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ARTICULOS / *ARTICLES*

ECONOMIC ANALYSIS

R E V I E W

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DEPENDENCIA CONDICIONAL ENTRE LOS MERCADOS BURSATILES DE MEXICO Y ESTADOS UNIDOS

CONDITIONAL DEPENDENCE BETWEEN STOCK MARKETS IN MEXICO AND THE UNITED STATES

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Universidad de las Américas, Puebla

Abstract

In this paper the conditional dependence of stock market in Mexico and the United States is studied. Symmetric Joe-Clayton copula is used and conditional probabilities of increases (decreases) in Mexico stock index when there are increases (decreases) in the U.S. stock index are estimated. For the marginal distributions, AR-TGARCH and AR-EGARCH models with a standardized Student's t *distribution for innovations are proposed. Empirical results suggest that there is a high degree of conditional dependence in the tails, presenting higher volatility on the upper (right) tail throughout the period.*

Keywords: *Stock returns, copulas, TGARCH, EGARCH.*

JEL Classification: *C52, G11, G15, G32.*

Resumen

En este trabajo se estudia la dependencia condicional de los mercados accionarios de México y Estados Unidos. Se emplea la cópula de Joe-Clayton simétrica y se estiman las probabilidades condicionales de que existan incrementos (decrementos) en el índice accionario de México, dado que hay incrementos (decrementos) en el índice accionario de Estados Unidos. Para las distribuciones marginales se proponen modelos AR-TGARCH y AR-EGARCH con distribución t *de student estandarizada para*

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las perturbaciones. Los resultados empíricos sugieren que existe alto grado de dependencia condicional en las colas, presentándose mayor volatilidad en la cola superior (derecha) a lo largo del periodo.

Palabras clave: *Rendimientos accionarios, cópulas, TGARCH, EGARCH.*

Clasificación JEL: *C52, G11, G15, G32.*

I. INTRODUCCION

Desde finales del siglo XX se ha podido observar que las crisis financieras se contagian con gran rapidez, esto debido a la mayor conexión y, por tal razón, dependencia entre los mercados financieros. La crisis de 2008 que comenzó en Estados Unidos es un ejemplo de dicha dependencia por sus repercusiones en los mercados financieros internacionales.

La dependencia incide sobre la diversificación de los portafolios de inversión, ya que esta última se complica cuando existen movimientos conjuntos entre los diferentes mercados. La crisis puede ir más allá del sector financiero afectando a la economía en su conjunto.

Los estudios empíricos realizados para describir los movimientos conjuntos entre los activos financieros han empleado diferentes herramientas estadísticas y econométricas. Una de las herramientas que está teniendo mucho auge son las cópulas que permiten comprender la dependencia a un nivel más profundo.

Las cópulas se basan en medidas alternativas. En lugar de un estudio de correlación simple, las cópulas permiten desarrollar una modelización separada de la dependencia entre variables aleatorias y sus respectivas funciones de distribución marginales. Como han señalado Chollete, Heinen y Valdesogo (2008), las cópulas son muy útiles cuando se trata de información financiera, ya que permiten la dependencia en las colas, es decir, cuando hay cambios extremos en los rendimientos de los activos financieros.

Entre los autores que han realizado estudios de este tipo se encuentran Canela y Pedreira (2012), que aplicaron cópulas bidimensionales con el fin de estudiar las estructuras de dependencia por pares de los rendimientos diarios de Argentina, Brasil, Chile, México, Perú y Venezuela.

Otros trabajos que aplicaron cópulas son los de Rodríguez (2007), que utilizó rendimientos de los índices bursátiles de Tailandia, Malasia, Indonesia, Corea y Filipinas en Asia, de México, Argentina, Brasil y Chile en América Latina; y Okimoto (2008) que se centró en los índices bursátiles de Estados Unidos y del Reino Unido. Ambos estudios utilizaron cópulas con modelos de cambio de régimen con el fin de encontrar evidencias de cambios en la estructura de dependencia durante los periodos de crisis. En estos estudios llegaron a la conclusión de que las dependencias entre los mercados bursátiles presentan mayor probabilidad de pérdidas extremas, por tanto, podemos esperar que la estructura de dependencia se fortalezca en los periodos de crisis. Lorenzo y Massa (2013) estudiaron la dependencia entre México y Brasil con tres tipos de cópulas diferentes y en distintos periodos, encontrando también un aumento de dependencia en periodos de crisis.

Cuando se trabaja con cópulas que tienen un comportamiento diferente en las colas, superior e inferior, la conducta típica de los periodos de crisis financieras se puede estudiar con cambios en la dependencia de la distribución de las colas, para ello la cópula debe variar en el tiempo.

Patton (2001a, 2001b) introdujo el concepto de cópula condicional, que permite llevar a cabo el análisis mediante la inclusión de la densidad condicional (dependiente del tiempo) para cada variable individual, además de la dependencia condicional entre ellas. En su trabajo estudia las asimetrías en la estructura de dependencia del marco alemán y del yen japonés en relación con el dólar americano. En trabajos posteriores, Patton (2006a, 2006b) desarrolló un modelo bivariado empleando la cópula de Joe-Clayton simétrica aunado a un modelo GARCH para describir la evolución de las varianzas condicionales de los rendimientos. Este modelo permitió a los parámetros de la cópula ser funciones del tiempo y describir la dependencia entre ellos durante los eventos extremos.

De igual manera, Johansson (2011) utilizó dependencia condicional y la aplicó a los mercados financieros de Europa y Asia del Este, concluyendo que la volatilidad regional y los movimientos comunes fueron más altos durante la crisis de 2008 que durante la crisis financiera asiática de los años 90. Más recientemente, Czapkiewicz y Majdosz (2014) emplearon cópulas para encontrar la interdependencia dinámica y similitudes entre mercados europeos, americanos y asiáticos, encontrando que las similitudes entre los mercados financieros varían con el tiempo.

El objetivo de nuestro trabajo es utilizar las cópulas para medir la dependencia condicional en las colas entre el mercado bursátil de México y el de Estados Unidos. Asimismo, describir el comportamiento de los rendimientos de los índices accionarios y su volatilidad con modelos TGARCH y EGARCH que describen las características típicas de las series de tiempo financieras.

El resto de este documento se divide de la siguiente manera: en la segunda sección se discute la definición de cópula y sus medidas de dependencia. Posteriormente se presentan los modelos del tipo GARCH y la metodología utilizada en el documento; los datos y los resultados se muestran en la cuarta sección, para terminar con las conclusiones sobre el asunto.

II. COPULAS

La modelación por cópulas permite describir la función de distribución de probabilidades multivariada por medio de las funciones de distribución marginales y una relación de dependencia llamada cópula. Nelsen (1999) presenta un trabajo muy completo de los aspectos prácticos y teóricos sobre el tema de las cópulas. En esta parte solo se presentan los conceptos básicos de cópulas que se emplean en el estudio.

Empezamos definiendo una cópula bivariada $C(u_1, u_2)$, como una función de distribución acumulada (FDA) con marginales uniformes sobre el intervalo unitario. El teorema de Sklar (1959) dice que si $F_j(x_j)$ para $j = 1, 2$ es la FDA de una variable aleatoria continua univariada X_j, entonces $C\left(F_1(x_1),F_2(x_2)\right)$ es una función de distribución bivariada para $X(X_1, X_2)$ con distribuciones marginales F_j, $j = 1, 2$. Inversamente, si F es una FDA continua bivariada con marginales univariadas F_1, F_2, entonces existe una única cópula bivariada C tal que $F(x_1,x_2)=C\left(F_1(x_1),F_2(x_2)\right)$.

Las propiedades de cópulas nos permiten estudiar las dependencias en los mercados financieros de forma más sencilla. Entre estas propiedades, podemos mencionar en primer lugar, que las cópulas son invariantes a transformaciones monótonas de variables aleatorias. En segundo lugar, existen relaciones directas entre los parámetros de las cópulas y las medidas de concordancia, como la tau de Kendall, ampliamente utilizada. En tercer lugar, proporciona un tratamiento asintótico de la dependencia en las colas de las distribuciones.

La tau de Kendall, mencionada anteriormente, es una medida de concordancia entre dos variables aleatorias; dos puntos (x_1, x_2), (y_1, y_2) se dice que son concordantes si $(x_1 - y_1)(x_2 - y_2) > 0$ y discordantes si $(x_1 - y_1)(x_2 - y_2) < 0$. En forma similar, dos vectores aleatorios (X_1, X_2), (Y_1, Y_2) son concordantes si la probabilidad $P\left[(X_1 - Y_1)(X_2 - Y_2) > 0\right]$ es mayor que la probabilidad $P\left[(X_1 - Y_1)(X_2 - Y_2) < 0\right]$; es decir, si X_1 tiende a crecer con X_2 por lo que la concordancia es una relación de dependencia. De igual forma, dos vectores son discordantes si pasa lo contrario. La tau de Kendall mide las diferencias en probabilidad, por lo que es una medida de concordancia:

$$\tau\left(X_1,X_2\right)=P\left[\left(X_1-Y_1\right)\left(X_2-Y_2\right)>0\right]-P\left[\left(X_1-Y_1\right)\left(X_2-Y_2\right)<0\right] \tag{1}$$

La ventaja al utilizar cópulas es la posibilidad de asociarlas con la tau de Kendall por medio de la siguiente relación:

$$\tau\left(X_1,X_2\right)=4\int\int C\left(u_1,u_2\right)dC(u_1,u_2)-1 \tag{2}$$

Otras medidas de dependencia definidas por las cópulas es la dependencia asintótica en las colas, que miden el comportamiento de las variables aleatorias durante eventos extremos. Para este trabajo se emplean medidas que indican la probabilidad de que se observe un incremento (decremento) extremo en los rendimientos del índice mexicano, debido a que hay un incremento (decremento) extremo en los rendimientos del índice de Estados Unidos. Para lo anterior, se definen los coeficientes de dependencia en colas inferior τ^I y superior τ^S como:

$$\begin{aligned}\tau^I &= \lim_{\alpha\to 0^+} P\left(X_2 < F_2^{-1}(\alpha)\mid X_1 < F_1^{-1}(\alpha)\right) = \lim_{\alpha\to 0^+}\frac{C(\alpha,\alpha)}{\alpha},\\ \tau^S &= \lim_{\alpha\to 1^-} P\left(X_2 > F_2^{-1}(\alpha)\mid X_1 > F_1^{-1}(\alpha)\right) = \lim_{\alpha\to 1^-}\frac{1-2\alpha+C(\alpha,\alpha)}{1-\alpha}.\end{aligned} \tag{3}$$

Existe independencia en las colas si los valores son cero y dependencia si los valores están entre cero y uno, con dependencia perfecta si el valor es de uno.

En particular, este estudio utiliza la cópula de Joe-Clayton simétrica debido a que existen las dos medidas antes mencionadas. Si el comportamiento es simétrico, entonces los coeficientes de dependencia superior e inferior coinciden. La forma funcional de esta cópula es la siguiente:

$$C_{JCS}\left(u_1,u_2 \mid \tau^S,\tau^I\right)=0{,}5\Big[C_{JC}\left(u_1,u_2 \mid \tau^S,\tau^I\right)+ C_{JC}\left(1-u_1,1-u_2 \mid \tau^I,\tau^S\right)+u_1+u_2-1\Big] \quad (4)$$

donde $C_{JC}(u_1,u_2)$ es la cópula de Joe-Clayton conocida también como BB7 (Patton, 2006a), y cuya forma funcional es la siguiente:

$$C_{JC}\left(u_1,u_2 \mid \tau^S,\tau^I\right)=1-\left(1-\left\{\left[1-(1-u_1)^{\kappa}\right]^{-\gamma}+\left[1-(1-u_2)^{\kappa}\right]^{-\gamma}-1\right\}^{-1/\gamma}\right)^{1/\kappa} \quad (5)$$

con $\kappa=\dfrac{\ln(2)}{\ln\left(2-\tau^S\right)}$ y $\gamma=-\dfrac{\ln(2)}{\ln\left(\tau^S\right)}$.

Para este trabajo se estimarán las medidas de dependencia en colas condicional siguiendo a Patton (2006). Los coeficientes de dependencia en colas inferior τ^I y superior τ^S se suponen dependientes del tiempo con las ecuaciones de evolución para cada una como sigue:

$$\begin{aligned}\tau_t^I &= \Lambda\left(\lambda_{0I}+\lambda_{1I}\tau_{t-1}^I+\lambda_{2I}\left|u_{1t-1}-u_{2t-1}\right|\right),\\ \tau_t^S &= \Lambda\left(\lambda_{0S}+\lambda_{1S}\tau_{t-1}^S+\lambda_{2S}\left|u_{1t-1}-u_{2t-1}\right|\right),\end{aligned} \quad (6)$$

con Λ la función logística para asegurar que los valores estén entre cero y uno.

III. METODOLOGIA

Para evaluar la dependencia condicional en las colas entre los mercados accionarios de México y Estados Unidos se toman los precios de cierre semanales del índice accionario del país *i* (México o Estados Unidos) en el periodo *t*, P_{it}, y se calculan los rendimientos continuos por periodo:

$$r_{it}=\ln P_{it}-\ln P_{it-1} \quad (7)$$

Una de las medidas de riesgo más utilizada en finanzas es la volatilidad. Se puede definir como la desviación estándar condicional y se presenta, generalmente, en forma anualizada. Esta volatilidad es el proceso estocástico utilizado para describir la dispersión de los rendimientos continuos (en logaritmos). Existen muchas aplicaciones de la estimación y predicción de la volatilidad entre las que se encuentran la elección de portafolios con el mínimo riesgo, la estimación del valor en riesgo (VaR), la cobertura de portafolios y la valuación de activos como las opciones financieras.

La volatilidad es una medida que no es observable, se tiene que emplear un modelo para su estimación y predicción. No se puede decir que existe una volatilidad "verdadera", ya que esta depende del modelo utilizado para calcularla.

La inclusión de la volatilidad en los modelos permite describir ciertas características típicas de las series de tiempo financieras como son: i) la probabilidad de tener rendimientos extremos superiores a los que se tendría si se supone una distribución normal, es decir, la distribución de probabilidades de los rendimientos presenta colas más anchas que una distribución normal, conocido como exceso de *curtosis*; ii) el efecto apalancamiento, cuando existe una correlación negativa entre el rendimiento y la volatilidad en el sentido de que cuando el rendimiento baja la volatilidad aumenta y iii) la relación temporal de la volatilidad que forma *cluster*, es decir, la volatilidad en un periodo depende de la volatilidad en periodos anteriores.

Algunas de estas características se pueden describir con diferentes modelos de la familia ARCH, desarrollados inicialmente por Engle (1982) y generalizados por Bollerslev (1986). En particular existen dos modelos que describen todas las características descritas anteriormente: el modelo TGARCH (*Threshold Generalized Autoregressive Conditional Heteroskedasticity*), introducido por Zakoian (1994) y por Glosten *et al.* (1993) en forma independiente, y el modelo EGARCH (*Exponential Autoregressive Conditional Heteroskedasticity*) que se utilizará en este estudio, propuesto por Nelson (1991).

En este trabajo se estimará la volatilidad diaria de los rendimientos en logaritmo (tasa de crecimiento continuo de los precios) de los índices accionarios de México y Estados Unidos. Se emplearán dos modelos con objeto de comparación. El primero es un modelo AR(1)-TGARCH (1,1) para los rendimientos del índice accionario del país *i*:

$$\begin{aligned} r_{it} &= \varphi_{i0} + \varphi_{i1} r_{it-1} + u_{it} \\ u_{it} &= \sigma_{it}\varepsilon_{it} \\ \sigma_{it}^2 &= \alpha_{i0} + \alpha_{i1} u_{it-1}^2 + \beta_i \sigma_{it-1}^2 + \gamma_i I(u_{it-1} < 0) \end{aligned} \tag{8}$$

El segundo modelo es un AR(1)-EGARCH(1,1) en el que se modifica la última ecuación que describe el comportamiento dinámico de la volatilidad:

$$\begin{aligned} r_{it} &= \varphi_{i0} + \varphi_{i1} r_{it-1} + u_{it} \\ u_{it} &= \sigma_{it}\varepsilon_{it} \\ \ln\left(\sigma_{it}^2\right) &= \alpha_{i0} + \alpha_{i1}\left|\varepsilon_{it-1}\right| + \beta_i \ln\left(\sigma_{it-1}^2\right) + \gamma_i \varepsilon_{it-1} \end{aligned} \tag{9}$$

Las perturbaciones ε_{it} se distribuyen como una *t* de *student* estandarizada y se estiman los grados de libertad (ν). El modelo presenta una ecuación para los rendimientos que, en este caso, se define como un proceso autorregresivo de orden uno al depender los rendimientos del periodo de los mismos rendimientos en el periodo anterior, y una ecuación para la varianza (volatilidad al cuadrado). Esta última ecuación tiene un parámetro γ que mide la posibilidad del efecto apalancamiento, que en el modelo TGARCH tendría que ser estadísticamente positivo y en el modelo EGARCH negativo.

Para la estimación de los parámetros se utilizó la siguiente función de verosimilitud en logaritmos:

$$\ln L(\theta,\theta_1,\theta_2)=\sum_{t=1}^{T}\left(\ln c(F_1(\varepsilon_{1t};\theta_1),F_2(\varepsilon_{2t};\theta_2);\theta)+\ln f_1(\varepsilon_{1t};\theta_1)+\ln f_2(\varepsilon_{2t};\theta_2)\right) \qquad (10)$$

donde $c(F_1(\varepsilon_{1t};\theta_1),F_2(\varepsilon_{2t};\theta_2);\theta)$ es la densidad de la cópula; mientras f_1 y f_2 son las densidades de las marginales de los rendimientos de cada país y $\{\theta,\theta_1,\theta_2\}$ son el conjunto de parámetros.

IV. DATOS Y RESULTADOS

Los datos de nuestro estudio empírico consisten en precios de cierre semanales de los índices accionarios de México (IPC) y Estados Unidos (Dow Jones) del 30 de diciembre del 2005 al 28 de febrero de 2014.

Se calculan los rendimientos continuos semanales como en (7) y se presentan las estadísticas descriptivas en el Cuadro 1.

CUADRO 1

ESTADISTICAS DESCRIPTIVAS DE LOS RENDIMIENTOS DE LOS INDICES ACCIONARIOS DE MEXICO (IPC) Y ESTADOS UNIDOS (DJ)

Estadísticas descriptivas	IPC	DJ
Media	0,00184	0,00099
Desv. Est.	0,03223	0,02553
Coef. Asim.	-0,15322	-1,03189
Curtosis	9,08032	12,74524
Jarque-Bera	657,89037	1761,31376
P-value	0,00000	0,00000
Correlación	0,76284	
Tau de Kendall	0,49543	

La no normalidad de los rendimientos es confirmada mediante el estadístico de Jarque-Bera basado en la *curtosis* y el coeficiente de asimetría. La correlación positiva superior al 76% establece la dependencia lineal de los rendimientos del IPC y el Dow Jones en el periodo de estudio, así como la confirmación de la concordancia medida por la tau de Kendall. Estas dos medidas nos indican que durante el periodo de estudio existió una relación positiva entre los rendimientos de ambos índices.

En el Cuadro 2 se presentan los resultados de la estimación de la cópula de Joe-Clayton simétrica (4) y con los rendimientos de las marginales suponiendo un modelo AR(1)-TGARCH(1,1) como en (8) y un modelo AR(1)-EGARCH(1,1) como en (9). Aparece la estimación de los diferentes parámetros así como su *p*-value para la muestra completa. También se presenta el estimador de los grados de libertad de la distribución *t*-estandarizada.

CUADRO 2

RESULTADO DE LAS ESTIMACIONES DE LA COPULA JOE-CLAYTON SIMETRICA CUANDO LAS MARGINALES SIGUEN UN MODELO TGARCH (PANEL IZQUIERDO) Y CUANDO SIGUEN UN MODELO EGARCH (PANEL DERECHO)

	TGARCH				EGARCH			
	IPC		DJ		IPC		DJ	
	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.	Coef.	Prob.
ϕ_0	0,00261	0,02624	0,00198	0,02657	0,00291	0,01104	0,00188	0,03669
ϕ_1	-0,07967	0,06858	-0,05254	0,19376	-0,07256	0,10218	-0,05214	0,19300
α_0	0,00003	0,03074	0,00002	0,00237	-0,39440	0,00494	-0,42563	0,00344
α_1	-0,00712	0,80830	-0,04581	0,12451	0,14448	0,00086	0,07361	0,12153
γ	0,13651	0,00041	0,19089	0,00000	-0,11682	0,00002	-0,17298	0,00000
β	0,89762	0,00000	0,89476	0,00000	0,96071	0,00000	0,95292	0,00000
ν	5,8573	0,0001	8,2050	0,0002	5,7493	0,0000	8,4030	0,0001
λ_{0S}	-0,84740	0,09661			-0,70764	0,21922		
λ_{1S}	2,78346	0,00044			2,63875	0,00228		
λ_{2S}	-4,19793	0,08685			-4,66417	0,06992		
λ_{0I}	-1,76248	0,00000			-1,50076	0,01394		
λ_{1I}	3,79689	0,00000			3,38606	0,00019		
λ_{2I}	-0,55253	0,12901			-0,68856	0,19745		
Logl	2126,22				2126,32			
Akaike	-9,93499				-9,93547			

Se muestra el estimador y el *p*-value para los parámetros de la ecuación de la media (panel superior), ecuación de la volatilidad (segundo panel), grados de libertad (ν) y parámetros de la dependencia condicional para la cola superior e inferior.

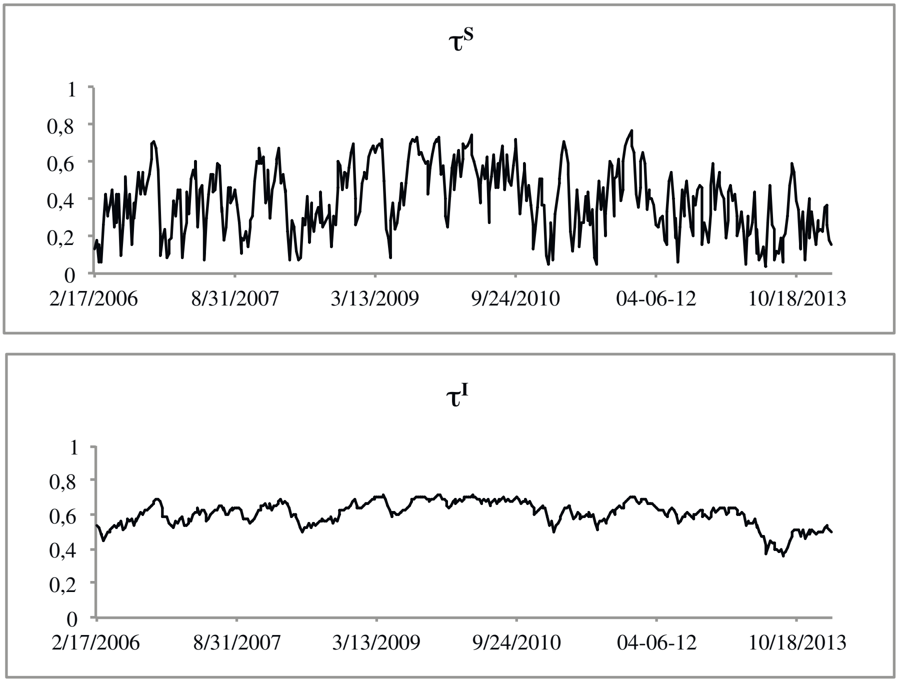
El ajuste del modelo se realiza revisando los correlogramas de los residuales y de los residuales al cuadrado que tienen que comportarse como ruido blanco y se cumple en todos los casos. El ajuste para ambos modelos de las distribuciones marginal es muy parecido. En ambos casos se confirma el efecto apalancamiento, medido por el parámetro γ, para ambos índices accionarios al ser estadísticamente positivo en el caso del modelo TGARCH *t* estrictamente negativo en el modelo EGARCH.

Los parámetros de las ecuaciones de las medidas de dependencia en colas inferior τ^I y superior τ^S también están presentes en la Cuadro 2 y son utilizados para obtener las series de dependencia que se presentan en la Figura 1 para el caso en que se emplea un modelo TGARCH y en la Figura 2 en la que se emplea el modelo EGARCH.

En la Figura 1 se muestra que en el periodo de estudio la probabilidad de que ocurra un incremento en los rendimientos del IPC, debido a que hay un incremento en los rendimientos del Dow Jones (dependencia condicional superior), es muy

FIGURA 1

GRAFICOS DE LOS COEFICIENTES DE DEPENDENCIA CONDICIONAL DE COLAS INFERIOR τ^I Y SUPERIOR τ^S PARA MODELO TGARCH



volátil, pasando del 3% al 76% y con una media del 40%. Los periodos en los que la probabilidad de que ambos rendimientos suban es justamente después de la crisis del 2008, durante 2009.

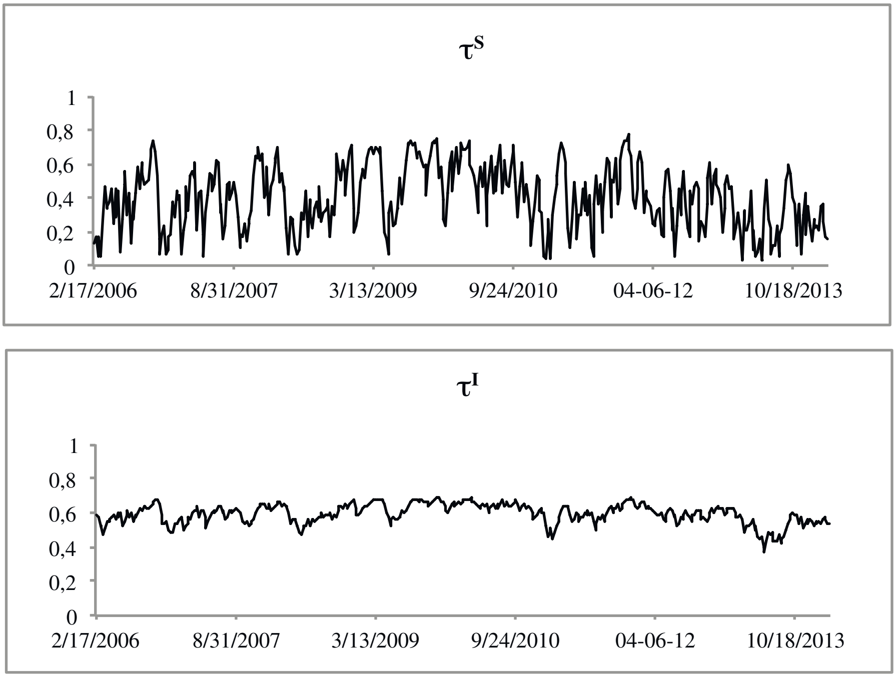
Esto se puede interpretar como un comportamiento cauto de los inversionistas y que existe una mayor dependencia cuando los mercados van al alza, lo que dificulta la diversificación.

Por otro lado, la probabilidad de que se observe un decremento en los rendimientos del IPC, porque hay un decremento en los rendimientos del Dow Jones (dependencia condicional inferior), es un poco más estable, pasando del 35% al 71% y con una media del 60%. De la misma forma, los periodos en los que la dependencia es mayor se dan nuevamente en los meses que siguen a la crisis del 2008, aunque esta relación es más estable en el tiempo y permite explicar la ausencia de diversificación.

La Figura 2 muestra resultados parecidos con la distribución marginal de los rendimientos siguiendo un modelo EGARCH por lo que la interpretación es similar.

FIGURA 2

GRAFICOS DE LOS COEFICIENTES DE DEPENDENCIA CONDICIONAL DE COLAS INFERIOR τ^I Y SUPERIOR τ^S PARA MODELO EGARCH



V. CONCLUSIONES

En este trabajo se encuentra evidencia empírica de la dependencia en las colas de la distribución de los rendimientos entre los mercados bursátiles de México y Estados Unidos. Las series analizadas han sido los precios de cierre semanales de los índices accionarios de México (IPC) y Estados Unidos (Dow Jones) entre el 30 de diciembre del 2005 y el 28 de febrero de 2014.

Los resultados empíricos del estudio sugieren que: 1) cada una de las series de rendimientos bursátiles analizadas puede describirse adecuadamente con el modelo AR(1)-TGARCH o con el modelo AR(1)-EGARCH propuestos; 2) se cumple la característica de efecto apalancamiento, es decir, cuando los rendimientos tienden a la baja, la volatilidad aumenta; 3) se cumple la característica del exceso de *curtosis*, mayor probabilidad de tener rendimientos extremos; 4) existe alta dependencia lineal durante el periodo de estudio, medida por el coeficiente de correlación (76%) y un alto grado de concordancia reflejada por la tau de Kendall y 5) existe un alto grado de dependencia condicional en las colas, presentándose mayor volatilidad en la probabilidad de incrementos de ambos índices y siendo mayores las probabilidades en tiempos de crisis.

El último punto nos lleva a afirmar que hay mayor probabilidad de que se observe un decremento en los rendimientos del IPC debido a un decremento en los rendimientos del Dow Jones. Es decir, hay mayor probabilidad de pérdida, dado que se tuvo una pérdida en el otro mercado, a que exista una ganancia, ya que se tuvo ganancia en el otro mercado. En cualquiera de los dos casos existe dificultad en la diversificación para los inversionistas y esta dificultad crece en tiempos de crisis.

Desde el punto de vista metodológico, los resultados demuestran la conveniencia de usar modelos de varianza condicional para describir el comportamiento de la volatilidad como son los de la familia ARCH que asuman las características típicas de las series de tiempo financieras como el efecto apalancamiento. Por esa razón los modelos TGARCH y EGARCH pueden emplearse para describir dichas características, así como para la toma de decisiones de administración de riesgos, de inversión y de valuación de activos. Además, el incluir las cópulas y considerar los parámetros de dependencia condicional en las colas permite describir de mejor manera el comportamiento conjunto de los rendimientos que tienen implicaciones para la teoría de portafolios y el análisis de riesgos.

Finalmente, para posibles estudios posteriores, se destaca que se pueden extender estos modelos y considerar otro tipo de distribuciones, ya sean simétricas o asimétricas, para las perturbaciones así como otras variaciones de la familia ARCH y comparar sus resultados.

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ECONOMY-WIDE EFFECTS OF IMPROVING SMALL AND MEDIUM ENTERPRISES' ACCESS TO CAPITAL MARKETS: AN APPLIED GENERAL EQUILIBRIUM ASSESSMENT

EFECTOS SOBRE LA ECONOMIA DE MEJORAR EL ACCESO DE LAS PEQUEÑAS Y MEDIANAS EMPRESAS AL MERCADO DE CAPITALES: UNA EVALUACION EN EQUILIBRIO GENERAL COMPUTADO

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Abstract

Is it possible to increase GDP, reduce unemployment and improve income distribution by providing small and medium enterprises (SMEs) better access to capital markets? In this study, we used a CGE model of Argentina to address this question and to evaluate the economy-wide net impact accounting for the reallocation of resources from other sectors. We find that although the benefits in question could be attained, SMEs should also be expected to self-exclude from programs that provide access to capital markets if that access is contingent upon higher formalization. Formalization can be expensive for SMEs. Additionally, this model estimated the gains in productivity necessary to incentivize SMEs to formalize and to voluntarily access capital markets; however, after gaining productivity, the SMEs created fewer jobs than initially expected.

Keywords: *Small and medium enterprises, CGE, access, capital markets, Argentina.*

JEL Classification: *C68, D58, O17, O54.*

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Resumen

¿Es posible aumentar el PIB, reducir el desempleo y mejorar la distribución del ingreso mejorando el acceso de las pequeñas y medianas empresas (PyMEs) al mercado de capitales? En este estudio usamos un modelo de Equilibrio General Computado de Argentina para analizar esta cuestión y para evaluar el impacto general sobre la economía, de modo de tener en cuenta la reasignación de recursos desde otros sectores. Encontramos que si bien los beneficios podrían ser alcanzables, las PyMEs podrían autoexcluirse de programas que mejoren el acceso, si este fuera condicional a un mayor grado de formalización. La formalización puede ser costosa para las PyMEs. Además, el modelo estima las ganancias de productividad necesarias para inducir a las PyMEs a formalizarse y acceder voluntariamente al mercado de capitales; sin embargo, después de ganar productividad las PyMEs terminan creando menos puestos de trabajo que los esperados al inicio.

Palabras clave: *Pequeñas y medianas empresas, EGC, acceso, mercado de capitales, Argentina.*

Clasificación JEL: *C68, D58, O17, O54.*

1. INTRODUCTION

Is it possible to improve the manufacturing performance of SMEs and simultaneously increase GDP, reduce unemployment and improve income distribution by providing SMEs better access to capital markets?

This paper uses the following approach to address that question. First, we use a general equilibrium model to account for the impact of the reallocation of resources between the SMEs and the rest of the economy. Second, we examine the possibility of self-exclusion of firms from programs providing access to capital markets that are conditional on higher formalization (because formalization could be costly as a result of higher effective taxes and required compliance with norms and standards).

We used a Computable General Equilibrium (CGE) model of the economy of Argentina to address these two objectives.

Why a CGE approach? There are great expectations and hopes on the capacity of SMEs to create jobs and help the Latin American economies to grow. Most of the available analyses and evaluations of that capacity do not take into account the cost of opportunity of resources, i.e. the cost for the economy of allocating other scarce factors to SMEs. The CGE evaluation gives the net results while at the same time takes into account changes in relative prices of goods and factors.

To construct the data, we separated the manufacturers sector in the Social Accounting Matrix into SMEs and large enterprises/firms (LE). We obtained information on the SMEs from the Fundación Observatorio Pyme's database. Separating activities by firm size in the Social Accounting Matrix was one of the contributions of this paper. The comprehensive data that was required to model the firms by size was only available for the manufacturing sector.

After dividing the manufacturing sector by size, the resulting groups had different characteristics. In the first group, SMEs, we included firms that operated on a lower scale, were less formal and were more labor-intensive on average. In the second group, we included large manufacturing firms, which were more capital-intensive, operated at a higher scale and were more formal (in terms of compliance with legal taxes and regulations).

It has been argued that although SMEs face several potential regulatory constraints, they do not pay the full legal taxes and their level of evasion is higher. For example, Bertranou and Paz (2003) found a high correlation between the size of a firm and the protection of its workers. The high positive correlation between formality and the size of the firms and their scale of operation has been observed in the literature following the analysis of Rauch (1991) –see, for example, Neumeyer (2013), Galiani and Weinschelbaum (2007) and Busso *et al.* (2012).

It can also be argued that the larger a firm's scale of operations, the higher the probability is of being detected and charged with taxes; therefore, firms must choose between gaining access to capital markets or maintaining a smaller operation and continuing to pay lower taxes.

The paper is organized as follows. The next section presents a discussion of SMEs' access to capital and formalization. In Section 3, we present the main characteristics of the SMEs in Argentina and the Social Accounting Matrix. In Section 4, the characteristics of the model used in the simulations are described followed by a theoretical illustration of the analytical structure. Section 5 shows the results of the simulations. Finally, Section 6 presents the main conclusions.

2. SMEs, ACCESS TO CAPITAL MARKETS AND FORMALIZATION

SMEs' limited access to capital markets and higher cost of capital, low productivity and informality have already been described by the Fundación de Investigaciones Económicas Latinoamericanas (1996) and by Auguste, Bebczuck and Sánchez (2013).

The higher costs of capital could be the result of unintended imperfections (such as asymmetries of information), but they could also be the natural response of capital markets to the low levels of firm formalization.

However, our study shows that even when formalization could eliminate the difference in costs of capital with large and more productive firms, formalization is not the primary preference of SMEs. A recent report by the Fundación Observatorio Pyme (2013) found that SMEs that self-excluded from formal credit markets were an important proportion of the total manufacturers (60% in 2012)[1].

Stein, Pinar and Hommes (2013) emphasize that self-exclusion from formalization is a common situation in developing countries: firms remain informal because they do

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[1] sic "*… existe todavía una amplia proporción de PyMEs industriales de tamaño inferior a las ya bancarizadas que se autoexcluyen del sistema bancario…*" (Fundación Observatorio Pyme, 2013, pp. 2).

not have the proper incentives or the capacity to formalize. Moreover, some country studies show that simplifying registration channels and reducing its costs have had little effect to increase the formalization of firms[2] -see Klewitz and Hansen (2011).

A somewhat vicious cycle is inherent to this process; the low productivity of SMEs are to some extent the reason for their self-exclusion and informality, and to be sustainable, they compensate for higher (labor) costs per unit of product with informality and a lower level of tax compliance[3]. This in turn explains the higher capital costs.

However, we did not explore the causes of higher costs of capital in this study; instead, we considered higher capital costs to be a fact and explored the net results of eliminating the differential costs of capital while simultaneously increasing the taxes paid at the average of the corresponding industry.

In our model, the units of analysis were not individual firms. Instead, we analyzed the sectors of SMEs and large firms. Those sectors could expand their activity or contract depending on how the allocation of capital and labor was incentivized. Thus the allocation of capital was not unidirectional; depending on the incentives, capital could move from SMEs to large firms or be reallocated from the large formal sector to the SMEs. The birth and death of firms were therefore not major events in this model; they responded to the incentives provided by the general equilibrium of the economy when all of the incentives were taken into consideration. This approach is consistent with the idea that not all firms want to grow and become formal because formalization could be costly in terms of tax and regulation compliance. However, there are consequences to the reallocation of resources regarding employment and income distribution because SMEs are on average more labor-intensive than larger firms.

An alternative view emphasizes instead the problems of development and its structural characteristics: difficult access to credit and capital, low compliance to tax and regulations and low productivity and specialization of SMEs in inferior goods. An interesting discussion of the characteristics of the SME sector was presented by Tybout (2000), in which the author identified two main characteristics of SMEs in less developed economies: limited access to capital markets and specialization in inferior-good markets. See also De Paula and Scheinkman (2007), Straub (2005) and Bennett and Estrin (2007).

One key component of informality is tax evasion. Tax evasion is not that uncommon in the economies of Latin American Countries (LAC). A recent analysis of tax evasion in LAC was conducted by Gómez Sabaini and Jiménez (2012). They observed that SMEs were more informal and that the taxation of SMEs was not easily enforced.

However, the need to combat this tax evasion creates a trade-off. Is the common belief that SMEs are critical for the creation of employment supported by evidence? Could the reallocation of resources absorb employment if legal taxes were enforced?

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2 De Giorgi and Rahman (2013) for Bangladesh, McKenzie and Sakho (2009) for Bolivia and Mel *et al.*(2013) for Sri Lanka.

3 Fundación Observatorio Pyme (2014) estimated that the productivity level of SMEs is around 74% lower that the LEs.

If SMEs are essential to creating employment opportunities, this could justify a light-handed approach to the issue of evasion. However, the critical question remains how this approach affects social welfare.

On the one hand, the role of SMEs seems to be important for the creation of employment in most LAC economies. SMEs are more labor-intensive than large firms, and their performance seems to be related to the performance of the economies of the region. Based on this perspective, it is important to recall the work of Marchand, Pestiau and Wibaut (1989), which showed that under unemployment, Ramsey taxes should be reduced when an industry is labor-intensive because higher employment could enhance social welfare even when the optimal taxation scheme is distorted[4].

On the other hand, the consequences of a light-handed approach to the SMEs' tax evasion could be a reduction in the average scale of firms, the loss of productivity at the level of the firms and a decrease in the economy's TFP.

3. A SOCIAL ACCOUNTING MATRIX WITH SMEs ACCOUNTS

In this section, we present the data and the calibration procedure utilized to build a SAM for Argentina in 2010. We separated the firms in the manufacturing sector into two groups: SMEs and large firms/enterprises (LE). Additionally, we describe the necessary sources to estimate the specific accounts for the SMEs included in the SAM.

3.1. Characterization of SMEs

SMEs are more labor-intensive and are less formal than LEs. The technical efficiency of SMEs is central to the debate regarding their role in economic development. Some studies have found them to be more efficient than large enterprises in some industries but not in others, while other studies have found them to be less efficient overall (Little, Mazumdar and Page, 1987; Cortes, Berry and Ishaq, 1987; Liedholm and Mead, 1987). More recent research has reported that most SMEs are less efficient on average than their larger counterparts in five countries (Malaysia, Indonesia, Mexico, Colombia and Taiwan) but with a high dispersion, as some SMEs were as efficient as large companies (Batra and Tan, 2003). Ayyagari, Demirguc-Kunt and Maksimovic (2011) observed that although small businesses were important contributors to total employment and job creation, they had a lower growth of productivity than large companies, which explains why job creation does not translate into faster growth.

We separated the firms in the manufacturing sector into two groups: SMEs and LEs. The first group, SMEs, included firms that operated at a lower scale, were less formal and were in general more labor-intensive than LEs. In the second group (LEs), capital-intensive firms were included. These firms operated at a higher scale and were more formal.

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4 See also Koskela and Schöb (2001) and Böhringer, Boeters and Feil (2005).

National Accounts do not contain disaggregated data by company size; hence sectoral information was collected to represent the firms in the SAM. An aggregate manufacturing sector was initially created; small and medium manufacturer information was then collected and large industrial enterprises emerged as the difference between the two. The process used to represent the small and medium enterprises within the SAM is described next.

Studies that measure the share of SMEs in the GDP have investigated different periods and economic activities, which limit their comparability. Ayyagari, Beck and Demirgüc-Kunt (2003) estimated that from 1990 to 1999, all small and medium firms (not only manufacturing) accounted for an average of 54% of Argentina's GDP. Peres and Stumpo (2000) estimated a contribution of 36% with respect to the manufacturing GDP in 1993. Additionally, the National Economic Census 2004 showed a share of 24% of the GDP in the manufacturing sector. Given these mixed results, we used the most current information available to weight SMEs within manufacturing: sales statistics recorded by the federal fiscal agency (Administración Federal de Ingresos Públicos)[5] in 2010.

Based on the SMEs' gross value of production, economic statistics were obtained from a specific survey of SMEs conducted by the Fundación Observatorio PyME (FOP)[6]. The survey was composed of a panel of 2500 industrial SMEs that were classified using the two-digit United Nations International Standard Industrial Classification. In terms of geographical coverage, the survey covered the industry nationwide. The variables surveyed included the firm's characteristics, problems and expectations, investments, use of information technologies and communications, performance, human resources, finance and economic-financial relations, customers and suppliers and infrastructure and logistics[7].

In particular, the statistics used were: the intermediate consumption/value added ratio, the capital/labor ratio and the proportion of exports to total sales. The remaining sales were distributed among other uses (intermediate consumption, final consumption and exports) based on the sales distribution of the aggregate manufacturing sector. The tax burden by firm size was obtained from the National Economic Census 2004.

Table 1 presents a comparison of the manufacturing statistics by firm size.

SMEs represented 33% of the manufacturing industry's gross output, 37% of the value added and 30% in terms of the intermediate consumption. SMEs were also more intensive in their use of labor than large manufacturing industries. SMEs had less participation in international markets. Finally, a lower tax burden on SMEs was observed when compared with larger firms.

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5 Based on the definition of a SME used by the Secretariat of Small and Medium Enterprises and Regional Development (Resolution N0 21/2010), the term "SME" represents companies with annual sales of between $2.4 million and $111.9 million.

6 Periodically, and to cover the information gap between small and medium enterprises in this sector, the FOP generates surveys that produce relevant information on the structural characteristics and development of SMEs. This information was provided by the FOP through a joint project with the Universidad Argentina de la Empresa (UADE).

7 This survey considered SMEs to be firms with 10 to 200 employees.

TABLE 1

ARGENTINA, 2010. MANUFACTURING STRUCTURE BY FIRM SIZE

Sectors	Gross Output	Value Added / Gross Output	Labor / Value Added	Exports / Gross Output	Net Tax Burden
Manufacturing: SME	33	41	45	6	9
Manufacturing: LE	67	33	21	30	13
Total Manufacturing	100	35	30	22	12

Source: Own elaboration based on AFIP, National Economic Census 2004 and FOP.

3.2. Social Accounting Matrix

The basic data for the model were obtained from a social accounting matrix (SAM) that also separated the manufacturing industry by firm size. We summarize the most critical aspects of data collection and treatment in the following paragraphs.

Data on the global supply and demand and on the sectoral value added as of 2010 were obtained from the National Accounts published by the National Institute of Statistics and Census (INDEC). Information on the government accounts was obtained from the Ministry of the Economy (Oficina Nacional de Presupuesto). The information on national and local taxes was provided by the Administración Federal de Ingresos Públicos and by Provincial ministries. Regarding data on the demand side, household demand by good was obtained from the Survey of Household Expenditure 2004/2005 and data on exported goods was from INDEC.

The model included 8 production sectors: 2 primary sectors (agriculture and mining), 2 manufacturing industry sectors (SME and LE) and 4 service sectors. The factors of production that were modeled were labor and capital. The 2008 matrix of factor payment created by the Generation of Income Account (CGI) of INDEC was updated using the cross-entropy method.

Table 2 presents the share of each sector in terms of gross value of production, value added, intermediate consumption, factors and tax burden.

The sectors that contributed the most to gross value of production were Other services, Manufacturing and Agriculture. SMEs comprised 33% of the Manufacturing industry in terms of gross output value, 37% in terms of VA and 30% in terms of intermediate consumption. Additionally, SMEs were more intensive in their use of labor than large manufacturing industries. A lower tax burden on SMEs industries was also observed when compared with larger firms.

On the demand side, consumer groups were divided into domestic households (rich and poor), the government, foreign consumers and foreign producers. The assumption of a small open economy was adopted, which implied that Argentina was a price taker in international markets.

TABLE 2

ARGENTINA, 2010. PRODUCTION AND VALUE ADDED STATISTICS
AS A PERCENTAGE OF THE TOTAL

Sector	Gross Output	Value Added	Intermediate Consumption	Labor	Capital	Net Tax Burden
Agriculture, Forestry & Fishing	7	9	5	7	15	7
Oil & Mining	2	3	1	1	5	9
Manufacturing: SME	11	8	13	9	6	9
Manufacturing: LE	22	13	31	7	9	13
Electricity, Gas & Water	2	1	3	3	3	-27
Construction	9	6	12	4	7	6
Transport	6	6	7	5	7	3
Other Services	41	53	28	64	47	7
Total	100	100	100	100	100	8

Source: Own elaboration based on INDEC.

Two types of households distributed by per capita income level were modeled. Poor Households corresponded to the first six deciles of per capita income, and Rich Households applied to the remaining four richest deciles[8]. In this model, households made expenditures on consumer goods and investments and pay taxes. Their income was provided based on the factor production payment and on transfers. Sectoral consumption was obtained from the Survey of Household Expenditure 2004/2005. The statistics on household income by type of factor and transfer were obtained from the Permanent Household Survey 2010.

In the model, government resources were tax revenues, social contributions and other non-tax revenues. Government expenses related to both the acquisition of goods and services for consumption and investment as well as to transfers to households. The income and expenditures of the public sector were consolidated for the federal administration, the provinces and the municipalities. Information on the government accounts was obtained from the Ministry of the Economy.

The consumption of the rest of the world was generated from Argentina's exports and goods from other countries. The production of the rest of the world was Argentina's imports and transactions with other countries. Data on sectoral exports and imports were obtained from INDEC. The revenues and expenditures for factor income were subsequently obtained from the balance of payments from INDEC.

For the modeled institutions, the balance of income and expenses was the net financial status, the latter being the financial account used for the closure of the SAM. For the government and households, financial status was determined by the difference

8 40% of the richest households comprised 30.5% of the population in the Permanent Household Survey 2010.

between the modeled revenues and expenditures, and for the rest of the world, it was the surplus/deficit on the current account of the balance of payments.

4. THE MODEL

In this section, we present the main features of the CGE model utilized for simulations and a simplified model that represented an economy with heterogeneous firms.

4.1. Characteristics of the general equilibrium model used for the simulations

Our CGE model was static, had all of the basic properties of the Walrasian perspective and was numerically determined using GAMS/MPSGE[9]. Prices were computed to clear all of the markets except for the labor market because it was assumed that unemployment was present and therefore that there was a minimum wage constraint.

The economy was assumed to be small with respect to international markets. The rest of the world bought domestic exports and sold imports in addition to making bond transactions and collecting dividends from investments.

Regarding the supply side, the production function in each sector was a Leontief function between value-added and intermediate input; one output unit required *x* percent of an aggregate of productive factors (labor, physical capital, financial capital and land) and (1–*x*) percent of intermediate inputs. The intermediate input function was a Leontief function of all of the goods, which was a strict complement to production. Value-added, on the other hand, was a Cobb-Douglas (CD) function of productive factors. Private savings, public savings and foreign savings were totaled to finance investments.

The demand side was modeled through two representative households (poor and rich), a government and an external sector. Households bought or sold bonds, invested and consumed in constant proportions (Cobb-Douglas) based on the remuneration of the factors they owned (and the government transfers they received). The selection of the optimal proportion of the goods consumed was obtained from a nested production function in the utility function through a cost minimization process.

The government was represented as an agent that participated in investment markets, consumed and made transfers to households and had a Cobb-Douglas utility function; its main source of income was tax collection (although it also made financial transactions through bonds). The rest of the goods were assumed to be complementary, and the elasticity of the substitution between them was zero. Therefore, a CD utility function was attributed to the government. This decision was motivated by the property of the CD function to maintain the same share of each type of expense in the total, which seemed to be a neutral way of modeling the behavior of the government. Thus, it was assumed that each dollar of revenue was spent on different factors and goods in the same proportion as it was originally spent in the benchmark year.

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9 The solution of the model was obtained using the representation of General Equilibrium and using the Mixed Complementarities Approach.

For private agents, welfare changes were calculated using the Equivalent Variation, and the same measure was used for the public sector. We believed that this would represent a monetary proxy of the changes in society welfare stemming from the modifications in the availability of goods and services provided by the public sector (education, health and defense, for example). A simple change in revenue would not account for the changes in price of the goods, services and factors; using the Equivalent Variation thus helped generate an estimate of those changes.

The basic data for the model were organized into a social accounting matrix (SAM). As is customary in applied general equilibrium analysis, the model was based on the economic transactions in a particular benchmark year. Benchmark quantities and prices – together with exogenously determined elasticities – were used to calibrate the functional forms.

Accordingly, the initial level of positive unemployment observed during the benchmark year was assumed; the evolution of the economy determined endogenously whether unemployment persisted. To represent unemployment, we assumed that there was a minimum real wage rate constraint and that the typical Walrasian mechanism did not apply to unemployment (however, it is possible to simulate different rules of adjustment of wages, e.g., constant in nominal terms).

4.2. A model of an economy with heterogeneous firms

A general equilibrium perspective considers changes in industrial structure, and the industrial structure is important in accounting for additional dimensions such as evasion, informality and creation of employment[10].

With regard to the industrial structure, the basic idea is to consider that firms in the industrial sector are heterogeneous with respect to four main categories: the productivity of the factors, the efficiency in the use of intermediate inputs, the quality of goods produced and the level of formality and of tax evasion.

The first two characteristics refer to internal efficiency. They address the question of whether it is possible to produce the same quantity of products using smaller quantities of capital, labor and/or intermediate goods and services.

The third characteristic can be interpreted as an external effect that is related to the efficiency of the markets and not necessarily of the shareholders. To approximate this efficiency, it is assumed that if the goods produced are not of standard quality, the consumers will have to purchase more units to obtain the expected service, which will increase their expenses. The problem of quality could underlie a substantial portion of the discussion regarding the capacity of SMEs to access foreign markets.

The fourth feature is often quoted as being intrinsic to SMEs, which can dwell in markets without complying with regulations or paying all of the necessary taxes. This characteristic is the issue that we explored with the CGE model.

In this simplified version of the model, we considered evasion of labor taxes only, which are likely the easiest to evade; however, the model used for simulations

[10] Little work has been done concerning the presence of heterogeneous technologies in general equilibrium. See, for instance, Zhai (2008) and Balistreri and Rutherford (2013).

encompassed several taxes and differing levels of evasion. Although we did not focus explicitly on productivity or efficiency, it should be noted that the above mentioned lack of efficiency or of quality (as well as the additional cost of capital, see below) could be compensated for with a lower degree of fulfillment of obligations and higher tax evasion. In the following section, we describe the addition of two characteristic syndromes that are typically attributed to SMEs: i) limited access to capital markets or a higher cost of capital due to imperfections, such as asymmetries of information, and ii) limited access to export markets. As we observed, these phenomena can be connected, as gaining access to capital markets can reduce costs and improve the competitiveness of firms in the international markets.

We considered an economy that consisted of only one private agent, three types of industrial firms (large firms that produce tradable goods, large firms that produce non-tradable goods and SMEs) and a public sector (that collects taxes and purchases goods and labor).

We accounted for two mobile non-specific factors, labor (L) and a fraction of the total capital (K_m), while the rest of the capital was assumed to be specific and not mobile between industries. Thus, even when the production functions exhibited a constant return to scale, there continued to be profits associated with the remuneration of specific capital.

Regarding access to capital markets, it was assumed that there were no quantitative constraints. Instead, we assumed that SMEs had to pay a mark-up on mobile capital to replicate their differential costs for accessing capital markets.

Labor unemployment was also included, which was associated with a rule that determined the wage rate (indexation to prices of goods faced by final demand).

The economy was considered to be small with respect to the rest of the world's economies.

4.2.1. *Households*

The budget constraint of the households sector was:

$$\begin{aligned} P_{1T}C_{1T} + P_{1N}C_{1N} + P_2C_2 + P_M M = W\left(L^0 - Un\right) + \\ \pi_{1T} + \pi_{1N} + \pi_2 + r_m K_{1Tm} + r_m K_{1Nm} + r_m K_{2m}\left(1+\gamma\right) \end{aligned} \tag{1}$$

where P_i was the price of the goods produced by the larger firms, indicated with sub-index 1 (T for tradable goods and N for non-tradable goods) and by SMEs, sub-index 2; P_M was the price of imported goods; C_{1T}, C_{1N} and C_2 represented the household demand for domestic goods and M represented the household consumption of imported goods. The sources of income for the household were labor earnings determined by wage (W) and actual employment, the difference between the endowment of labor (L^0) and unemployment (Un), profits of the firms (π_i) and the remuneration (r_m) of mobile capital and the K_m employed in firms 1 and 2. In the case of SMEs, there was an additional cost of capital indicated by γ.

The utility function U of a representative household depended on the consumption of C_{1T}, C_{1N}, C_2 and M, and it adhered to habitual regularity conditions. The first order conditions for the determination of consumption of goods produced by both types of firms were calculated as:

$$U_{1T} / U_2 = P_{1T} / P_2 \left(1+\theta\right) \tag{2}$$

$$U_{1N} / U_2 = P_{1N} / P_2 \left(1+\theta\right) \tag{3}$$

$$U_1 / U_M = P_1 / P_M . \tag{4}$$

The general model assumed that the production functions were homogenous in degree one and that those profits became zero, although a certain amount of specific non-mobile capital was included with a specific remuneration. The term "positive profits" can be considered another way of depicting the remuneration of specific non-mobile capital. A relevant parameter implicit in equation (3) was determined a priori to be the elasticity of the substitution between goods produced by large firms and SMEs; in the model, the basic simulations assumed that this elasticity was one.

4.2.2. *Firms*

The profit function of the large firms for tradable goods was:

$$\pi_{1T} = \left(P_{1T} - a_{1T}P_2 - m_{1T}P_M\right) FT\left(L_{1T}, K_{1Tm}\right) - WL_{1T}\left(1+t\right) - r_m K_{1Tm}, \tag{5}$$

where FT was the (neoclassical) production function and was dependent on labor employed in the sector L_{1T} and on mobile capital, K_{1Tm}. The parameter a_{1T} was the input requirement of the goods produced by SMEs per unit of production of large firms. The input requirement of imported goods was m_{1T}.

The conditions for the maximization of profits were determined to be:

$$\left(P_{1T} - a_{1T}P_2 - m_{1T}P_M\right) FT'_L\left(L_{1T}, K_{1Tm}\right) - W\left(1+t\right) = 0, \tag{6}$$

$$\left(P_{1T} - a_{1T}P_2 - m_{1T}P_M\right) FT'_K\left(L_{1T}, K_{1Tm}\right) - r_m = 0. \tag{7}$$

The profit function for non-tradable goods and services was:

$$\pi_{1N} = \left(P_{1N} - a_{1N}P_2 - m_{1N}P_M\right) FN\left(L_{1N}, K_{1Nm}\right) - WL_{1N}\left(1+t\right) - r_m K_{1Nm}, \tag{8}$$

where $FN(L_{1N}, K_{1Nm})$ was the (neoclassical) production function that was determined by the labor and capital employed in the sector. The parameter a_{1N} was the input requirement of the goods produced by SMEs per unit of production of non-tradable goods and services.

The corresponding first order conditions for the maximization of profits were:

$$\left(P_{1N} - a_{1N}P_2 - m_{1N}P_M\right)FN'_L\left(L_{1N}, K_{1Nm}\right) - W\left(1+t\right) = 0, \tag{9}$$

$$\left(P_{1N} - a_{1N}P_2 - m_{1N}P_M\right)FN'_K\left(L_{1N}, K_{1Nm}\right) - r_m = 0. \tag{10}$$

4.2.3. *SMEs*

Profits were defined in a similar manner:

$$\begin{gathered}\pi_2 = \left(P_2 - a_{2T}P_{1T} - a_{2N}P_{1N} - m_2P_M\right)H\left(L_2, K_{2m}\right)/ \\ \left(1+\varepsilon\right) - WL_2\left(1+tv\right) - r_mK_{2m}\left(1+\gamma\right).\end{gathered} \tag{11}$$

In this expression, the production function was $H(L_{2,}\ K_{2m})$, and there were three additional parameters: ε, v and γ. The first parameter represented an index of productivity in the use of labor and capital; a higher level of ε indicated a lower level of productivity. Parameter v stood for the degree of evasion of labor taxes ($0 \le v \le 1$); a lower of level of v implied a lower effect rate tv. The additional cost of capital faced by SMEs was indicated by γ; a higher level of this parameter indicated that the firm would have to pay an additional cost to access one unit of capital.

The profit maximization conditions for those firms were:

$$\left(P_2 - a_{2T}P_{1T} - a_{2N}P_{1N} - m_2P_M\right)H'_L\left(L_2, K_{2m}\right)/\left(1+\varepsilon\right) - W\left(1+tv\right) = 0. \tag{12}$$

$$\left(P_2 - a_{2T}P_{1T} - a_{2N}P_{1N} - m_2P_M\right)H'_K\left(L_2, K_{2m}\right)/\left(1+\varepsilon\right) - r_m\left(1+\gamma\right) = 0. \tag{13}$$

4.2.4. *Government*

The tax revenue R of the government was calculated by the collection of taxes:

$$R = tW\left(L_1 + vL_2 + L_g\right). \tag{14}$$

This revenue was devoted to the purchase of goods and labor, which were indicated by G_i and L_g:

$$G_{1T} = g_{1T}R / P_{1T}, \tag{15}$$

$$G_{1N} = g_{1N}R / P_{1N}, \tag{16}$$

$$G_2 = g_2R / P_2\left(1+\theta\right), \tag{17}$$

$$L_g = g_LR / W\left(1+t\right). \tag{18}$$

The corresponding shares were determined by the constants g_{1T}, g_{1N}, g_2 and g_L, respectively. Those shares were constant; thus, equations (15) to (18) could be obtained from the maximization of a Cobb-Douglas utility function attributed to the government, as suggested in Ballard *et al.* (1985). As a result, a measure of the welfare of the public sector could be introduced. In the simulations, the Equivalent Variation was used both for households and for the public sector.

4.2.5. *Market equilibrium*

We were able to characterize the market equilibrium for this economy (notice that this was pseudo-equilibrium because we admitted the existence of involuntary unemployment). The model was determined by computing a vector of prices (and quantities) such that households maximized welfare, firms maximized profits and all of the markets were simultaneously in equilibrium.

The demand for labor plus unemployment had to be equal to the total endowment L^0.

$$L_{1T} + vL_{1N} + L_2 + L_g + Un = L^0. \tag{19}$$

As there was unemployment, it was necessary to include a rule regarding the determination of wages above the equilibrium level. This rule was assumed to be represented by:

$$W = \varphi_{1T}P_{1T} + \varphi_{1N}P_{1N} + \varphi_2 P_2, \tag{20}$$

where φ_i was the share of good i in the Consumers Price Index. Notice that higher labor taxes (the only type of tax considered in the simplified version) increased the prices of final demand and therefore increased nominal wages.

Equation (20) had to be interpreted in a more general form as a minimum wage condition; thus, the simulations allowed the possibility of increasing real wages under full employment.

The market for mobile factors illustrated the equalization of demand for capital and supply of mobile capital owned by households, represented by $K_m{}^0$:

$$K_{1Tm} + K_{2Tm} + K_{2m} = K_m^0. \tag{21}$$

The last three equations represent the market equilibrium conditions for goods produced by large firms and by SMEs in the economy:

$$C_{1T} + G_{1T} + a_{2T}H(L_2, K_{2m}) / (1+\varepsilon) + X = FT(L_{1T}, K_{1Tm}), \tag{22}$$

$$C_{1N} + G_{1N} + a_{2N}H(L_2, K_{2m}) / (1+\varepsilon) = FN(L_{1N}, K_{1Nm}), \tag{23}$$

$$C_2 + G_2 + a_{1T}FT(L_{1T}, K_{1Tm}) + a_{1N}FN(L_{1N}, K_{1Nm}) = H(L_2, K_{2m}) / (1+\varepsilon). \tag{24}$$

The left-hand side of these equations represents the demand: private consumption, government expenditure of the respective good and demand of the good as a production input of the rest of the economy. Notice that a gain in productivity (an increase in parameter ε) reduces the demand for intermediate uses per unit of value added.

This was a general equilibrium model, which in principle was consistent because it contained 24 unknown variables to be determined: 1) the demand for labor in every sector and unemployment, L_{1T}, L_{1N}, L_2, L_g and Un; 2) the demand for mobile capital, K_{1Tm}, K_{1Nm} and K_{2m}; 3) the prices of factors and goods, W, r_m, P_{1N} and P_2; 4) the household and government demand for goods, C_{1T}, C_{1N}, C_2, G_{1T}, G_{1N} and G_2; 5) the profits and revenue of the public sector, π_{1T}, π_{1N}, π_2, and R; and 6) the export X and import of goods M.

4.3. Calibration and Validation

To calculate the benchmark and counterfactual solutions, we used MPSGE as developed by Tom Rutherford based on the works of Mathiesen (1985), who showed that economic general equilibrium can be expressed as a set of equalities and inequalities (mixed complementary programming). The program includes a procedure of self-calibration that facilitates its use and a change in specification of elasticities and structural characteristics. Thus, provided that the SAM was correctly balanced, the first solution of the model computed the parameters that enabled the replication of the benchmark year data. The counterfactual exercises were in effect comparative statistic simulations using the calculated parameters. Therefore, calibration was obtained in the first run of the model, which is a standard procedure for this type of research (see Chisari and Romero (2009) for a summary of the methodology and references). We have used this methodology for different countries in Latin America as well as for the analysis of economies with sectors that are under regulation (see Chisari, Estache and Romero, 1999).

For validation, we attempted to replicate the dynamic path of the economy. To do so, we identified the main shocks (of policy or exogenous) that impinged upon the economy in year t+1 and tried to replicate the observed main macroeconomic indicators based on the information regarding changes in stocks, technology and labor force with respect to year t. One key variable that was consistently useful in validating the model was the degree of mobility of capital, i.e., the proportion of capital employed by production sectors that was not specific but was mobile. Thus, the validation included the determination of the proportion of capital that was mobile for the first two years, which for Argentina was approximately 12.5%. A more thorough discussion is presented in Chisari, Maquieyra and Miller (2012).

5. SIMULATION RESULTS

In this section, we report the results of the analysis of the general equilibrium effects derived from potential programs enabling access to capital markets conditional on higher formalization. Formalization was considered to imply greater effective taxes and compliance with norms and standards. Additionally, we estimated the minimum level of productivity improvement necessary to prevent the self-exclusion of SMEs from these programs.

Based on these objectives, we conducted three groups of simulations: a) access of SMEs to capital markets and access conditional on formalization (tax compliance), b) tax substitution and equal-yield-replacements and c) compensatory productivity gains of SMEs.

The results are summarized using a set of indicators for the economies. We included the change in GDP and trade balance and the equivalent variations for the poor, the rich and the public sector. The last indicator (equivalent variation of the public sector) is less standard, but as has already been argued, we assumed a Cobb-Douglas utility function for the government because that function implies constancy of the share of different types of expenses. We also included the average rate of profit in primary, secondary and tertiary sectors to appraise how the industrial structure responded or would respond to the new relative prices.

Using the simple version of the model, we considered the following comparative exercises:

a. Elimination of a differential cost of capital (equivalent to reductions of γ).
b. Increase in the formalization of SMEs (represented as an increase in v, the tax differential between SMEs and LEs)
c. Increase in the productivity required to compensate for the negative effects of formalization ($\varepsilon < 0$)

As described above, it has been argued that SMEs do not have access to capital markets and that they have to pay an additional cost per unit of capital. Regarding the model, that argument is equivalent to saying that γ is positive and most likely very high. A policy that is oriented to reduce that cost could help increase the scale of SMEs, but it could also foster some substitution of labor for capital. Large firms would also see an increase in the price of capital, which would reduce the demand for labor.

Auguste, Bebczuk and Sánchez (2013) supported the idea that financial constraints influence SMEs. In our model, this constraint was approximated by a mark-up. However, the possibility that SMEs would choose to not enter formal capital markets for reasons other than the direct marginal cost of funds cannot be ruled out. For example, accessing formal capital markets could require the disclosure of certain information about the firm, including projects in development as well as sensible information on tax bases. Hence, a firm might face a trade-off between the lower cost of funds and higher taxes due to formalization. The net effect of a movement to formalization that reduces the cost of capital has to be complemented by an evaluation of the effective taxes paid by the firm (e.g., those charged on labor expenses).

Accordingly, two exercises were performed. In the first one, we reduced γ, and in the second, we assumed that this reduction was accompanied by an increase in v, the parameter that indicates tax compliance.

Our benchmark included the higher cost of capital paid by SMEs. Therefore, to represent the differential interest rate, we divided the remuneration of mobile capital into two parts: the mobile capital at market remuneration and the differential cost of capital or mark-up charged on the normal remuneration of capital. We modeled the differential cost of capital as an additional mark-up on the remuneration of capital by SMEs that was collected by the richest households. The elimination of this mark-up allowed for an estimate of the effect of a program to provide SMEs access to capital markets. The simulations considered a differential rate of 10% that was paid by the SMEs (Table 3).

An increase in GDP was observed. The change was slight because of the reduced proportion of manufacturing SMEs in relation to the whole economy. In addition, manufacturing SMEs showed a significant increase in activity level, but this was accompanied by a reduction in the activity level of the large manufacturers and of other sectors of the economy. This result was due to the substitution at the consumption level of other goods for products of SMEs and to the fact that the capital moved from the rest of the economy to the SMEs. Accompanying this reallocation of capital was a reduction in the rate of unemployment because SMEs are labor intensive and require more workers than the number of positions that would be eliminated in other sectors.

There was also a fiscal reduction, as SMEs pay lower effective taxes than the large manufacturers.

The reduction in the cost of capital included a gain in the international competitiveness of SMEs. Consequently, their exports were the main driver of the increase in activity level[11]. SMEs could face a number of different restrictions when accessing foreign markets. Therefore, to obtain the benefits of eliminating the differential cost of capital, it would be necessary to implement polices directed at removing those restrictions.

The poor showed an increase in welfare that was greater than that of the rich. This result was due to the reduction in the differential cost of capital that was eliminated, as it was assumed that this cost comprised part of the total income of the rich.

The third column of Table 3 shows the results of reducing the 10% cost of capital differential when the reduction is matched with an increase in the effective taxes paid by SMEs, thus equating the taxes paid by SMEs with those paid by the large manufacturing firms (the same average effective tax).

This simulation showed a full reversal of the results. There was a decrease in GDP, an improvement in fiscal result, an increase in the level of unemployment and a reduction in the activity level and in the rate of profits of SMEs.

This simulation confirmed the belief that many firms would self-exclude from gaining better access to the capital markets if formalization, and thus tax compliance, were required.

What was more notable about these results was that the economy was weakened by the decrease in the activity level of the SMEs and that there was a reduction in the activity level of all of the other industrial sectors. The main reason for this result could be that because SMEs were paying higher taxes, including taxes on labor, the rate of unemployment increased, which reduced the level of household consumption and investment.

[11] We simulated the elimination of the cost of capital differential maintaining the benchmark level of SME's exports. We observed that the profit rate and production of SMEs also remained close to the benchmark levels.

TABLE 3

SIMULATIONS OF ACCESS TO CAPITAL MARKET, FORMALIZATION AND PRODUCTIVITY IMPROVEMENTS

Indicators	Elimination of Cost of capital Differential	Tax rates equalization of SME & LE	Tax rates equalization with ex-ante fiscal neutrality	Productivity gains required to compensate fiscal pressure on SME
Macroeconomic Indicators				
GDP	0.14	–3.64	–1.25	0.60
Trade balance	0.34	–3.69	0.24	0.56
Unemployment rate (base= 7.75)	7.46	12.87	9.60	8.94
Fiscal Result	–0.72	–0.87	–2.33	1.95
Welfare Indicators				
Welfare of the Poor	0.29	–3.57	–1.79	0.82
Welfare of the Rich	0.21	–4.31	–1.04	–0.22
Rate of profit				
Agriculture, Forestry & Fishing	–0.25	–0.99	4.07	–0.81
Manufacturing: SME	3.44	–2.93	1.56	0.00
Manufacturing: LE	–1.03	–7.52	–0.14	–3.50
Services	1.02	–4.71	–0.32	1.83
Sectoral activity level				
Agriculture, Forestry & Fishing	–0.63	–0.49	1.19	–1.05
Oil & Mining	–0.54	0.11	1.66	–0.71
Manufacturing: SME	4.26	–12.71	–9.84	8.50
Manufacturing: LE	–1.20	–4.74	–0.74	–2.97
Electricity, Gas & Water	0.19	–3.40	–0.94	0.68
Construction	0.09	–2.88	–1.02	0.75
Transport	0.05	–3.49	–0.72	0.13
Other Services	0.03	–2.10	–0.52	1.00

Source: own elaboration.

The negative impact on the economy was mitigated when the increase in effective taxes paid by SMEs was compensated with a reduction in the average rate of effective taxes for the whole economy. Although this helped sustain the activity level, it was not sufficient to recover the benchmark levels of the economy and of the SMEs.

However, after formalization and gaining access to capital markets, SMEs did become more productive[12]. The gains in productivity of the SMEs were equivalent to the reductions in parameter ε. Those gains reduced the costs of production and the use of intermediate goods. Accordingly, two main consequences can be expected.

[12] However, SMEs could witness gains in quality too, which would be a gain in efficiency for the market; the firms would most likely not have a large enough incentive to make the necessary efforts to obtain those changes unless they were for free or were forced by competitive conditions. Whatever the case, the question is how the economy would react to those quality gains, which would be observed in the impact on relevant variables, such as employment. Quality can also be a critical variable to gaining access to export markets –see González and Hallak (2013). Although the main factor that González and Hallak found was knowledge, in our model, SMEs could face difficulties if they had to increase quality to gain access to export markets because that would require additional capital and, as already mentioned, more formalization and consequently an increase in effective taxes.

On the one hand, there could be a direct decrease in employment. On the other hand, indirectly, an increase in the demand for the goods produced by SMEs could be observed because a reduction in costs would transfer to some extent to prices; this would increase SMEs' production.

Therefore, we estimated the necessary productivity gain after reforms to sufficiently compensate SMEs to equalize their rate of profit with that of the benchmark. We found that that this productivity gain would need to be approximately 20%.

As the GDP grew, we observed that although the activity level of SMEs increased, the rate of unemployment remained high. This is not surprising, as SMEs are more productive and therefore need to hire fewer workers.

This result demonstrates a negative effect of a policy oriented to reduce unemployment by granting SMEs access to capital markets.

6. MAIN RESULTS AND FINAL REMARKS

This paper examines the impact of facilitating SMEs' access to capital markets using a computable general equilibrium model of Argentina.

Although there is abundant literature on this topic, most of which emphasizes the possible economic gains by eliminating the differential cost of capital paid by SMEs, there have been no quantitative studies. In this study, we used a CGE model to investigate the economy-wide impact of a policy removing the differential cost of capital, i.e., considering the repercussions on other sectors.

First, the simulations showed that the economy would gain from better access of SMEs to capital markets. However, this was at the cost of reducing the activity level of other sectors. Additionally, although the rate of unemployment was reduced, this result was not as significant as expected. Moreover, the economic gains were at the expense of the fiscal result because SMEs pay lower effective taxes than the other industries.

Second, if the elimination of the differential cost of capital paid by SMEs was conditional on formalization and tax compliance, then SMEs would have an incentive to self-exclude from that type of program to remain informal and excluded from capital markets. Additionally, our results showed that a reduction in the average effective taxes for the economy would not be enough to compensate SMEs.

Finally, when higher formalization and access to capital markets was complemented with an increase in the productivity of SMEs, the economy grew again, and SMEs reached the profit rates of the benchmark. However, the rate of unemployment was higher than at the benchmark because the productivity gain reduced the SMEs' required number of workers.

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ESTIMATING BIOMASS MIGRATION PARAMETERS BY ANALYZING THE SPATIAL BEHAVIOR OF THE FISHING FLEET

ESTIMACION DE PARAMETROS MIGRATORIOS DE LA BIOMASA A TRAVES DE UN ANALISIS DEL COMPORTAMIENTO ESPACIAL DE LA FLOTA DE PESCA

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Abstract

In this study, a method will be developed and applied for estimating biological migration parameters of the biomass of a fishery resource by means of a decision analysis of the spatial behavior of the fleet. First, a model of discrete selection is estimated, together with patch capture function. This will allow estimating the biomass availability on each patch. In the second regression, values of biomass are used in order to estimate a model of biological migration between patches. This method is proven in the Chilean jack mackerel fishery. This will allow estimating statistically significant migration parameters, identifying migration patterns.

Keywords: *Biological dispersion, industrial fishing, fishing migration, spatial bioeconomics model, stock distribution.*

JEL Classification: *Q22.*

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Resumen

En este artículo se desarrolla y aplica una metodología para estimar parámetros biológicos de migración de la biomasa de un recurso pesquero, por medio del análisis de las decisiones del comportamiento espacial de la flota. Primero se estima un modelo de elección discreta, conjuntamente con una función agregada de captura por parche. Esto permite estimar la disponibilidad de biomasa en cada parche. En la segunda etapa se utilizan los valores de la biomasa para estimar un modelo de migración biológica entre parches. La metodología se aplica a una pesquería del jurel en Chile. Esto permite estimar parámetros de migración estadísticamente significativos, identificando patrones de migración.

Palabras claves: *Dispersión biológica, pesca industrial, migración pesquera, modelo bioeconómico espacial, distribución del stock.*

Clasificación JEL: *Q22.*

1. INTRODUCTION

Bioeconomic analysis in fisheries has experienced remarkable development in recent years, especially in the analysis of the spatial behavior of fishermen and fish stock. This is mainly due to the utilization of Marine Protected Areas (MPA) as a tool for fisheries management. Spatial research has been carried out on both the biological and economics aspects of the fishery but also combining the two areas for optimal bioeconomic policy evaluation. Biological studies characterize the fish resource with emphasis on zonal features such as rates of reproduction and growth (e.g. Janmaat, 2005; Kelly *et al.*, 2000; Jones, 2006)[1]. Economics studies characterized the behavior of fishermen in harvesting decisions, such as determinants of the choice of fishing zones and the search process itself, and moreover, information flows among fishermen on the spatial availability of fish resources in the different fishing zones (e.g. Díaz and Salgado, 2006; Zhang, 2010 among other)[2]. A bioeconomic model combines the spatial behavior of the fish biomass and fishermen to fully capture the dynamics of spatial models that leads to optimal policies on management of the fisheries (e.g. Sanchirico and Wilen, 1999; Sanchirico and Wilen, 2001; Smith and Wilen, 2003).

The use of spatial management tools in fisheries, such as the MPA is not trivial due to the uncertainty about the impacts they may present. Different biological and

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1 See too: Bohnsack 1998; Wallace 1999; Pezzey, Roberts, and Urdal 2000; Murawski *et al.*, 2000; Rowe, 2001; 2002; Halpern, 2003; Russ, Alcala, and Maypa, 2003; Gell and Roberts, 2003; Layton, Haynie, and Huppert, 2003; Grafton, Kompas, and Lindenmayer, 2005; Denny and Babcock, 2004.

2 See too: Smith and Wilen, 2003; Smith 2005 and Cartigny *et al.* 2008.

economic effects are generated by this sort of tools in comparison with others, such as Catch Limits or Territorial Use Rights, for instance. First, when the captures in a fishing area are closed, positive effects on the biomass are expected. However, when the economic behavior of the fishermen is incorporated, it is possible to see different effects outside the target area of regulation; however, some of those effects may be negative. This can subtract the possible biological benefits of creating a reservoir. On the other hand, it is possible that migration characteristics of the stock between zones can make possible the fact that the creation of reservoir zones even generates a double payoff. One of these would be biological due to an increment on the biomass, and one economic, due to the recovery of the biomass. Not only within the reserve area, but also outside of it, leading to an increase in the captures and in the economic outcomes of the fishery (Sanchirico and Wilen 2001).

Despite the importance of the spatial analysis in fisheries, the empiric works developed to date have been focused on the economic aspects of the analysis because there is neither information nor adequate knowledge on the biological processes -such as migration in this case- that could determine the behavior of the biomass of the fishing resources in a way that could be incorporated into mathematically treatable bioeconomic models. Thus, empiric studies have focused only on decision processes by the fishermen, ignoring the biology of the resource; or they have assumed that the biology of the resource is known, and calibrated values are used for the simulations.

In Chile, Díaz and Salgado (2006) and Cartigny *et al.* (2008) have analyzed the problem of the spatial distribution of the fishing zones between industrial and artisanal sectors, using tools from the MPA literature. In such works, the authors parameterized a bioeconomic model of a marine reservoir with data from the *anchoveta* (Engraulis ringens Jenyns, 1842) fishery in Northern Chile. By using this model, the different distributions of the fishing zone between industrial and artisanal fishermen are simulated by analyzing the long-term evolution of the biomass and both artisanal and industrial captures in the different fishing areas. The authors conclude that a zoning of the fishing area may attain biological and economic objectives as well as income distribution between both sectors. Thus, these authors divide the fishing zone in two patches and assume certain parameters of biological dispersion between these two zones. In order to counteract the scarce information on this issue, the authors simulate their results for different dispersion rates of the biomass amongst patches, concluding that the dispersion rate is a crucial parameter towards achieving biological and economic objectives in the use of the fishing areas zoning as a tool for fisheries management.

On the other hand, Cartigny *et al.* (2008) developed a Bioeconomic model of dynamic optimization in order to analyze the optimal distribution of a fishing zone between artisanal and industrial sectors, taking into account that the areas reserved for artisanal fishing also have a biological importance due to the presence of zones coastal upwelling, which implies higher rates of biomass growth and a process of biomass dispersion from coastal areas to zones where the industrial sector is permitted to catch. Again, the authors conclude that the biological parameters associated with the growth of the resource and the biomass dispersion rates between patches are fundamental to find an internal solution and a stationary balance in the problem of the dynamic optimization. Due to the lack of information about the biomass migration that allows a realistic application of the model, these authors only present simulations by means of standard parameters from the bioeconomic literature for illustrative purposes. The impossibility of finding biological information that allows the application of this theoretical model to a study case has prompted the development of this research.

Some authors have developed the notion of analyzing the stock of biomass as a latent variable in the decision to capture by fishermen, basically through the inclusion of dummies per period that represent aspects which will remain constant among fishermen (Murdock 2006; Timmins and Murdock 2007; Zhang 2010). For instance, Zhang (2010) developed a model for analyzing the decision of capture effort for fishermen in the Gulf of Mexico. The author develops a three-stage econometric procedure that allows identifying the economic model that explains the determination of fishing effort of the individuals and their labor supply.

The most directly related work to this study is that by Smith *et al.,* (2009). In this article, the authors analyze the importance of considering spatial and dynamic processes in the analysis of the renewable resources management, such as fishery resources. The authors apply a model to the estimation of the biological parameters of migration in the reef-fish fishery in the Gulf of Mexico. The article states that "*…a critical component of the spatial-dynamic systems is the dispersion or diffusion mechanisms that link temporary and spatial components of the model…*" (Smith *et al.,* 2009: 108). However, these authors are aware of the practical difficulties of knowing these components, due to the lack of specific information on the migratory biology of the fishery resources. Nevertheless, they point out that it is possible to develop methods that will allow estimating the parameters of the migration models by observing the behavior of fishermen. That is the contribution of this work, in the sense that it is proposed an estimation method of migratory parameters through disaggregated information based solely on observing the behavior of the fleet. In our model, disaggregated data at the level of the behavior of the fishermen are not required; it suffices to know the aggregated fishing effort and the captures per patch and period. To that end, an input function estimation method of demand proposed by Berry (1994) is used. Additionally, estimation of the function of capture by patches, which will enable the direct identification of the biomass level estimated by patch and period in the first estimation stage.

The organization of this article is as follows: In the next section, the theoretical model that allows estimating the parameters of biological migration is presented and discussed, using aggregated data for the fishery on distribution of effort and captures per patch and fishing area. In Section 3 the most important elements of the Chilean mackerel fishery in Central Southern Chile are presented, as well as data used for the estimation. This for contextualize the example. Section 4 presents and discusses the results of the estimation and finally, Section 5 concludes.

2. METHODOLOGY

In this section, the bioeconomic model is presented. Its structural estimation allows identifying economic parameters associated to the functions of capture, as well as biological parameters associated to the growth of the resource and carrying capacity of the system. In the second step, parameters of stock migration between different fishing patches are identified.

In the first step, the assumptions of the biological model that describes both growth and migration of the stock between patches are described. Subsequently, the economic model associated to the technology of captures is presented. Finally, the assumptions of the fishermen's behaviors that allow explaining the observed data and the estimation of the structural parameters of the model are also described.

Biological model

The biological component of the model is based on the works developed by the economic literature in order to analyze the migration of fishery resources between patches. Among the literature that analyzes these models, Cartigny *et al.,* (2008); Sanchirico and Wilen, (1999); Sanchirico and Wilen, (2001); Smith, (2005); Smith and Wilen, (2003) and Smith *et al.,* (2009) can be mentioned, amongs others.

It is assumed that the fishing zone is divided in $k \times 1$ patches. The dynamics of the stock in the k patch is given by:

$$x_{t+1}^k = x_t^k + f(x_t^k) - H_t^k + MN_t^k \tag{1}$$

Where, x_t^k is the stock in the patch, $\mathrm{f}(x_t^k)$ is the natural growth of the biomass in patch k, and H_t^k is the fishing mortality or capture. *MN* represents the net migration of the patch, defined as the difference between immigration from other patches and migration to other patches.

Patches are different spatial environments that contain subpopulations of a same biomass. As it is common in the literature (Smith *et al.*, 2009), it is assumed that the growth of the biomass is logistical:

$$f\left(x_t^k\right) = rx_t^k\left(1 - \frac{x_t^k}{K^k}\right) \tag{2}$$

Here, K is the carrying capacity of the patch k; and r is the instantaneous growth rate. Using the formulation proposed by Sanchirico and Wilen (2001), it is assumed that the net migration presents the following shape:

$$MN_t^k = d_{kk}x_t^k + \sum_{\substack{h=1 \\ h\neq k}}^{K} d_{hk}x_t^k, \quad k = 1,\ldots,n. \tag{3}$$

In this case, the growth component is omitted (in comparison with the original one) because this is included explicitly in equation (1). On the one hand, d_{kk} represents the migration rate; therefore it is negative. On the other hand, d_{hk} represents dispersion rates between patches h and k. These very authors accept that this parameter is "in itself very stylized" ignoring many other aspects, but it is "analytically tractable". So, it is possible to rewrite (1) in a matrix form for the K patches as:

$$x_{t+1} = x_t + \boldsymbol{F}\left(x_t\right)_t - H_t + \boldsymbol{D}x_t \tag{4}$$

Equation includes k equations where k is a vector dimension (k) that represents the biomass in each patch. Additionally, $\boldsymbol{F}(\cdot)$ is a diagonal matrix ($k \times k$) whose elements include natural growth rates $f_k(x_k)$ and $\boldsymbol{D}$ is a ($k \times k$) dimension matrix whose elements show dispersion rates among patches. Finally, H_t shows the vector that includes captures in each patch.

For the case analyzed in this work, it is assumed that the dispersion matrix follows a multidirectional scheme with the constraint that migration occurs only to neighboring patches, where each row adds to one. Thus, for a general case, the dispersion matrix shows the following shape:

$$\mathrm{D} = \begin{bmatrix} d_{11} & d_{12} & \cdots & 0 \\ d_{21} & d_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & d_{kk} \end{bmatrix}$$

Some representations for this matrix may be as useful as other, simpler ones, equally allowing the measurement of all dispersion parameters for each patch.

Assuming that the migration occurs only between neighboring patches is not an a-priori pre-requisite for modelling; everything will depend on the level of temporary disaggregation of the database. Namely, if it is a very long period, this assumption will be hardly sustainable. However, for every-day data, as in this case, it is a reliable assumption.

2.1. Captures-per-patch function

We assume that the capture per patch function has a Cobb-Douglas form, as presented in equation (5). In this functional form, the variable γ represents a technological coefficient, E_t^k represents the aggregated effort in the patch, and z represents other variables that may affect the capture.

According to Berry's methodology (1995), the z vector possesses the features observed by the econometrist. It must contain the fishermen's characteristics (vessel dimensions, warehouse capacity, engine horsepower, etc.), and the patches' characteristics (sea surface temperature, sea level, wave height, etc.). The choice of these variables will depend on their feasibility, according to the case.

In addition, α, β, γ and ρ are parameters which are assumed as constant among the different patches.

$$H_t^k = \gamma\left(E_t^k\right)^{\alpha}\left(x_t^k\right)^{\beta}\left(z_t^k\right)^{\rho} \tag{5}$$

2.2. Selection per fishing area

Our model assumes that every time fishing is performed, the fishermen must decide in which patch capture effort is performed; and in which patch it is not (and therefore, no captures will be made). Thus, when fishing, the decision of the fishermen must be represented as a dichotomous decision where the selection options are represented by selecting a patch for fishing or not to go fishing.

In order to make this decision, it is assumed that the fisherman performs an estimation of the capture that could be obtained in each patch if an effort is applied $(E_t^k = 1)$. This would be given by:

$$\widehat{H}_t^k = \gamma\left(x_t^k\right)^{\beta}\left(z_t^k\right)^{\rho} e^{\varepsilon_t^k} \tag{6}$$

In the previous equation it is assumed that the existing biomass in each patch is known by the fishermen at the time of deciding where to go fishing. This is based on the fact that fishermen possess experience in the development of their work, and added to that the fact that they can share information on the best fishing zones with other fishermen at the port. Therefore, it is assumed that their decision of sailing is rational, i.e. optimized.

Additionally, it is assumed that the fisherman takes into account the net price per capture unit, which also includes the costs of the expected capture unit in the patch. In order to simplify the subsequent estimation of the model, it is assumed that a constant parameter $(\hat{p}^k)$ collects information on the price per net ton, net of costs, of capturing in a specific patch.

A price vector is constructed that will sensitize the fisherman's benefits to the distance traveled from the port to the patch. The vector has the form: $\hat{p}_t^k = \left(\bar{p}_t - \hat{c}_t^k\right)$. Here, $\bar{p}_t$ refers to the price of the resource unloaded in the t period, and $\hat{c}_t^k$ is the operating expense (OE) of the fisherman per ton captured $\left(OE_t^k / H_t^k\right)$. The operational expense considered the displacement time per performance (in nautical miles of each vessel). For this, it is necessary that the researcher know an estimated of this performance, the price of fuel, and the distance from each patch to each port. In this manner, the perspective of the researcher is to design the fisherman's exercise as a consumer who declares their preferences for each patch, in function of the net utilities that each one obtains, evaluating the distance between the benefit per capture and the operating expenses of going fishing to said patch.

Thus, in order to decide in which patch the fishing effort must be applied, the fisherman solves the following problem:

$$k_t^k = \arg\max\left\{\Pi_t^k = \hat{p}^k \hat{H}_t^k : k = 1,2,...,K\right\} \tag{7}$$

This expression does not suggest that the fisherman captures in a single patch on each trip, but they can indeed capture in a single patch at a time, thus allowing them to choose several ones in a hierarchical order on each trip.

N ships are considered that capture a homogeneous species. The array of choice by each fisherman corresponds to the patches that are feasible spatially and politically; namely, considering that although some patches are geographically accessible, they may be forbidden from capturing activities.

2.3. Econometric model

The econometric estimation requires the decomposition of the model into two components: economic and biological. On the one hand, the economic component includes the capture function and the decision made by the fishermen about the patch in which their captures are performed. On the other hand, the biological model is composed by the equation that defines the migration of the stock between patches. The estimation of the model is carried out in two stages.

Both economic and biological components are linked through the biomass level existing in each patch. This is an explicative variable of the capture function in each patch and it also determines the benefits obtained by the fishermen in each fishing area. However, this variable is not observed in the data; instead, it is assumed that it is known by the fishermen at the time of making their decision. This allows estimating the biomass level that explains both captures and decisions on fishing areas by the fishermen.

Thus, in a first stage the capture function and the demand per patch are jointly estimated, also obtaining an estimated biomass level per patch and period. These biomass levels are used in a second estimation stage in order to obtain the parameters of both biological dispersion and growth model of the biomass.

In order to perform the estimation of the demand, the logit model of demand with unobserved characteristics proposed by Berry (1994) is used. In order to adapt the model to our estimation problem, a market is defined. Each of the home ports of the fishing vessels in each month. Each of the fishing patches is defined as product and as alternative option: not to perform captures in such month.

Based on the model expressed in the previous section, the linear random utility function that explains the decision of the fishermen is defined as:

$$u_{tk} = \ln \Pi_t^k + \beta_1 \ln\left(\hat{p}_t^k\right) + \beta_2 \ln\left(z_t^k\right) + \beta_3 \ln\left(\hat{x}_t^k\right) + \varepsilon_t^k \tag{8}$$

This equation can be interpreted in terms of the discrete selection models as:

$$u_{tk} = \alpha_0^I + \alpha_1^I \ln\left(p_t^k\right) + \alpha_2^I \ln\left(z_t^k\right) + \xi_t^k + \varepsilon_t^k \tag{9}$$

Where α_0^I, α_1^I and α_2^I represents parameters of reference on the characteristics observed and the superscript I is referred to the fact that they are parameters estimated in the first stage. ξ_t^k represents characteristics not observed in the patches. These are assumed to be proportional to the logarithm of the biomass $(\beta \ln x_t^k)$ which are thought independent from the z vector; and ε_t^k is the random error for the prediction of the capture by the fisherman. It is assumed that it has an Extreme Value distribution.

The non-observed features are estimated in the first step which, once identified, represent the estimated biomass for every fisherman. This biomass is the one used in the second step of the estimation.

According to the method pointed out by Berry (1994), the structural parameters of the above demand model can be estimated at the aggregate level by means of a function on the market participation of each patch in the characteristics observed for each market. In our case, this implies the estimation of a system of equations, one for each port of origin, where each observation corresponds to the monthly observations of both captures and fishing destinations. Thus, the equation to be estimated for each patch is as follows:

$$\ln(s_k) - \ln(s_0) = \alpha_0^I + \alpha_1^I \ln\left(p_t^k\right) + \alpha_2^I \ln\left(z_t^k\right) + \xi_t^k \tag{10}$$

Where s_k corresponds to the percentage of fishermen that decided to capture in the patch k in the considered period, and s_0 is the aggregated percentage of fishermen that decided not to go fishing during that period. Following Berry *et al.* (1995), the left-side construction of the equation (10), estimated by means of a logit, will provide an estimate of the unknown parameters ξ_t^k.

In order to prove the method proposed, the first stage of our model considers a system of equations where five equations –such as the one in the previous case– are included; four equations for each patch, and other equation with the capture function. As in the previous case, there is one for each port of origin. These are jointly estimated with the capture function through the use of a non-linear SURE system (Zellner, 1962). Additionally it is possible to use information on the estimated biomass for each year in order to identify exactly the value of the parameter ξ present in equation (9) and the biomass levels in each patch $\hat{x}_t^k$.

In the second stage, estimation coefficients of the previous biomass are used in order estimate the growth equation parameters and biomass migration presented in equations (1), (2) and (3). These can be rewritten for estimation purposes as:

$$\hat{x}_{t+1}^k = \alpha_0^{II} \hat{x}_t - \alpha_1^{II} \left(\hat{x}_t\right)^2 + \sum_{\substack{h=1 \\ h \neq k}}^{K} d_{hk} \hat{x}_t^k + \varepsilon_t^{II} \tag{11}$$

Were $\alpha_0^{II} = \left(r - d_{kk}\right)$ and $\alpha_1^{II} = \dfrac{r}{K_k}$. The identification of the structural parameters, d_{kk} and K_k requires an auxiliary estimation. For this, it is assumed that r is equal for all patches and the sum of the carrying capacities of each patch must be equal than the carrying capacity of the whole system. Thus, the values r and $K = \sum_k K_k$ are estimated by using the data of the entire fishery. This allows for the identification of all biological parameters of each patch.

In order to estimate the system of equations of (11) type, one for each patch, a SURE equations system is also used.

3. STUDY CASE AND DATA

The developed model is applied on a trial basis to the mackerel fishery in Central Southern Chile. This is one of the most important fisheries in both Chile and the world. This fishery comprises the areas located between the Valparaiso and Puerto Montt Regions. For estimation purposes, all industrial vessels whose port of origin is San Antonio, Talcahuano, Coronel and Valdivia that performed any capture operation between 2001 and 2004 were considered. The selection of this period corresponds to the integrity and availability of the database for the researchers.

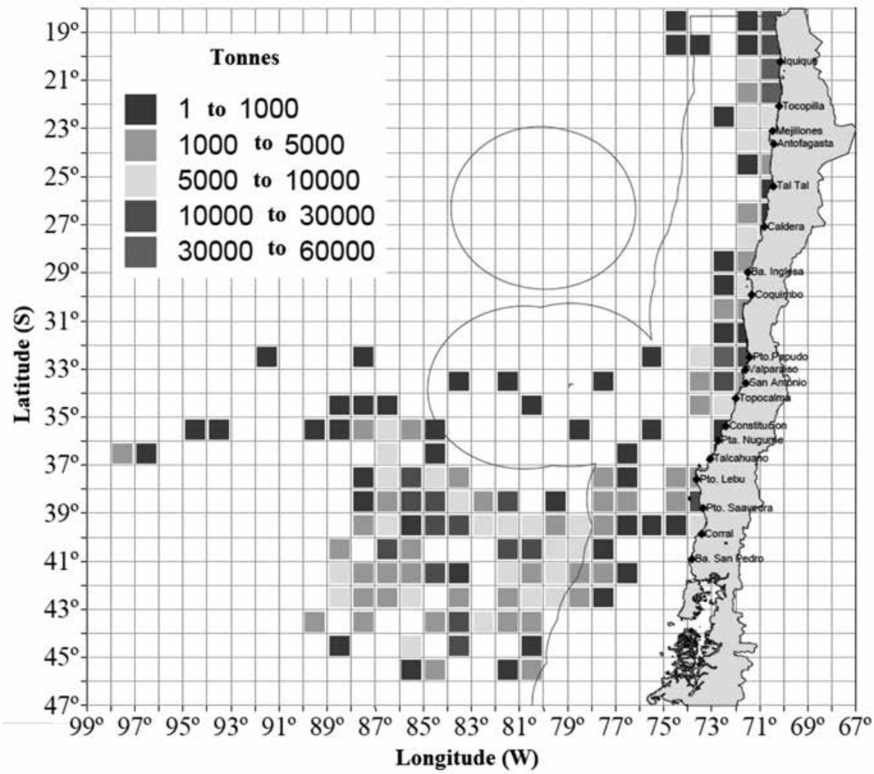
Fisheries in this zone during 2004 recorded a landing of *circa* 1.5 million tons, out of which 79% corresponds to Chilean jack mackerel.

In this area the landings of mackerel carried out mainly in four ports. Since 2002 to 2004, the ports of Talcahuano and Valdivia, concentrated 86% of the captures. In 2004 the Central Southern industrial fleet performed 2,785 fishing trips. 95% of such trips returned to port with effective capture. In spatial terms, between January and February the activity was concentrated between the localities of Constitución (35°20’ S 72°25’ W) and Talcahuano (36°43’30” S-73°6’40” W), without exceeding 100-129 nautical miles from the coast. Between March and July the activity moved to the Isla Grande in Chiloé (41°51’43” S-73°49’52” W). In mid-June and July the oceanic operation began, following the resource beyond 600 nautical miles until September, in which the fleet continued operating in the northwestern area off Chilean coasts. Finally, between October and November the capture was reduced, being concentrated in the coastal areas around Mocha Island (38°23’06” S-73°52’00” W). In December, the captures experience an upturn with the return to coastal areas off Coquimbo Region coasts. This can be noted in Figure 1 that shows the spatial distribution of the captures during 2004.

Some authors have studied the migration behaviors of the Chilean jack mackerel from a biological standpoint. Arcos *et al.* (2001) point out that the migration patterns of this species consider a significant fraction of the population and as they occur on a regular basis, as the result of the alternation between two or more separated habitats. Thus, these authors have pointed out that the movements from one habitat to another determine the seasonal behavior of the fishery in the Central Southern area, with higher captures in the Winter season (April to August in Chile), when the mackerel is more available in coastal waters for fattening reasons. On the other hand, lower captures take place during spring and summer seasons, as a result of the migration process to oceanic waters for spawning (September to March). Finally, these authors

FIGURE 1

SPATIAL DISTRIBUTION OF THE MACKEREL CAPTURES IN 2004



Source: SERNAPESCA.

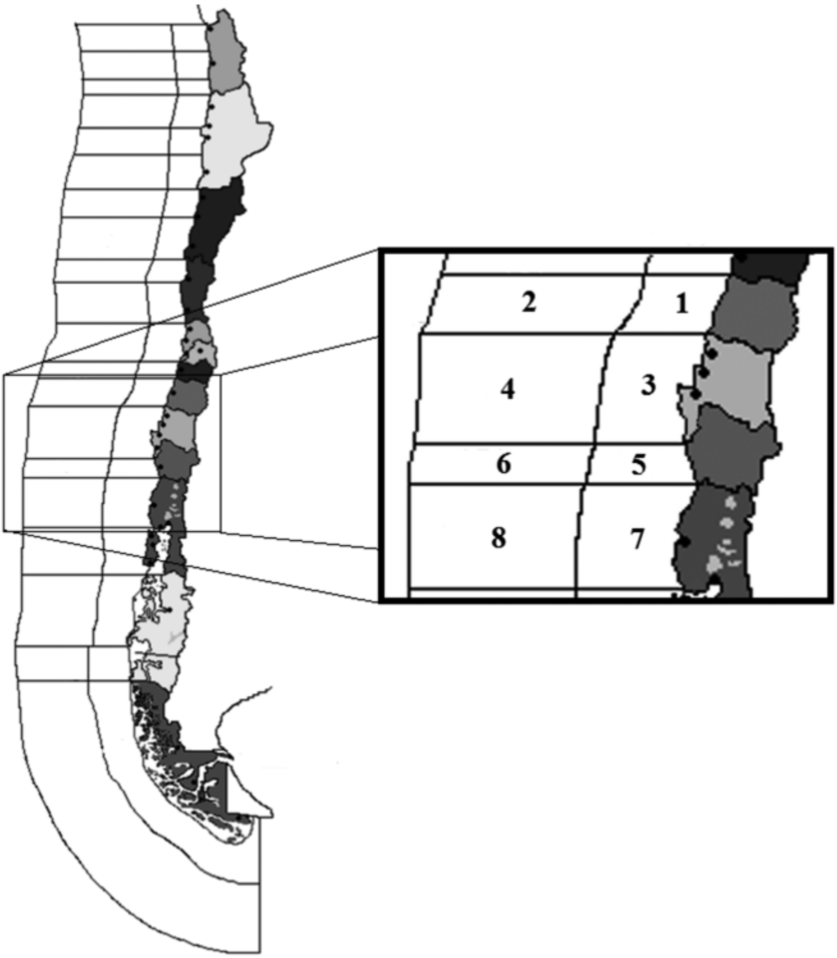
acknowledge that other migration patterns may exist in different spatial and temporal scales. These patterns should be related to the use of the space as well as changes in the balance between benefits and costs of residence in each habitat.

Because of the migration characteristics of this species in the analyzed fishing zone, and the importance of this species for the Chilean fishery, this becomes an ideal area as a study case for the proposed model.

For both spatial and migration analysis the central southern area is divided into eight patches according to the classification used by the Chilean Undersecretary of Fishing (SERNAPESCA) to define the Chilean fishing areas. Figure 2 shows the location of the central southern zone of Chile as well as the eight patches taken into account for the analysis. The four ports of origin from which the extractive industrial activity is performed are also indicated.

FIGURE 2

CHILEAN MAP THAT CONSIDERS PATCHES AND PORTS DEFINED BY SERNAPESCA

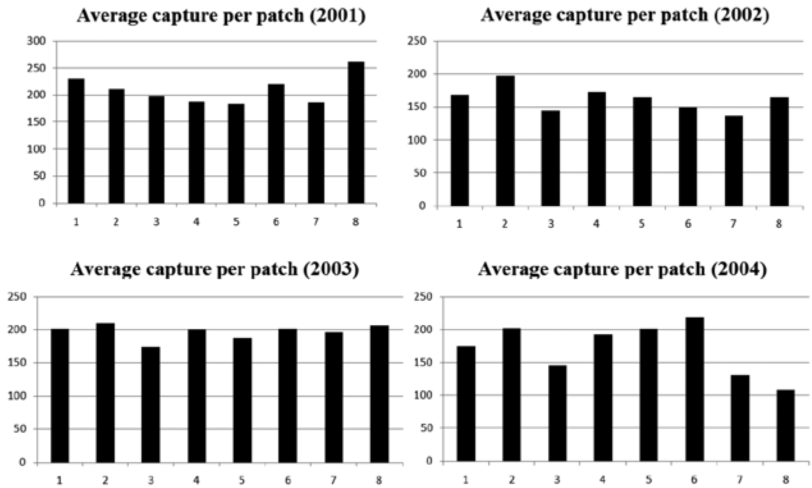


Note: Patches used in the analysis are highlighted.
Source: own.

The information comes from the landing records from the Chilean Undersecretary of Fishing, and includes the number of monthly trips and the landings per fishing zone for each of the vessels that operated in the fishery between 2001 and 2004. The database shows the variability in both average capture per patch and month. These can be observed in Figure 3 and Figure 4.

FIGURE 3

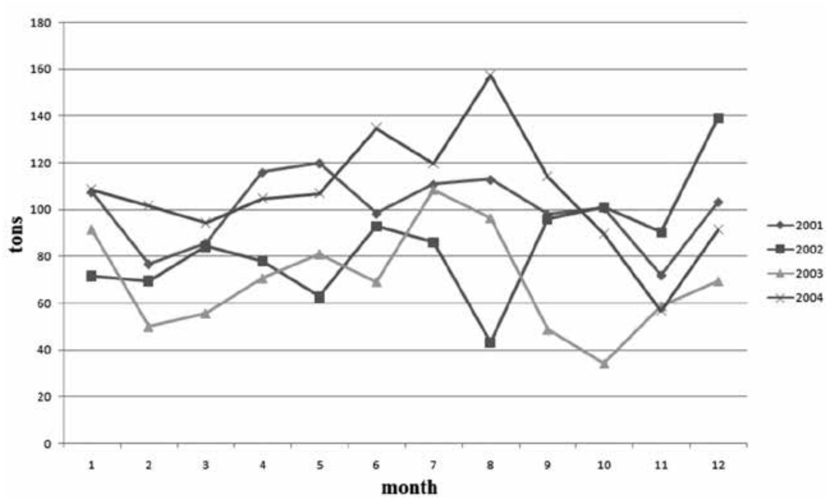
AVERAGE CAPTURE PER PATCH AND YEAR (IN THOUSANDS OF TONS)



Source: SERNAPESCA.

FIGURE 4

AVERAGE CAPTURE PER MONTH AND YEAR



Source: SERNAPESCA.

The database possesses daily information from the Chilean Marine Fisheries Service (SERNAPESCA henceforth). It contains 35,063 observations with 113 vessels of diverse technical features. The data were aggregated monthly for the estimation (and for the practical use of dummy variables). Said vessels had *trachurus murphyi* as their sole target species.

TABLE 1

DESCRIPTIVES FOR TRAVEL PER YEAR

	2001	2002	2003	2004
Total travel	27 774	36 730	34 947	32 560
Mean travel per vessel	100.408	83.98	69.20	104.45
SD travel per vessel	14.52	22.60	20.86	23.82

Source: SERNAPESCA.

4. RESULTS

The results in the reduced form of the parameters of the estimation of the discrete selection model in step 1 are presented in Table 2. The parameters $\alpha_{0,t}^{I}$ show the coefficient corresponding to the constant for each year t. Parameters with the form $\alpha_{1,t,j}^{I}$ correspond to the coefficients associated to the net benefits of capture per ton in each patch, in year t, for a ship that departs from port j. Given the fact that the distances to the patches are different depending from the port of origin, it is considered that this parameter is also different for each port. The parameters $\alpha_{2,t}^{I}$ correspond to the exponent of the fishing aggregated effort on the function of captures in each year. In this stage, biomasses per patch and month are estimated.

The net benefit corresponds to the difference between the price and cost per capture, all measured in tons. Consequently, the parameters $\alpha_{1,t}^{I}$ are interpreted as the net benefits for going fishing from any of the four ports in each year.

By using dummy variables per patch and year, it is possible to identify the biomass as $d_t^k = \beta \ln\left(x_t^k\right)$. The estimated biomasses are presented in Figure 5.

With these coefficients estimated in the second stage we proceed to estimate the biological migration model.

In the Table 3 we present the results for the estimation of reduced form of the biological migration model.

The parameters of the form $\alpha_{0,k}^{II}$ match the coefficients corresponding to the variable x_{tk} used to identify r and d_{kk}. In turn, the parameters of form $\alpha_{1,k}^{II}$ match the coefficients corresponding to the variable $x_{t,k}^{2}$ for each of the eight patches (k) considered in the study, and it's required to identify the charge capacity.

Parameters in reduced form obtained from the first and second steps of estimations allow generating the structural parameters of both economic and biological models; particularly those parameters associated to both capture and migration functions

TABLE 2

RESULTS FROM THE ESTIMATION REDUCED FORM, STEP 1

	Parameter	St. Error	z-value
$\alpha^{I}_{0,2001}$	4.8311	0.0576	83.86
$\alpha^{I}_{0,2002}$	5.0050	0.0579	86.43
$\alpha^{I}_{0,2003}$	5.0164	0.0474	105.86
$\alpha^{I}_{0,2004}$	4.7792	0.0492	97.11
$\alpha^{I}_{1,2001,1}$	0.1500	0.0138	10.88
$\alpha^{I}_{1,2001,2}$	0.0281	0.0037	7.62
$\alpha^{I}_{1,2001,3}$	0.0612	0.0036	17.09
$\alpha^{I}_{1,2001,4}$	0.0059	0.0012	4.99
$\alpha^{I}_{1,2002,1}$	0.1510	0.0138	10.98
$\alpha^{I}_{1,2002,2}$	0.0292	0.0036	8.01
$\alpha^{I}_{1,2002,3}$	0.0614	0.0036	16.90
$\alpha^{I}_{1,2002,4}$	0.0057	0.0012	4.81
$\alpha^{I}_{1,2003,1}$	0.1450	0.0138	10.51
$\alpha^{I}_{1,2003,2}$	0.0297	0.0036	8.25
$\alpha^{I}_{1,2003,3}$	0.0636	0.0036	17.92
$\alpha^{I}_{1,2003,4}$	0.0061	0.0011	5.36
$\alpha^{I}_{1,2004,1}$	0.1460	0.0137	10.65
$\alpha^{I}_{1,2004,2}$	0.0268	0.0036	7.55
$\alpha^{I}_{1,2004,3}$	0.0596	0.0035	17.16
$\alpha^{I}_{1,2004,4}$	0.0056	0.0011	4.99
$\alpha^{I}_{2,2001}$	1.0798	0.0133	80.96
$\alpha^{I}_{2,2002}$	1.0464	0.0132	79.30
$\alpha^{I}_{2,2003}$	1.0538	0.0109	96.44
$\alpha^{I}_{2,2004}$	1.0940	0.0115	95.10
	Obs	Parameters	R^2
Equation 1	906	98	0.79
Equation 2	906	102	0.08
Equation 3	906	102	0.45
Equation 4	906	102	0.24
Equation 5	906	102	0.75

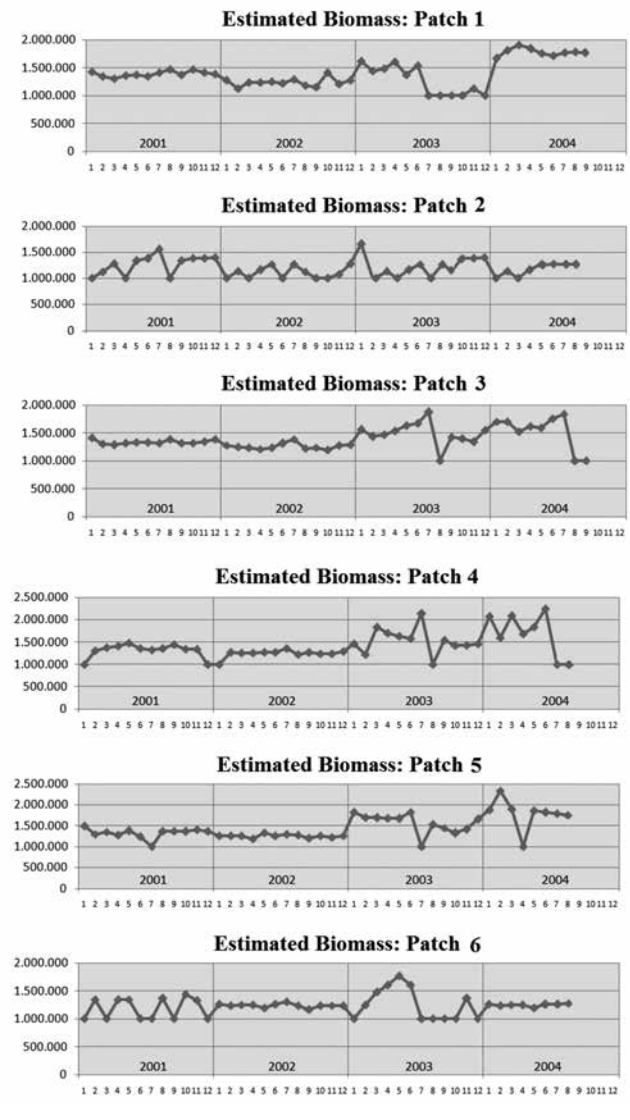
Source: Own.

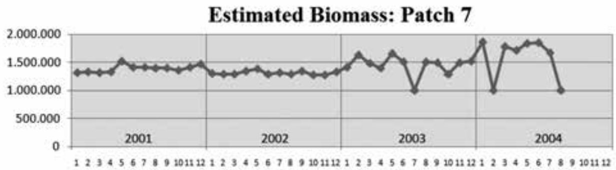
between patches. Thus, Table 4 shows the estimated parameters of the capture function and Table 5 shows the estimations of migration and growth parameters.

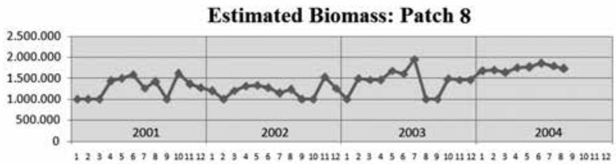
Results in Table 4 show the parameters associated to the technological constant of the capture function, as well as the elasticity of the aggregated fishing effort. It can be observed that the elasticity is slightly higher than one and significantly higher than this value. All economic variables are statistically significant and they showcase the expected signs and magnitudes according to the literature; e.g., on the one hand, the capture is positive and its magnitude is expressed in tons. On the other hand, the elasticity shows that if the net benefits per patch increases, then the amount demanded for that patch is increased as well.

FIGURE 5

ESTIMATED BIOMASS PER MONTH AND PATCH







Source: own.

TABLE 3

RESULTS FROM THE ESTIMATION REDUCED FORM, STEP 2

	Parameter	St. Error	z-value
$\alpha^{II}_{0,1}$	-0.03547	0.15802	-0.22
$\alpha^{II}_{0,2}$	-0.07644	0.19494	-0.39
$\alpha^{II}_{0,3}$	0.86710	0.09543	9.09
$\alpha^{II}_{0,4}$	0.86040	0.14392	5.98
$\alpha^{II}_{0,5}$	-0.11972	0.18741	-0.64
$\alpha^{II}_{0,6}$	0.07991	0.12954	0.62
$\alpha^{II}_{0,7}$	0.62316	0.13785	4.52
$\alpha^{II}_{0,8}$	-0.83693	0.24211	-3.46
$\alpha^{II}_{1,1}$	-9.87E-08	5.56E-08	-1.77
$\alpha^{II}_{1,2}$	-4.51E-07	7.30E-08	-6.18
$\alpha^{II}_{1,3}$	-5.68E-07	4.90E-08	-11.58
$\alpha^{II}_{1,4}$	-7.26E-07	4.65E-08	-15.62
$\alpha^{II}_{1,5}$	-1.93E-07	6.34E-08	-3.05
$\alpha^{II}_{1,6}$	-3.49E-07	4.98E-08	-7.00
$\alpha^{II}_{1,7}$	-5.46E-07	6.50E-08	-8.39
$\alpha^{II}_{1,8}$	2.34E-08	9.42E-08	0.25
	Obs	Parameters	R^2
Equation 1	571	4	0.38
Equation 2	571	4	0.62
Equation 3	571	5	0.28
Equation 4	571	6	0.34
Equation 5	571	5	0.24
Equation 6	571	6	0.44
Equation 7	571	5	0.16
Equation 8	571	6	0.20

Source: own.

TABLE 4

ESTIMATION OF PARAMETERS CAPTURE FUNCTION

	Parameter	St. Error	z-value
γ_{2001}	125.352	1.0593	83.86
γ_{2002}	149.160	1.0596	86.43
γ_{2003}	150.864	1.0485	105.86
γ_{2004}	119.006	1.0504	97.11
$\alpha_{\mathbf{2001}}$	1.07982	0.0133	80.96
$\alpha_{\mathbf{2002}}$	1.04644	0.0132	79.30
$\alpha_{\mathbf{2003}}$	1.05384	0.0109	96.44
$\alpha_{\mathbf{2004}}$	1.09403	0.0115	95.10

Source: own.

TABLE 5

ESTIMATED BIOLOGICAL PARAMETERS OF GROWTH AND MIGRATION

	Parameter	St. Error	t-value
r	0.02868	0.0548	5.24
d_{11}	0.32227	0.1580	-0.22
d_{22}	0.36324	0.1949	-0.39
d_{33}	-0.58030	0.0954	9.09
d_{44}	-0.57359	0.1439	5.98
d_{55}	0.40652	0.1874	-0.64
d_{66}	0.20689	0.1295	0.62
d_{77}	-0.33636	0.1378	4.52
d_{88}	1.12373	0.2421	-3.46
d_{12}	-0.03225	0.0230	-1.40
d_{13}	0.17289	0.0764	2.26
d_{21}	0.56443	0.0803	7.02
d_{24}	0.02172	0.0805	0.27
d_{31}	-0.10329	0.0297	-3.47
d_{34}	0.06132	0.0304	2.02
d_{35}	-0.03265	0.0436	-0.75
d_{42}	-0.28887	0.0252	-11.48
d_{43}	0.43961	0.0758	5.80
d_{46}	-0.07317	0.0249	-2.94
d_{53}	0.43810	0.0778	5.63
d_{56}	-0.10528	0.0296	-3.56
d_{57}	0.03319	0.0877	0.38
d_{64}	0.20394	0.0531	3.84
d_{65}	0.29074	0.0538	5.40
d_{68}	-0.15976	0.0548	-2.92
d_{75}	0.16404	0.0494	3.32
d_{78}	-0.03292	0.0282	-1.17
d_{86}	0.87619	0.1177	7.45
d_{87}	-0.10154	0.0463	-2.19

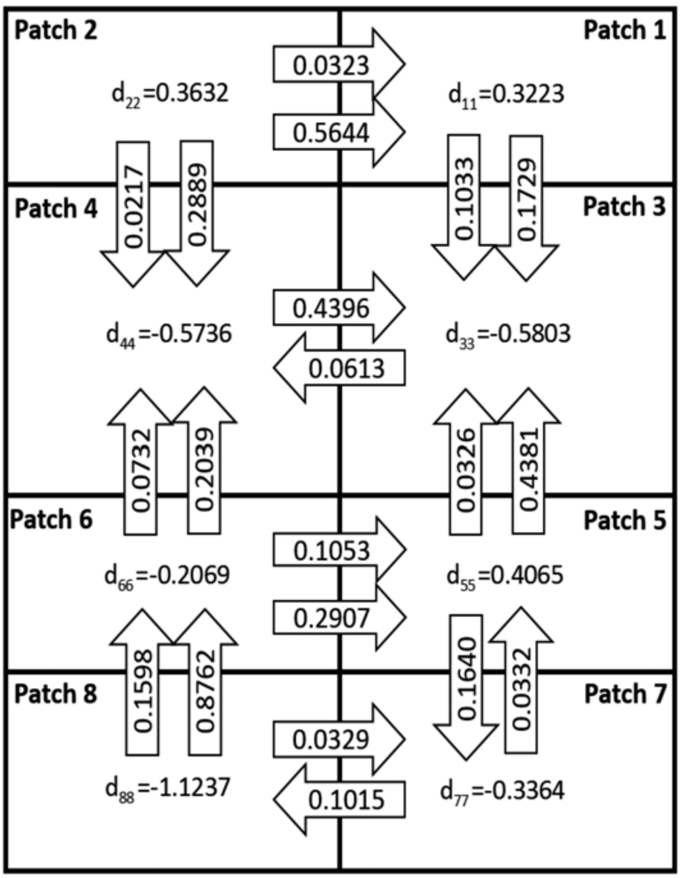
Source: own.

The Table 5 shows the parameters associated to the migration of the stock, identified from the second stage of estimation. Results indicate that an important fraction of the migration parameters are statistically significant. *A priori*, no restriction has been imposed to the signs of these parameters, allowing the data to indicate unrestricted migration parameters. Results associated to these migration patterns are presented in Figure 6.

Regarding the identification of the carrying capacity per patch, unfortunately one of the parameters in reduced form associated to the carrying capacity of the

FIGURE 6

MIGRATION PARAMETERS ESTIMATED IN A REPRESENTATION OF PATCHES



Source: own.

TABLE 6

CARRYING CAPACITY PER EACH PATCH

Patch	Upper limit confidence interval			Mean
	At 80%	At 90%		Estimated
K_1	6.736	6.987		19.045
K_2	2.105	2.325		4.168
K_3	1.815	2.045		3.309
K_4	1.459	1.655		2.589
K_5	4.179	4.470		9.740
K_6	2.779	3.080		5.386
K_7	1.821	2.033		3.443
K_8	11.757	10.056		-80.330

Source: own.

system has a negative sign, which is statistically significant and prevents the correct identification of the carrying capacities of all patches. This is due to the fact that the sum of the carrying capacities must equate the total carrying capacity of the system. This is shown in Table 6, which indicates that the procedure discussed in the previous section presents a negative carrying capacity for the entire system, if the estimated average value of the parameters is assessed.

In order to solve the above problem the estimation of the carrying capacities is taken into account, by using the upper limits of the confidence intervals of the estimated parameters because they are positive, thus meeting the estimation requirements of the carrying capacities for each patch. Results are presented in Table 6. It is observed that this allows obtaining the estimations on the carrying capacity sensitive to the limit used.

5. CONCLUSIONS

In this study, it has been proposed and applied a method for the estimation of a bioeconomic model that considers the migration of the stock between patches. The model has been estimated for the jack mackerel fishery in central southern Chile.

By using a two SUR estimation models, it is possible to identify migration parameters across eight patches, in four years, from four ports, thanks to the use of a simultaneous method which will allow incorporating all this information.

In the first step, a capture function is used, with one equation for the demand of each patch. One regression per each year will allow obtaining the biomass estimated per patch. In the base example, the biomass estimated is consistent with the observations made by the National System of Statistical Fishery of Chile.

In the second step, another SUR model is deployed by using a dispersion matrix and by identifying the carriage capacity. Once the database is set, the behavioral pattern of the biomass can be detected; e.g., from patch eight to patch four, and from patch two to patch four. In addition, it is perceived that the biomass is close to the coast in patches one and five. Finally, in patches three and seven the biomass migrates offshore.

In this particular case, the results indicate that with the model presented in this work it is possible to calculate with statistical significance the parameters in function of captures as well as the migration parameters between patches. However, it is not possible to clearly identify the carrying capacities of each patch, at least for the sample available. Of course, the results obtained can be used to perform analyses of the spatial behavior of the fishing fleet as well as biological and economic models on policies of spatial management. By using a model demand with non-observed characteristics as proposed by Berry *et al.* (1998) with aggregated data such as per-patch capture; and by knowing the origin port, the spatial behavior can be obtained.

The model can be also tested in other fisheries, especially those with broad patterns of migration. All these possible analyses, although they were outside the scope of this investigation, constitute an opportunity to continue deepening on this sort of analyses in fisheries in further investigations.

Possibly, the weakness in this proposal may lie in the necessity for a richer database to be estimated. In fact, the serial time must be continual and balanced in each patch. In other cases, this methodology can be applied to other sea species with migratory behaviors more or less similar to the ones analyzed in this work.

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HIGH INFLATION, PRICE STABILITY AND HYSTERESIS EFFECT: EVIDENCE FROM ARGENTINA

ALTA INFLACION, ESTABILIDAD DE PRECIOS E HISTERESIS: EVIDENCIA EN ARGENTINA

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Abstract

We estimate a Currency Substitution model for 1980-2013 periods in Argentina. Following the Mongardini and Mueller (2000) specification, our paper studies the persistence of lower demand of local money, or dollarization, by including a hysteresis variable. By applying an ARDL (Auto Regressive Distributed Lags) model, we found a clear ratchet effect, which implies that in the short run agents do not adjust to changes on the fundamentals, leading to a significant hysteresis variable.

Keywords: *Hysteresis effect, money demand, currency substitution.*

JEL Classification: *E00, E41, C01.*

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Resumen

En el presente trabajo estimamos un modelo de sustitución de moneda para Argentina en el período 1980-2013. Siguiendo la especificación de Morgandini y Mueller (2000) estudiamos la baja demanda de moneda local, o dolarización, incluyendo una variable de histéresis. Utilizando un modelo ARRD (Auto Regresivo de Rezagos Distribuidos) encontramos un claro efecto Ratchet, lo que implica que en el corto plazo los agentes no ajustan a cambios en los fundamentales, ocasionando que la variable de histéresis sea significativa.

Palabras clave: *Histéresis, demanda de dinero, sustitución de moneda.*

Clasificación JEL: *E00, E41, C01.*

I. INTRODUCTION

The relationship between macroeconomic instability and money demand has been central in the macroeconomics literature. In relation to price instability, over the past decades Latin America experienced periods which went from moderate to high inflation and even hyperinflations (Dabús *et al.* (2009)), and in most cases these episodes were nearly associated to fast devaluations. In turn, developing countries in general have exhibited lower monetization coefficients than countries of higher levels of per-capita GDP (Mc Loughlin and Kinoshita (2012)). Moreover, lower monetization is associated with lower local currency demand, which in turn represents persistent currency substitution (CS) for foreign money. In the literature this persistence is known as a phenomenon of hysteresis effect, and in some empirical contributions this is approximated by a "ratchet variable" (see for example Mongardini and Mueller (2000), and Valev (2010)). In countries that experienced high inflation periods the CS remained at high levels, even though such episodes were followed by a successful disinflation process. In other words, a lower degree of local currency demand set in. Indeed, Kamin and Ericsson (2003) find a persistent dollarization in Argentina, even after the rapid disinflation that followed the hyperinflations of the end of the '80.

Currency substitution has been vastly studied for many regions and countries. Sharma *et al.* (2005) find that the domestic currency and the U.S. dollar are substitutes in six Asian countries. In particular, they found that the demand for dollars relative to the domestic currency is due to a change in the opportunity cost of holding domestic money, i.e. exchange rate depreciation, in relation to the opportunity cost of holding dollar, which is given by the domestic interest rate. This result may be an intuitive explanation for the persistence of the dollarization or the Ratchet effect. Also for Asian countries Tavlas (1996) studies the case of Japan and shows that the degree of economic integration and relative inflation performance are key factors to generate currency substitution. In turn, Arize (1991) provides evidence of a negative and significant substitution effect on the demand for money during the period of financial deregulation in Korea. Meanwhile, looking to western developed countries, Miles (1978, 1981) states the existence of CS in the United States, Canada, and Germany.

On the other hand, a particular issue is the CS behavior in an inflationary environment. According to Kamin and Ericsson (2003, p. 185), the "heavy usage of foreign currency generally has occurred in countries with high and variable inflation rates and where the rate of currency depreciation has been high and variable as well." Moreover, they state that in this kind of economies the opportunity cost of holding domestic currency is often high and uncertain, which induce residents to use foreign currency. High inflation experiences were common in developing countries during the past decades. Latin America was particularly affected by this issue. Despite nowadays most of the countries of this region have controlled their inflationary process, and they have converged to world inflation rates, in the past decades they have been seriously affected by periods of extreme price instability (Dabús (1994), Johnson (2002), Capristán and Ramos Francia (2009)). As a matter of fact, during the ´70s and along the ´80s several countries of the region experienced episodes of very high and hyperinflation.

The dollarization process increased in times of high inflation as foreign currencies, usually the dollar, substituted the domestic currency[1]. Meanwhile, in several cases the demand for local money did not recovered to previous levels after a stabilization plan, i.e. when disinflation was achieved; instead, a Histeresis effect could be verified, because foreign currency remained in use in the financial system and in transactions (Valev (2010)). In this sense, numerous studies on currency substitution in Latin American countries show that there is a significant degree of dollarization, i.e., the U.S. dollar and domestic currencies are jointly used. For example, Ramirez-Rojas (1985) find the existence of CS in Argentina, Mexico and Uruguay, while Calvo and Vegh (1992) also observed CS in Bolivia, Mexico, Peru, and Uruguay. Nonetheless, Prock *et al.* (2003) observe that currency substitution occurs especially in Argentina and Brazil, but Mexico exhibits a lower degree of CS. Similarly, Feige *et al.* (2003) generates estimates of dollarization for Latin American countries and finds evidence in favor of hysteresis effect: a period of financial instability raises the level of dollarization for a long period after the episode of instability has ended. Also Clements and Schwartz (1993) and Reding and Morales (2004) find this effect for Bolivia, where currency substitution increases rapidly in unstable macroeconomic environments, but this is difficult to reverse even after many years of stability. In particular, dollarization levels in Bolivia remained high even after the stabilization of the hyperinflation periods. In this sense, Kamin and Ericsson (2003) find a Histeresis effect due to inflation by means of a cointegration analysis of local money demand in Argentina. In fact, this supports the idea of a reduction in the Argentinean peso demand, attributable to a Histeresis effect, which implies that, even though a successful disinflation policy was carried out after the hyperinflations, there was a persistence of a dollarization process.

[1] See for example Ramirez-Rojas (1985), Melvin (1988); Rojas-Suarez (1992) and Clements and Schwartz (1993), who have documented a positive association between exchange rate devaluations and dollarization, in particular in Latin America.

To sum up, CS seems to be a common feature that arises as a consequence of periods of high instability, more specifically after processes of high inflation and important devaluations of the currency. Regarding this results Latin America, and Argentina as a specific country, appear as cases of special interest. In fact, Argentina suffered two episodes of hyperinflation between 1989 and 1990 followed by long periods of stability and a new episode of rising inflation during the ‘2000, during the devaluation that followed the crisis of 2002. Therefore, during the whole inflationary process that the region experienced during the past decades there seems to be a persistent dollarization even after inflation was under control.

In short, there is wide evidence that supports the CS as well as the hysteresis effect as consequence of inflationary experiences in unstable macroeconomic environments. This substitution for foreign currency should reduce the margin for monetary policy to the policymakers, so that this can be ineffective if agents react by shifting away from local currency into its substitutes (Sharma *et al.* (2005)). Thus, this issue seems to deserve more research. In this sense, the goal of this paper is to determine the role of the hysteresis effect in Argentina during the 1980-2013 periods. This is a country with long lasting high inflation and fast devaluations history during this particular period. In fact, Argentina could be an excellent case to analyze the CS process after the episodes of high price instability during the last decades.

The idea is that this study allows to reach a more comprehensive evaluation of the relation between economic instability and currency substitution during periods of high price instability, in particular in episodes in which the economy have suffered of high inflation, recurrent devaluations and fast currency substitution in favor of foreign money. The hypothesis is that big devaluations, which in general are associated with periods of high inflation, left irreversibility on the preference for foreign assets, in particular the US dollar. The idea is to explore the behavior of currency demand in Argentina during the high instability decade of the ‘80s, the price stability period of the ‘90s associated with the fixed exchange rate and the period of devaluations and relative stability of the ´2000. The paper seeks to determine if hysteresis on the demand for local currency took place along these periods.

As usual, CS is approximated by the ratio of local currency in relation to foreign currency, which also considers deposits in both currencies, while the persistence of CS is represented by a hysteresis variable. Our results show the presence of a hysteresis effect after the long period of price stability observed during the convertibility period as well as a deep fall on the currency demand after the devaluation of 2002.

The paper is structured as follows. Section 2 describes the data and methodology. Section 3 presents the empirical results, and finally Section 4 concludes.

II. DATA AND VARIABLES

II.1. Data

The sources of the data are the Central Bank of Argentina (BCRA), the World Bank and the IMF. The variables used for this work are deposits in local currency, deposits in foreign currency, cash holdings in local currency, cash holdings in foreign currency, inter-annual interest rate variation and exchange rate.

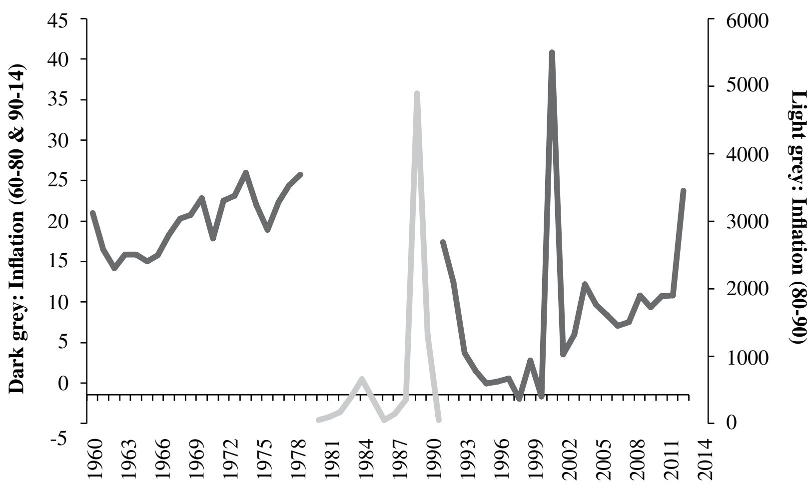
As it can be seen in Figure 1, during the period under study Argentina experienced high inflation during the ‘80s with a mild control from the Austral plan. By the end of the ‘80s high inflation reappeared, mostly between 1987 and 1988, leading to hyperinflations from April to July of 1989 and in the beginnings of 1990. These events were followed by a short period of stable but high inflation that ended at the beginning of 1991 with new episodes of increasing inflation rate.

In order to control the inflationary process the government implemented a convertibility program, fixing the exchange rate between the Argentinean peso and the US dollar at a rate of 1 to 1. This policy leaded to a long period of price stability that ended with the cancellation of the program in January 2002. At that time the economy suffered a strong devaluation and new episodes of inflation that were controlled during the 2003-2007 period. From 2007 onwards price rose steadily year by year at an average annual rate higher than 20%, which forced to periodical exchange rate devaluations. Hence, the Argentinean economy suffered different periods of inflation, ranging from moderate to hyperinflations. In turn, on the side of the exchange rate the country experienced several devaluations, which in general were associated with increases on inflation.

In Figure 2 we can observe peaks of high currency substitution ratios in two particular periods. Not surprisingly, the first was during the hyper inflationary process

FIGURE 1

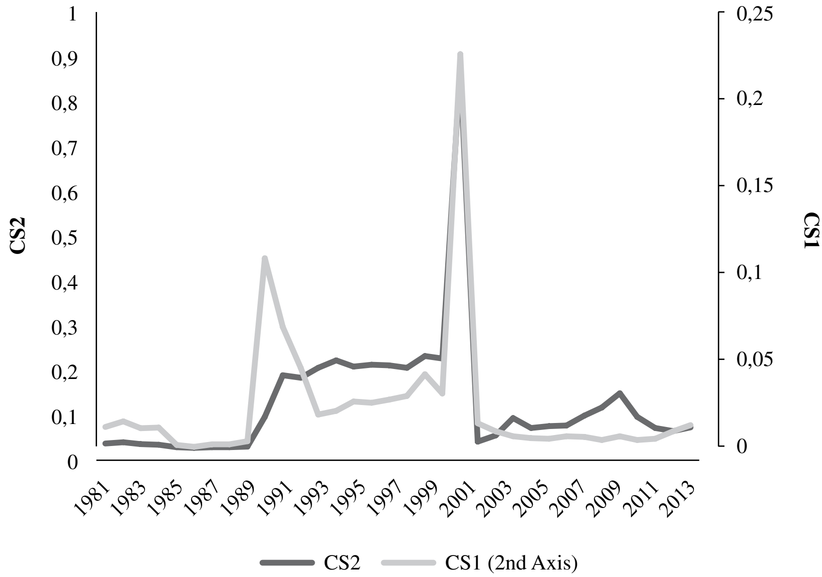
ARGENTINEAN ANNUAL INFLATION RATE



Source: IMF.

FIGURE 2

CURRENCY SUBSTITUTION RATIOS



Source: Author's elaboration based on BCRA data.

in the late 80s, while the second case, which was the highest CS ratio along all the period under study, occurred during 2001 and 2002. This episode is associated with the end of the convertibility plan and the subsequent devaluation, as well as the brief inflationary process related with this.

II.2. Econometric Model

We work with two CS coefficients: CS1, which is based on deposits (deposits in dollars over overall deposits), and CS2, that includes cash. The hysteresis variables are the maximum values reached by the CS ratios. Thus, they represent the historical pikes of the ratio. We work in base to the following structural model to explain the Currency Substitution ratios:

$$CSi_t = \alpha + \beta_1 CSi_{t-1-L} + \beta_2 \Delta INT_{t-L} + \beta_3 ER_{t-L} + \beta_4 RAT_{t-L} + \mu_t \quad (1)$$

The main difference between our paper and Mongardini and Mueller (2000) is that we include as explicative the difference in the deposit interest rate, instead of the difference between US treasury bills and the sovereign bonds. This is because of the lack of a long and homogenous series of bonds to contrast with those AAA from USA[2].

The transformation of the CS ratios that Mongardini and Mueller (2000) suggest is:

$$LCSi_t = Log\left(\frac{1-CSi_t}{CSi_t}\right) \quad (2)$$

However, we use CSi as the dependent variable because when we consider this transformation the results are not trustable due to autocorrelation problems (see Table 5 in the Appendix). This will be explained in more detail in Section 3.

II.3. Methodology

Equation (1) will be estimated by means of an ARDL (Auto Regressive Distributed Lags) model[3]. We chose this specification in order to estimate the short and long run coefficients. A valid alternative will be to estimate a VEC model, but as we have in mind only one dependent variable the ARDL procedure is preferred.

Table 3 in the Appendix shows the Augmented Dickey-Fuller, the Phillips-Perron and the Zivot-Andrews unit root tests for the series under analysis. The results of these tests indicate that a cointegration analysis is inappropriate due to different integration levels within the variables.

The first step in the ARDL procedure by Pesaran and Smith (1995) is to test for the long-run significance of the explanatory variables. In the case of equation (1), it involves the testing of the joint long-run significance of the constant, the interest rate, the exchange rate, and the ratchet variables. The tests are distributed according to a nonstandard F-statistic, which has different critical values depending on whether the dependent variable is stationary or nonstationary. Pesaran *et al.* (2001) presents the tables with the F-critical values.

We then proceed to estimate equation (1). We use two ways to represent the CS ratios, in differences and in the logarithmic transformation proposed by Mongardini and Mueller (2000). We also estimate with different lags (and present the Information Criteria of each regression). The estimation procedure uses the ARDL package for *Stata*, with the option of expressing the regression as an error correction form, i.e. with the differenced variables. Tables 1 and 2 in the next section present the regression results.

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2 We also used other specifications in order to fill the gap between local and foreign interest rates by including the EMBI index or the US TB10y. Nonetheless, both variables were removed from the specification because they were not significant and provoke collinearity problems. These estimations are available upon request.

3 Pesaran and Smith (1995), Pesaran *et al.* (2001), and Mongardini and Mueller (2000).

III. EMPIRICAL EVIDENCE

First, we can observe the unit root tests shown in Table 3 in the Appendix. The ADF concludes that the series are I(1) in all cases. The results displayed are with a specification of two lags but they are robust to other quantity of lags (e.g. 1 or 4 lags).

In light of these results, we estimate equation (1) as a differenced model, with the distributed lags acting like an error correction model. Tables 1 and 2 contain the short and the long run coefficients of the model with the best information criteria[4]. It is crucial the absence of serial correlation in the model, which is confirmed by the alternative Durwin-Watson test.

The F-tests for joint significance are made against the critical values given in Pesaran *et al.* (2001). The critical values depend on the k+1 variables specified in the model and whether the series are I(0) or I(1).

When we performed the bound tests, the F-statistics found were always significant when the ratchet variables were included in the model. When they are not, the rejection of the null hypothesis of non-joint significance depends on the dependent variable explained in the regression. For the equation when CS1 is the dependent variable, we found an F-statistic of 68.74, which is higher than the bounds from Pesaran *et al.* (2001). Also, for the specification of CS2 the F-statistic is 9.06 and the bounds are also below that value (for the k used and even at a significance of 1%).

Tables 1 and 2 show the relation between the explanatory variables. In general they present the expected signs. In first place, regarding the short run effects the dependent variable lagged one period is significant and with negative sign in most cases, which implies that a higher CS is followed by a lower increase of this coefficient in the next periods. Thus, currency substitution seems to show a convergent trend during the period considered. Interest rate, in current and lagged values, as expected, affects negatively CS when significant, i.e. a higher interest rate leads to higher local currency demand, thus lower substitution. In turn, the lagged exchange rate is also significant, which is intuitively acceptable: higher devaluation of local currency leads to a future currency demand reduction and then higher currency substitution. Finally, the results show that the ratchet effect is significant and with the expected sign in all cases. In current values this affects positively CS coefficients, i.e. a higher persistence of preference for foreign currency implies higher currency substitution.

On the other hand, also the long run regressions show the expected results. CS1 coefficient is affected negatively by the interest rate, positively by the exchange rate and the ratchet effect. Moreover, similarly to Mongardini and Mueller (2000), there is no long run effect in the case of the wider version of currency substitution, i.e. CS2, which includes cash.

Our results show that there is evidence of a long run relationship in both of the ratios estimated. The difference is that when we include cash the relationship seems weaker.

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[4] We used the ARDL command of Stata to obtain this model. This command automatically chooses the best model based on information criteria. Tables 4 and 5 in the Appendix exhibit additional estimations.

TABLE 1

CURRENCY SUBSTITUTION (CS1) ESTIMATION RESULTS

VARIABLES	ADJ	LONG RUN	SHORT RUN
D. (deposit interest rate)			1.57E–07 (8.56E–07)
LD. (deposit interest rate)			–1.23E–05*** (2.15E–06)
L2D. (deposit interest rate)			–1.80E–05*** (1.88E–06)
L3D. (deposit interest rate)			–3.16E–06** (1.25E–06)
D.(exchange rate)			0.0344 (0.0256)
LD.(exchange rate)			0.0711* (0.039)
L2D.(exchange rate)			–0.0656** (0.0257)
L3D.(exchange rate)			–0.0222** (0.00825)
D.ratchet1			1.001*** (0.0214)
LD.ratchet1			–1.662*** (0.19)
L2D.ratchet1			–0.189 (0.109)
L3D.ratchet1			0.268*** (0.0693)
L. (deposit interest rate)		–0.000141 (8.89E–05)	
L. (exchange rate)		0.331** (0.129)	
L.ratchet1		–1.209** (0.459)	
L.cs1	0.111 (0.0653)		
Constant			–0.00813 (0.00712)
Observations	29		
R-squared	0.998		

Standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.
L: lagged; D: difference; LD: lagged difference, L2D: second lagged difference.
L: lagged; D: difference; LD: lagged difference, L2D: second lagged difference.

TABLE 2
CURRENCY SUBSTITUTION (CS2) ESTIMATION RESULTS

VARIABLES	ADJ	LR	SR
LD.cs2			–0.265 (0.202)
D. (deposit interest rate)			3.39E–07 (3.61E–07)
LD.(deposit interest rate)			–6.79E–06*** (1.14E–06)
L2D.(deposit interest rate)			1.11E–06 (1.41E–06)
L3D.(deposit interest rate)			2.19E–06*** (6.41E–07)
D.(exchange rate)			0.00565 (0.0089)
LD.(exchange rate)			0.0151 (0.0122)
D.ratchet2			1.631*** (0.0543)
LD.ratchet2			–1.649*** (0.346)
L2D.ratchet2			–0.765* (0.415)
L.(deposit interest rate)		–6.95E–05 (0.00018)	
L .(exchange rate)		0.0929 (0.314)	
L.ratchet2		–1.458 (4.788)	
L.cs2	0.056 (0.148)		
Constant			–0.00453 (0.00355)
Observations	29		
R-squared	0.996		

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.
Note: L: lagged; D: difference; LD: lagged difference, L2D: second lagged difference.

IV. CONCLUSIONS

Our paper has considered episodes of high inflation and price stability in Argentina that span along the 1980-2013 period. During this period exchange rates and interest rates fluctuated frequently, leading to changes in the portfolio of Argentinean residents between local and foreign currency.

One important question that needs to be answered is whether agents adjust their currency portfolio after observing changes in the fundamentals or not. On this regard, it can be thought that agents do not adjust immediately because they expect more changes on the short run, while in the long run the hypothesis of adjustment should take place.

We test this idea by using a Ratchet effect variable. This specification of the currency substitution allow us to explain the demand for local currency that agents have as a function of the interest rate, the exchange rate and some sort of past events, like previous peaks of CS associated with increasing inflation and fast devaluations (this is the idea behind the Ratchet variable).

For the Argentinean case, by means of an ARDL estimation, we show that in the short run agents do not adjust to changes on the fundamentals, leading to a significant Ratchet effect. Our results show that agents prefer to keep high holdings of foreign currency even when the interest is higher than before and wait for the new conditions to hold for a period before changing their portfolio in favor of local currency. In turn, the second important implication of our paper is that in the long run only the fundamentals matter; in fact, we found that in the long run agents adjust their portfolio in favor of local currency.

Our paper contributes to the idea that countries that experienced high inflation periods have trouble to reposition their currency since agents hold a safer currency in order to avoid future loses of the purchasing power of their savings. In order to prevent this pattern of behavior, countries should commit to long periods of price stability. This recommendation goes in line with the consensus that central banks should focus on inflation targeting as their main policy if they want to have control over the money demand by influencing the interest rate.

Further work can consists in expand the sample to other countries with a history of price instability. This could allow determining if it is possible to generalize those episodes of high inflation and fast devaluations influence in the composition of the agents´ portfolio, as well as in their preferences for local currency.

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APPENDIX

TABLE 3

UNIT ROOT TESTS RESULTS

Variable		ADF	PPERRON	ZA
cs1	level	–2.274	–4.42***	–7.91***
	difference	–4.717***		
cs2	level	–2.848*	–4.78***	–6.14***
	difference	–5.124***		
Lcs1	level	–1.676	–2.152	–5.440**
	difference	–3.123**	–7.177***	
Lcs2	level	–2.392	–2.584	–4.863*
	difference	–4.595***	–6.174***	
ratchet1	level	–2.25	–0.78	–17.59***
	difference	–5.672***	–5.77***	
ratchet2	level	–2.327	–1.016	–5.39**
	difference	–5.852***	–5.86***	
inflation	level	–2.537	–2.7	–4.29
	difference	–6.084***	–6.59***	–6.86***
Deposit interest rate	level	–3.264	–5.42***	–7.15***
	difference	–5.349***		
EMBI	level	–1.66	–2.7	–5.36***
	difference	–2.171	–4.274***	
Exchange rate	level	2.272	2.55	–4.40
	difference	–3.342**	–6.40***	–7.93***
US treasury bills	level	–0.826	–1.196	–6.076***
		–4.194***	–8.929***	

*,** and ***: signifative at 10, 5 and 1% respectively Lags selected: 2.
ADF: Augmented Dickey Fuller test.
PPERRON: Phillips Perron test (*Z(t)* statistic).
ZANDREWS: Zivot Andrews test.

TABLE 4

EXTRA CURRENCY SUBSTITUTION ESTIMATION RESULTS

Dependent	1	2	3	4	5	6
	d.cs1	d.cs2	d.cs1	d.cs2	d.cs1	d.cs2
Dep. L1	–0.9323257 (0.00)***	–0.809793 (0.00)***	–0.1845301 (0.364)	–0.4250911 (0.00)***	–0.3749371 (0.08)*	–0.4818969 (0.00)***
Dep. LD			–0.031831 (0.508)	0.0085045 (0.799)	0.2437502 (0.218)	–0.0236613 (0.836)
Dep. L2					–0.0411856 (0.127)	–0.0048084 (0.83)
d.INT	–0.0000645 (0.00)***	6.72E–06 (0.134)	–3.29E–06 (0.907)	–0.0000107 (0.008)***	–0.0000698 (0.024)**	–0.0000198 (0.00)***
d.INT L1			0.0000255 (0.159)	–0.0000113 (0.00)***	–0.0000562 (0.033)**	–0.0000198 (0.00)***
d.INT L2					–0.000041 (0.013)**	–8.34E–06 (0.006)***
d.ER	0.0219445 (0.001)***	–0.001490 (0.345)	0.0001334 (0.99)	0.0028924 (0.033)**	0.0227696 (0.052)*	0.0063862 (0.00)***
d.ER L1			–0.008775 (0.19)	0.001845 (0.026)**	0.0184722 (0.058)*	0.0049456 (0.00)***
d. ER L2					0.011037 (0.056)*	0.0030104 (0.00)***
d.RAT	1.194194 (0.00)***	1.808319 (0.00)***	1.04529 (0.00)***	1.74321 (0.00)***	1.083278 (0.00)***	1.754212 (0.00)***
d.RAT L1			–0.973897 (0.00)***	–1.009788 (0.00)***	–1.076623 (0.00)***	–0.8632007 (0.01)**
d.RAT L2					0.3591525 (0.137)	–0.0255576 (0.906)
Constant	0.1682541 (0.00)***	0.0259578 (0.001)***	0.0425685 (0.309)	0.0145112 (0.008)***	0.0886563 (0.056)**	0.0250768 (0.00)***
Long run relations						
INT	0.0001356 (0.00)***	8.69E–06 (0.317)	0.0001559 (0.17)	0.000033 (0.005)***	0.000198 (0.00)***	0.0000428 (0.00)***
ER	–0.0504246 (0.00)***	–0.004975 (0.104)	–0.0544277 (0.153)	–0.0100562 (0.007)***	–0.0689099 (0.00)***	–0.014542 (0.00)***
RAT	–0.127391 (0.00)***	–0.106084 (0.042)**	–0.1913081 (0.204)	–0.1126139 (0.038)**	–0.1914474 (0.00)***	–0.1946534 (0.00)***
N. obs.	32	32	31	31	30	30
R2 adj.	0.95405511	0.9568342	0.96675172	0.98799139	0.99114464	0.99520325
DWA (Prob > chi2)	0.8906	0.1774	0.4861	0.0241	0.3507	0.8829
AIC	–99.1198	–188.6189	–133.6555	–206.8399	–130.0692	–205.9422
BIC	–87.6479	–177.147	–118.2423	–191.4267	–110.9271	–186.8001

*,** and ***: significant at 10%, 5% and 1% respectively.

TABLE 5

EXTRA CURRENCY SUBSTITUTION ESTIMATION RESULTS (WITH CS LOG-TRANSFORMED)

Dependent	1	2	3	4	5	6
	d.Lcs1	d.Lcs2	d.Lcs1	d.Lcs2	d.Lcs1	d.Lcs2
Dep. L1	–0.437652 (0.00)***	–0.2845489 (0.003)***	–0.0723144 (0.33)	–0.2483602 (0.007)***	–0.1835561 (0.017)**	–0.3615988 (0.00)***
Dep. LD			–0.1287837 (0.095)*	–0.0955479 (0.523)	0.230385 (0.2)	–0.159452 (0.393)
Dep. L2					–0.0393656 0.476	0.0992455 0.333
d.INT	0.0009102 (0.006)***	0.0005917 (0.006)***	0.00092 (0.004)***	0.0012744 (0.002)***	0.0013138 (0.001)***	0.002017 (0.001)***
d.INT L1			–0.0002309 (0.187)	0.0003183 (0.114)	0.0000636 (0.807)	0.0006379 (0.15)
d.INT L2					0.0004074 (0.011)**	0.0003454 (0.051)*
d.ER	–0.247695 (0.041)**	–0.1715483 (0.022)**	–0.2159089 (0.042)**	–0.3597671 (0.006)***	–0.3815997 (0.002)***	–0.6340359 (0.001)***
d.ER L1			1.37E–01 (0.034)**	–0.0394983 (0.535)	0.0217142 (0.797)	–0.1438447 (0.271)
d. ER L2					–0.1432606 (0.017)**	–0.1408646 (0.007)***
d.RAT	–6.52954 (0.00)***	–23.02295 (0.00)***	–5.005227 (0.00)***	–22.12786 (0.00)***	–5.318335 (0.00)***	–22.6562 (0.00)***
d.RAT L1			7.698748 (0.00)***	14.6955 (0.015)**	8.758995 (0.00)***	11.29802 (0.038)**
d.RAT L2					–4.142525 (0.011)**	–0.9112178 (0.843)
Constant	0.6532414 (0.177)	0.6478771 (0.221)	–0.0090576 (0.969)	0.5676046 (0.191)	0.1405947 (0.382)	0.6480704 (0.046)
Long run relations						
INT	–0.004415 (0.002)***	–0.0039655 (0.03)**	–0.0176114 (0.237)	–0.0059084 (0.011)**	–0.0088575 (0.006)***	–0.005488 (0.00)***
ER	1.46356 (0.001)***	1.299927 (0.029)**	4.513186 (0.237)	1.703939 (0.012)**	2.644256 (0.002)***	1.723539 (0.00)***
RAT	1.858852 (0.195)	13.58915 (0.088)*	2.407338 (0.569)	12.55667 (0.083)*	2.311221 (0.045)**	14.04712 (0.001)***
N. obs.	32	32	31	31	30	30
R2 adj.	0.5892728	0.69595032	0.92214088	0.83907454	0.97201652	0.94143144
DWA (Prob> chi2)	0.2051	0.3359	0	0.1	0.0006	0.0862
AIC	76.6235	72.38518	61.45549	57.40828	57.40244	57.49444
BIC	88.09539	83.85708	76.86866	72.82145	76.54458	76.63658

*,** and ***: signifative at 10, 5 and 1% respectively.

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Guest Editor
Bernardo Bátiz-Lazo

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