.79	0.03	2.75	(0.27)	0.51	4.790521604
2002	0.73740193	0.33	(0.12)	0.79	0.03	2.77	(0.27)	0.51	4.790521604

S3	ALPHA 3	PHI 33 *LN DA	PHI 13 * LN DV	PHI 21 * LN DP	PHI 25 * LN OD	PHI 26* LN CRED	RHO 13 * LN r	RHO 23 * LN w	S3
1997	1.141793	0.81	0.29	0.75	0.28	2.13	0.05	0.23	5.638435262
1998	1.141793	0.78	0.28	0.77	0.28	2.11	0.05	0.23	5.615370911
1999	1.141793	0.75	0.28	0.76	0.28	2.12	0.05	0.23	5.664110517
2000	1.141793	0.77	0.29	0.78	0.26	2.14	0.05	0.23	5.767413766
2001	1.141793	0.79	0.29	0.80	0.27	2.19	0.05	0.23	5.793644116
2002	1.141793	0.79	0.29	0.81	0.28	2.20	0.05	0.23	5.793644116

S4	ALPHA 4	PHI 44 *LN OD	PHI 14 * LN DV	PHI 23 * LN DP	PHI 25 * LN DA	PHI 27 * LN CRED	RHO 14 * LN r	RHO 24 * LN w	S4
1997	-0.27679788	(0.32)	(0.09)	0.03	0.36	(1.48)	0.03	(0.02)	-1.77609366
1998	-0.27679788	(0.33)	(0.09)	0.04	0.34	(1.47)	0.03	(0.02)	-1.797794365
1999	-0.27679788	(0.33)	(0.09)	0.03	0.33	(1.48)	0.03	(0.02)	-1.782951949
2000	-0.27679788	(0.30)	(0.09)	0.04	0.34	(1.49)	0.03	(0.02)	-1.817423273
2001	-0.27679788	(0.32)	(0.09)	0.04	0.35	(1.52)	0.03	(0.02)	-1.837831313
2002	-0.27679788	(0.33)	(0.09)	0.04	0.35	(1.54)	0.02	(0.02)	-1.837831313

S5	ALPHA 5	PHI 55*LN CRED	PHI 15 * LN DV	PHI 24 * LN DP	PHI 26 * LN DA	PHI 27 * LN OD	RHO 15 * LN r	RHO 26 * LN w	S5
1997	5.4330534	(17.00)	7.30	2.37	2.05	(1.11)	1.35	4.54	4.928984833
1998	5.4330534	(16.81)	7.22	2.45	1.96	(1.12)	1.34	4.45	4.606277264
1999	5.4330534	(16.92)	7.14	2.40	1.91	(1.13)	1.32	4.46	4.789316584
2000	5.4330534	(17.10)	7.27	2.49	1.94	(1.05)	1.30	4.49	4.653535395
2001	5.4330534	(17.45)	7.35	2.55	2.00	(1.09)	1.31	4.55	4.453012633
2002	5.4330534	(17.59)	7.35	2.56	2.00	(1.12)	1.28	4.54	4.453012633

SE	SE
1997	22.35111935
1998	22.02281709
1999	72.43214639
2000	22.61975146
2001	22.52359993
2002	22.52359993

Appendix 9
Calculus of scope economies for 1997-2002
Medium Banks

ECONOMÍAS DE ALCANCE		
	CONDITIONS	
	NECESARY	SUFFICIENT
PHI 12	-0.01396401	
PHI 13	0.03441617	
PHI 14	-0.01119409	
PHI 15	0.87830518	
PHI 21	0.09755069	
PHI 23	0.00451404	
PHI 24	0.30948997	
PHI 25	0.04312543	
PHI 26	0.2458813	
PHI 27	-0.17139608	
SUM		1.4167286
ALPHA 1		0.65603916
ALPHA 2		0.73740193
ALPHA 3		1.141793
ALPHA 4		-0.27679788
ALPHA 5		5.4330534
PITATORY		(0.83067)
TOTAL		0.58

Appendix 10
Results of estimation with random effects for 2003-2007
Medium Banks

Variable	Random Effects coefficients		S1	
ldv_p	6.644246		ALPHA 1	6.644246
ldp_p	5.5650559		PHI 11	2.4063399
lod_p	2.6848466		PHI 12	0.44795768
lda_p	-7.4359351		PHI 13	-0.28576859
lcred_p	0.10308446		PHI 14	0.55645205
ldv_p22	2.4063399		PHI 15	2.846084
ldp_p22	-0.29876016		RHO 11	0.14822889
lod_p22	0.17166572		RHO 21	-0.39732145
lcred_p22	1.1823475			
lda_p22	-0.99383807		S2	
dvxdp	0.44795768		ALPHA 2	5.5650559
dvxod	0.55645205		PHI 22	-0.29876016
dvxcred	2.846084		PHI 12	0.44795768
dpxod	0.65282861		PHI 21	-0.36766128
dpxcred	2.0744928		PHI 23	0.65282861
odxcred	-0.0250478		PHI 24	2.0744928
daxcred	0.61014109		RHO 12	0.22339599
daxod	-0.15067774		RHO 22	0.03074695
daxdp	-0.36766128			
daxdv	-0.28576859		S3	
lr_k	1.0453162		ALPHA 3	-7.4359351
lw_p	4.302226		PHI 33	-0.99383807
lr_k22	-0.28070685		PHI 13	-0.28576859
lw_p22	0.55481123		PHI 21	-0.36766128
rxw	0.3519257		PHI 25	-0.15067774
rxdv	0.14822889		PHI 26	0.61014109
rxdp	0.22339599		RHO 13	-0.42797062
rxdod	0.08139973		RHO 23	-0.19374102
rxcred	-0.21014355			
rxda	-0.42797062		S4	
wxdv	-0.39732145		ALPHA 4	2.6848466
wxdp	0.03074695		PHI 44	0.17166572
wxod	-0.08254302		PHI 14	0.55645205
wxcred	-1.2870139		PHI 23	0.65282861
wxda	-0.19374102		PHI 25	-0.15067774
_cons	26.423083		PHI 27	-0.0250478
			RHO 14	0.08139973
			RHO 24	-0.08254302
			S5	
			ALPHA 5	0.10308446
			PHI 55	1.1823475
			PHI 15	2.846084
			PHI 24	2.0744928
			PHI 26	0.61014109
			PHI 27	-0.0250478
			RHO 15	-0.21014355
			RHO 25	-1.2870139

Appendix 11
Calculus of se for 2003-2007
Medium Banks

SCALE ECONOMIES = S1+S2+S3+S4+S5

S1	ALPHA 1	PHI 11 *LN DV	PHI 12 * LN DP	PHI 13 * LN DA	PHI 14 * LN OD	PHI 15 * LN CRED	RHO 11 * LN r	RHO 21 * LN w	S1
2003	6.644246	20.26	3.71	(2.34)	3.67	25.53	0.90	(2.80)	55.57180196
2004	6.644246	20.74	3.84	(2.40)	3.67	25.93	0.93	(2.86)	56.48758802
2005	6.644246	20.99	3.89	(2.42)	3.69	26.23	0.94	(2.90)	57.05493978
2006	6.644246	21.17	3.94	(2.42)	3.74	26.45	0.95	(2.92)	57.55577586
2007	6.644246	21.44	4.00	(2.45)	3.82	26.82	0.97	(2.97)	58.27605723

S2	ALPHA 2	PHI 22 * LN DP	PHI 12 *LN DV	PHI 21 * LN DA	PHI 23 * LN OD	PHI 24 * LN CRED	RHO 12 * LN r	RHO 22 * LN w	S2
2003	5.5650559	(2.47)	3.77	(3.01)	4.30	18.61	1.36	0.22	28.33844211
2004	5.5650559	(2.56)	3.86	(3.09)	4.30	18.90	1.41	0.22	28.6097047
2005	5.5650559	(2.59)	3.91	(3.11)	4.33	19.12	1.42	0.22	28.85493858
2006	5.5650559	(2.63)	3.94	(3.12)	4.38	19.28	1.43	0.23	29.08158274
2007	5.5650559	(2.67)	3.99	(3.16)	4.48	19.55	1.46	0.23	29.44727415

S3	ALPHA 3	PHI 33 *LN DA	PHI 13 * LN DV	PHI 21 * LN DP	PHI 25 * LN OD	PHI 26* LN CRED	RHO 13 * LN r	RHO 23 * LN w	S3
2003	-7.4359351	(8.15)	(2.41)	(3.04)	(0.99)	5.47	(2.61)	(1.37)	-20.52748947
2004	-7.4359351	(8.35)	(2.46)	(3.15)	(0.99)	5.56	(2.69)	(1.40)	-20.91806554
2005	-7.4359351	(8.42)	(2.49)	(3.19)	(1.00)	5.62	(2.71)	(1.42)	-21.0418838
2006	-7.4359351	(8.43)	(2.51)	(3.24)	(1.01)	5.67	(2.74)	(1.43)	-21.12610998
2007	-7.4359351	(8.54)	(2.55)	(3.29)	(1.03)	5.75	(2.79)	(1.45)	-21.32676212

S4	ALPHA 4	PHI 44 *LN OD	PHI 14 * LN DV	PHI 23 * LN DP	PHI 25 * LN DA	PHI 27 * LN CRED	RHO 14 * LN r	RHO 24 * LN w	S4
2003	2.6848466	1.13	4.68	5.41	(1.24)	(0.22)	0.50	(0.58)	12.36050452
2004	2.6848466	1.13	4.80	5.59	(1.27)	(0.23)	0.51	(0.59)	12.62460059
2005	2.6848466	1.14	4.85	5.67	(1.28)	(0.23)	0.52	(0.60)	12.7489469
2006	2.6848466	1.15	4.90	5.75	(1.28)	(0.23)	0.52	(0.61)	12.88633763
2007	2.6848466	1.18	4.96	5.83	(1.29)	(0.24)	0.53	(0.62)	13.03976596

S5	ALPHA 5	PHI 55*LN CRED	PHI 15 * LN DV	PHI 24 * LN DP	PHI 26 * LN DA	PHI 27 * LN OD	RHO 15 * LN r	RHO 26 * LN w	S5
2003	0.10308446	10.61	23.96	17.18	5.00	(0.16)	(1.28)	(9.07)	46.33593706
2004	0.10308446	10.77	24.53	17.76	5.13	(0.17)	(1.32)	(9.28)	47.53171145
2005	0.10308446	10.89	24.83	18.00	5.17	(0.17)	(1.33)	(9.41)	48.08549749
2006	0.10308446	10.99	25.04	18.27	5.17	(0.17)	(1.35)	(9.47)	48.59325499
2007	0.10308446	11.14	25.36	18.54	5.24	(0.17)	(1.37)	(9.62)	49.22730861

SE	SE
2003	122.0791962
2004	124.3355392
2005	125.7024389
2006	126.9908412
2007	128.6636438

Appendix 12
Calculus of scope economies for 2003-2007
Medium Banks

	CONDITIONS	
	NECESARY	SUFFICIENT
PHI 12	0.44795768	
PHI 13	-0.28576859	
PHI 14	0.55645206	
PHI 15	2.846084	
PHI 21	-0.36766128	
PHI 23	0.65282861	
PHI 24	2.0744928	
PHI 25	-0.15067774	
PHI 26	0.61014109	
PHI 27	-0.0250478	
SUM		6.35880082
ALPHA 1		6.644246
ALPHA 2		5.5650659
ALPHA 3		-7.4359351
ALPHA 4		2.6848466
ALPHA 5		0.10308446
PITATORY		(76.09629)
TOTAL		(69.74)

Appendix 13
Results of estimations with fixed effects for 1997-2002
Small Banks

Variable	Fixed Effects coefficients		S1	
ldv_p	-0.29658104		ALPHA 1	-0.29658104
ldp_p	0.07010876		PHI 11	-0.0460576
lod_p	-0.0442724		PHI 12	-0.0116814
lda_p	-0.19889848		PHI 13	0.0213419
lcred_p	-0.28863336		PHI 14	-0.01402502
ldv_p22	-0.0460576		PHI 15	-0.10877766
ldp_p22	0.00092712		RHO 11	-0.01538817
lod_p22	-0.00488999		RHO 21	-0.00713607
lcred_p22	0.08150264			
lda_p22	-0.02614959		S2	
dvxdp	-0.0116814		ALPHA 2	0.07010876
dvxod	-0.01402502		PHI 22	0.00092712
dvxcred	-0.10877766		PHI 12	-0.0116814
dpxod	0.00274043		PHI 21	0.00534841
dpxcred	-0.00362647		PHI 23	0.00274043
odxcred	-0.01009649		PHI 24	-0.00362647
daxcred	0.004325		RHO 12	-0.01251219
daxod	-0.00624698		RHO 22	0.01478983
daxdp	0.00534841			
daxdv	0.0213419		S3	
lr_k	0.09295921		ALPHA 3	-0.19889848
lw_p	0.78239616		PHI 33	-0.02614959
lr_k22	0.00191231		PHI 13	0.0213419
lw_p22	0.01193669		PHI 21	0.00534841
rxw	-0.02106812		PHI 25	-0.00624698
rxdv	-0.01538817		PHI 26	0.004325
rxdp	-0.01251219		RHO 13	0.05441547
rxdod	0.00671635		RHO 23	-0.04890208
rxcred	0.00074943			
rxda	0.05441547		S4	
wxdv	-0.00713607		ALPHA 4	-0.0442724
wxdp	0.01478983		PHI 44	-0.00488999
wxod	0.00018234		PHI 14	-0.01402502
wxcred	-0.04718367		PHI 23	0.00274043
wxda	-0.04890208		PHI 25	-0.00624698
_cons	-0.0492331		PHI 27	-0.01009649
			RHO 14	0.00671635
			RHO 24	0.00018234
			S5	
			ALPHA 5	-0.28863336
			PHI 55	0.08150264
			PHI 15	-0.10877766
			PHI 24	-0.00362647
			PHI 26	0.004325
			PHI 27	-0.01009649
			RHO 15	0.00074943
			RHO 25	-0.04718367

Appendix 14
Calculus of se for 1997-2002
Small Banks

SCALE ECONOMIES = S1+S2+S3+S4+S5

S1	ALPHA 1	PHI 11 * LN DV	PHI 12 * LN DP	PHI 13 * LN DA	PHI 14 * LN OD	PHI 15 * LN CRED	RHO 11 * LN r	RHO 21 * LN w	S1
1997	-0.29658104	(0.36)	(0.08)	0.17	(0.08)	(0.90)	(0.08)	(0.04)	-1.670915222
1998	-0.29658104	(0.37)	(0.08)	0.17	(0.08)	(0.91)	(0.08)	(0.04)	-1.687526497
1999	-0.29658104	(0.37)	(0.08)	0.17	(0.08)	(0.92)	(0.08)	(0.04)	-1.705433916
2000	-0.29658104	(0.37)	(0.09)	0.17	(0.08)	(0.93)	(0.08)	(0.04)	-1.725664631
2001	-0.29658104	(0.37)	(0.09)	0.17	(0.08)	(0.93)	(0.08)	(0.04)	-1.720430363
2002	-0.29658104	(0.37)	(0.09)	0.17	(0.09)	(0.93)	(0.08)	(0.04)	-1.735086125

S2	ALPHA 2	PHI 22 * LN DP	PHI 12 *LN DV	PHI 21 * LN DA	PHI 23 * LN OD	PHI 24 * LN CRED	RHO 12 * LN r	RHO 22 * LN w	S2
1997	0.07010876	0.01	(0.09)	0.04	0.02	(0.03)	(0.06)	0.09	0.035636107
1998	0.07010876	0.01	(0.09)	0.04	0.02	(0.03)	(0.07)	0.09	0.034146396
1999	0.07010876	0.01	(0.09)	0.04	0.02	(0.03)	(0.07)	0.09	0.034811704
2000	0.07010876	0.01	(0.09)	0.04	0.02	(0.03)	(0.07)	0.09	0.035854509
2001	0.07010876	0.01	(0.09)	0.04	0.02	(0.03)	(0.07)	0.09	0.033991676
2002	0.07010876	0.01	(0.09)	0.04	0.02	(0.03)	(0.07)	0.09	0.034846545

S3	ALPHA 3	PHI 33 *LN DA	PHI 13 * LN DV	PHI 21 * LN DP	PHI 25 * LN OD	PHI 26* LN CRED	RHO 13 * LN r	RHO 23 * LN w	S3
1997	-0.19889848	(0.21)	0.17	0.04	(0.04)	0.04	0.28	(0.29)	-0.212891833
1998	-0.19889848	(0.21)	0.17	0.04	(0.04)	0.04	0.28	(0.29)	-0.20663176
1999	-0.19889848	(0.21)	0.17	0.04	(0.04)	0.04	0.29	(0.30)	-0.206924606
2000	-0.19889848	(0.21)	0.17	0.04	(0.04)	0.04	0.28	(0.30)	-0.208985947
2001	-0.19889848	(0.20)	0.17	0.04	(0.04)	0.04	0.29	(0.29)	-0.20047264
2002	-0.19889848	(0.20)	0.17	0.04	(0.04)	0.04	0.29	(0.30)	-0.202828407

S4	ALPHA 4	PHI 44 *LN OD	PHI 14 * LN DV	PHI 23 * LN DP	PHI 25 * LN DA	PHI 27 * LN CRED	RHO 14 * LN r	RHO 24 * LN w	S4
1997	-0.0442724	(0.03)	(0.11)	0.02	(0.05)	(0.08)	0.03	0.00	-0.262175294
1998	-0.0442724	(0.03)	(0.11)	0.02	(0.05)	(0.08)	0.04	0.00	-0.26236484
1999	-0.0442724	(0.03)	(0.11)	0.02	(0.05)	(0.09)	0.04	0.00	-0.26329099
2000	-0.0442724	(0.03)	(0.11)	0.02	(0.05)	(0.09)	0.04	0.00	-0.265696017
2001	-0.0442724	(0.03)	(0.11)	0.02	(0.05)	(0.09)	0.04	0.00	-0.263268524
2002	-0.0442724	(0.03)	(0.11)	0.02	(0.05)	(0.09)	0.04	0.00	-0.264885754

S5	ALPHA 5	PHI 55*LN CRED	PHI 15 * LN DV	PHI 24 * LN DP	PHI 26 * LN DA	PHI 27 * LN OD	RHO 15 * LN r	RHO 26 * LN w	S5
1997	-0.28863336	0.67	(0.86)	(0.02)	0.03	(0.06)	0.00	(0.28)	-0.801346143
1998	-0.28863336	0.68	(0.87)	(0.03)	0.03	(0.06)	0.00	(0.28)	-0.811434487
1999	-0.28863336	0.69	(0.87)	(0.03)	0.03	(0.06)	0.00	(0.29)	-0.80758594
2000	-0.28863336	0.69	(0.88)	(0.03)	0.03	(0.06)	0.00	(0.29)	-0.819087387
2001	-0.28863336	0.69	(0.87)	(0.03)	0.03	(0.06)	0.00	(0.28)	-0.795773715
2002	-0.28863336	0.70	(0.88)	(0.03)	0.03	(0.06)	0.00	(0.29)	-0.811628024

SE	SE
1997	-2.911692385
1998	-2.933811187
1999	-2.948423748
2000	-2.983579473
2001	-2.945953566
2002	-2.979581766

Appendix 15
Calculus of scope economies for 1997-2002
Small Banks

	CONDITIONS	
	NECESARY	SUFFICIENT
PHI 12	-0.0116814	
PHI 13	0.0213419	
PHI 14	-0.01402502	
PHI 15	-0.10877766	
PHI 21	0.00534841	
PHI 23	0.00274043	
PHI 24	-0.00362647	
PHI 25	-0.00624698	
PHI 26	0.004325	
PHI 27	-0.01009649	
SUMA		-0.12069828
ALPHA 1		-0.29658104
ALPHA 2		0.07010876
ALPHA 3		-0.19889848
ALPHA 4		-0.0442724
ALPHA 5		-0.28863336
PITATORIA		0.00006
TOTAL		(0.12)

Appendix 16
Result of estimations with fixed effects for 2003-2007
Small Banks

Variable	Fixed Effects coefficients		S1	
ldv_p	0.97134658		ALPHA 1	0.97134658
ldp_p	0.00162356		PHI 11	0.34158345
lod_p	0.09792985		PHI 12	0.01456517
lda_p	-0.21340851		PHI 13	-0.04152148
lcred_p	0.20558675		PHI 14	0.11409746
ldv_p22	0.34158345		PHI 15	0.04879114
ldp_p22	-0.03057348		RHO 11	-0.06644906
lod_p22	-0.04337143		RHO 21	0.02854272
lcred_p22	-0.02334777			
lda_p22	0.00181253		S2	
dvxdp	0.01456517		ALPHA 2	0.00162356
dvxod	0.11409746		PHI 22	-0.03057348
dvxcred	0.04879114		PHI 12	0.01456517
dpxod	0.02245602		PHI 21	0.00267435
dpxcred	-0.03224949		PHI 23	0.02245602
odxcred	0.05814933		PHI 24	-0.03224949
daxcred	-0.09124382		RHO 12	-0.0252529
daxod	-0.00944171		RHO 22	0.03118828
daxdp	0.00267435			
daxdv	-0.04152148		S3	
lr_k	-0.23190136		ALPHA 3	-0.21340851
lw_p	1.4586127		PHI 33	0.00181253
lr_k22	0.03052628		PHI 13	-0.04152148
lw_p22	0.08204349		PHI 21	0.00267435
rxw	-0.04461315		PHI 25	-0.00944171
rxdv	-0.06644906		PHI 26	-0.09124382
rxdp	-0.0252529		RHO 13	0.00029121
rxdod	-0.01168588		RHO 23	-0.01333171
rxcred	-0.13771274			
rxda	0.00029121		S4	
wxdv	0.02854272		ALPHA 4	0.09792985
wxdp	0.03118828		PHI 44	-0.04337143
wxod	0.04120064		PHI 14	0.11409746
wxcred	0.11790985		PHI 23	0.02245602
wxda	-0.01333171		PHI 25	-0.00944171
_cons	2.144678		PHI 27	0.05814933
			RHO 14	-0.01168588
			RHO 24	0.04120064
			S5	
			ALPHA 5	0.20558675
			PHI 55	-0.02334777
			PHI 15	0.04879114
			PHI 24	-0.03224949
			PHI 26	-0.09124382
			PHI 27	0.05814933
			RHO 15	-0.13771274
			RHO 25	0.11790985

Appendix 17
Calculus of se for 2003-2007
Small Banks

SCALE ECONOMIES = S1+S2+S3+S4+S5									
S1	ALPHA 1	PHI 11 * LN DV	PHI 12 * LN DP	PHI 13 * LN DA	PHI 14 * LN OD	PHI 15 * LN CRED	RHO 11 * LN r	RHO 21 * LN w	S1
2003	0.97134658	2.76	0.11	(0.32)	0.70	0.42	(0.35)	0.17	4.468769586
2004	0.97134658	2.80	0.12	(0.33)	0.71	0.42	(0.36)	0.18	4.511948114
2005	0.97134658	2.82	0.12	(0.33)	0.71	0.42	(0.35)	0.18	4.535178495
2006	0.97134658	2.82	0.12	(0.33)	0.71	0.42	(0.35)	0.18	4.544927996
2007	0.97134658	2.81	0.12	(0.32)	0.69	0.42	(0.36)	0.18	4.51099869
S2	ALPHA 2	PHI 22 * LN DP	PHI 12 * LN DV	PHI 21 * LN DA	PHI 23 * LN OD	PHI 24 * LN CRED	RHO 12 * LN r	RHO 22 * LN w	S2
2003	0.00162356	(0.24)	0.12	0.02	0.14	(0.28)	(0.13)	0.19	-0.180665483
2004	0.00162356	(0.25)	0.12	0.02	0.14	(0.28)	(0.14)	0.19	-0.183159459
2005	0.00162356	(0.25)	0.12	0.02	0.14	(0.28)	(0.13)	0.20	-0.179713732
2006	0.00162356	(0.25)	0.12	0.02	0.14	(0.28)	(0.13)	0.20	-0.181703461
2007	0.00162356	(0.25)	0.12	0.02	0.14	(0.28)	(0.14)	0.20	-0.185274952
S3	ALPHA 3	PHI 33 * LN DA	PHI 13 * LN DV	PHI 21 * LN DP	PHI 25 * LN OD	PHI 26* LN CRED	RHO 13 * LN r	RHO 23 * LN w	S3
2003	-0.21340851	0.01	(0.34)	0.02	(0.06)	(0.78)	0.00	(0.08)	-1.435013797
2004	-0.21340851	0.01	(0.34)	0.02	(0.06)	(0.78)	0.00	(0.08)	-1.439928191
2005	-0.21340851	0.01	(0.34)	0.02	(0.06)	(0.79)	0.00	(0.08)	-1.4471609
2006	-0.21340851	0.01	(0.34)	0.02	(0.06)	(0.79)	0.00	(0.08)	-1.447345154
2007	-0.21340851	0.01	(0.34)	0.02	(0.06)	(0.78)	0.00	(0.08)	-1.43844954
S4	ALPHA 4	PHI 44 * LN OD	PHI 14 * LN DV	PHI 23 * LN DP	PHI 25 * LN DA	PHI 27 * LN CRED	RHO 14 * LN r	RHO 24 * LN w	S4
2003	0.09792985	(0.27)	0.92	0.18	(0.07)	0.50	(0.06)	0.25	1.544743894
2004	0.09792985	(0.27)	0.94	0.18	(0.08)	0.50	(0.06)	0.26	1.562691528
2005	0.09792985	(0.27)	0.94	0.18	(0.08)	0.50	(0.06)	0.26	1.571155797
2006	0.09792985	(0.27)	0.94	0.18	(0.08)	0.50	(0.06)	0.26	1.575939959
2007	0.09792985	(0.26)	0.94	0.18	(0.07)	0.50	(0.06)	0.26	1.579278367
S5	ALPHA 5	PHI 55*LN CRED	PHI 15 * LN DV	PHI 24 * LN DP	PHI 26 * LN DA	PHI 27 * LN OD	RHO 15 * LN r	RHO 26 * LN w	S5
2003	0.20558675	(0.20)	0.39	(0.25)	(0.71)	0.36	(0.73)	0.72	-0.209907351
2004	0.20558675	(0.20)	0.40	(0.26)	(0.73)	0.36	(0.74)	0.73	-0.227881939
2005	0.20558675	(0.20)	0.40	(0.26)	(0.73)	0.36	(0.73)	0.74	-0.216208659
2006	0.20558675	(0.20)	0.40	(0.26)	(0.73)	0.36	(0.73)	0.74	-0.206918441
2007	0.20558675	(0.20)	0.40	(0.26)	(0.71)	0.35	(0.74)	0.74	-0.206554281
SE									SE
2003									4.18792685
2004									4.223670053
2005									4.263251
2006									4.284900899
2007									4.259998283

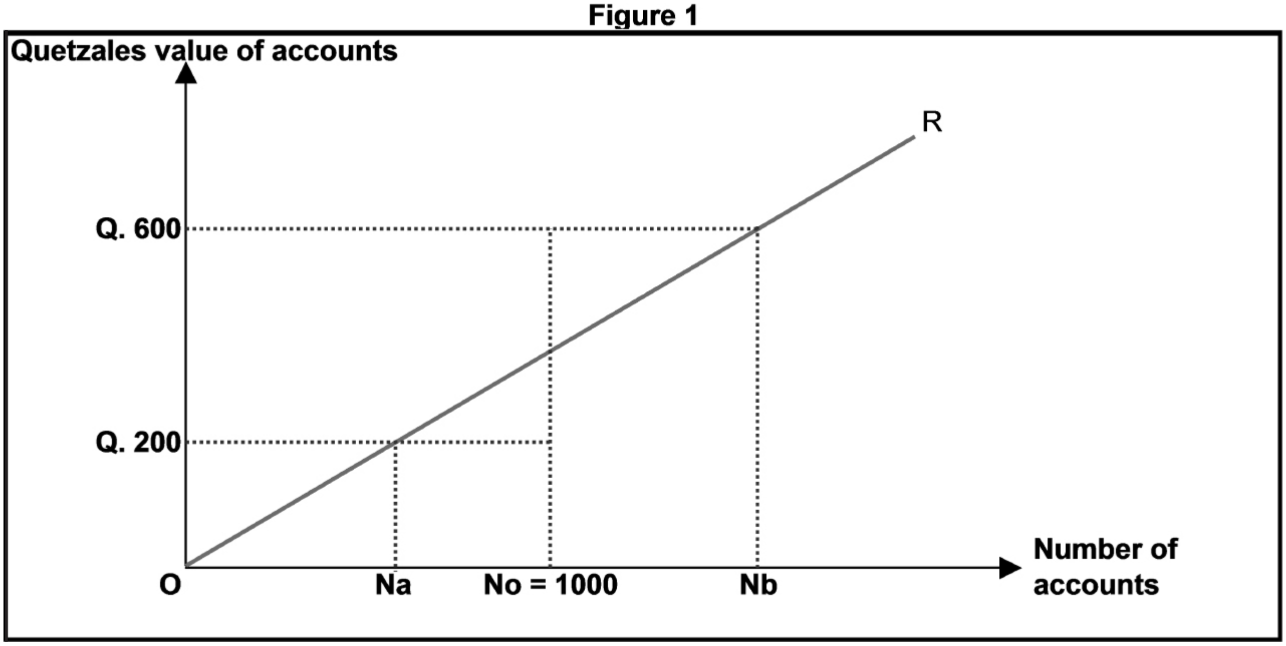
Appendix 18
Calculus of scope economies for 2003-2007
Small Banks

	CONDITIONS	
	NECESARY	SUFFICIENT
PHI 12	0.01456517	
PHI 13	-0.04152148	
PHI 14	0.11409746	
PHI 15	0.04879114	
PHI 21	0.00267435	
PHI 23	0.02245602	
PHI 24	-0.03224949	
PHI 25	-0.00944171	
PHI 26	-0.09124382	
PHI 27	0.05814933	
SUMA		0.08627697
ALPHA 1		0.97134658
ALPHA 2		0.00162356
ALPHA 3		-0.21340851
ALPHA 4		0.09792965
ALPHA 5		0.20558675
PITATORIA		(0.00001)
TOTAL		0.09

Appendix 19
Underestimation and overestimation of output with number of account

Following Kolari and Zardkoohi, figure 1 illustrates a potential bias using the number of accounts as a variable. Bank A and bank B are assumed to have 1,000 deposit accounts each. The average sizes of accounts in banks A and B are Q.200 and Q.600, respectively. The line OR shows a hypothetical regression line between size of accounts and number of accounts. If operative costs depend on the number of accounts, bank B would be larger than bank A, but they would have the same operative cost. Since operative expenses per unit asset are relatively lower for bank B than for bank A, bank A should increase its account size to be competitive with bank B.

Figure 1



Since the number of accounts considers large and small accounts as equals, bank activities to attract and service large accounts will be underestimated by the cost function leading to biased estimated parameters. In Figure 1 the segment No Nb approximates the number of accounts which bank underestimates B's activities in serving and attracting a large account. Conversely, the segment No Na approximates the number of accounts by which bank A's activities when serving and attracting a small account are overestimated.

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(15 de septiembre, 1907 - 6 de abril, 1975)

Fragmento de discurso de inauguración del Banco de Guatemala, por el Doctor Manuel Noriega Morales
(pronunciado el 1 de julio de 1946)

"Desde el nacimiento mismo del Ministerio de Economía, que se debe a la certera visión de los miembros de la ex-Junta Revolucionaria de Gobierno, la idea de la reforma monetaria y bancaria del país cobró aliento. Los magnos problemas de la economía nacional, descuidados a través de tantos regímenes autocráticos, reclamaban solución al entrar nuestra patria a los cauces de una vida democrática, inspirada sinceramente en el deseo de mejorar las condiciones económicas y sociales de Guatemala. Gobernantes anteriores decían amar a su pueblo, pero lo mantenían en la miseria, no obstante tener recursos monetarios y recursos fiscales para procurar, por medio de instituciones crediticias o de fomento a la producción, elevar el nivel de vida de la población guatemalteca."

Banco de Guatemala

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