THREE ESSAYS IN APPLIED ECONOMETRICS

by

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ABSTRACT OF THE DISSERTATION

Three Essays in Applied Econometrics

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This dissertation presents three essays which are linked by the use of econometric models to explain problems that are only explained descriptively in the literature. The first essay, statistically shows that a systematic measurement bias can significantly distort predictions obtained using an international accounting framework due to the sizable diversity of the parties involved in it. Once the measurement bias is taken into account, the average value gains on the US foreign asset and liability categories are estimated to be smaller, and no evidence is found on positive yield differential. The second essay estimates the value gains and the mismeasurement using data at multiple frequencies. The results show that positive sizable return differential is present after 2002. The third essay shows that the increasing availability of prescription opioids threatens sellers' profit margin since it is a close substitute for heroin and forces sellers to find alternative methods to compensate buyers in the case of a negative supply shock.

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Dedication

I would like to dedicate this dissertation to my father, Garip Yildirim and my mother, Hulya Yildirim

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Chapter 1

Introduction

This dissertation presents three examples of empirical work from both international economics and microeconomics fields.

The first paper, statistically show that a systematic measurement bias can significantly distort predictions obtained using an international accounting framework due to the sizable diversity of the parties involved in it. The second paper, takes the same problem one step further and presents Kalman smoother as a way to measure the bias in the mismeasurement using data at multiple frequencies. The method is presented as an alternative interpolation method for the missing observations. The third paper significantly estimates that temporary shocks to a given system could generate big temporary responses in indirect ways.

The first two paper presents the global imbalances literature which is centered on the consecutive and large current account deficits of the United States since 1990s. A large developed country, the US, borrowing from the rest of the world at a rate faster than its income growth rate was worrisome due to the deeply embedded ties of the US economy with the rest of the world. The sustainability of the fast growing debt and continuous borrowing of a country of this size stirred discussions on the unobserved factors inherently supporting the economy, such as intangible assets that the US held abroad (like trademark and know-how values) as well as the performance of the US foreign investment abroad in generating value gains.

The studies in the literature calculate rate of return on US foreign investment abroad either using weighted average of ad-hoc constructed return indices or using the implied gain assuming particular accounting identities are correct. In the first method the weights representing US foreign investment portfolio is subject to discussion due to

the diversity of the parties involved, investment types and currency composition. The second method is controversial since there has been discussions on the accuracy of the measurement of data regarding the transactions, since the update related to the flow data is difficult to obtain.

The next chapter is devoted to quantifying inherent biases and measurement errors in the implied capital gain method. We estimate the rate of mismeasurement on the flows and look into the total returns using the corrected data. The total net return using the value gains estimated this way show that there is not significant evidence on persistent excess gain compared to the gain received by foreign investors in the US. It is also shown that the mismeasurement in capital flows is significantly present in the data. The results show that the actual capital flows are larger than the amount recorded.

The following chapter uses quarterly investment flow data and annual investment position data and estimates quarterly investment position taking the mismeasurement into account. The results show significant evidence that the flows are undermeasured. The estimated latent capital gain shows that since 2003 the rate of return on US foreign investment abroad has been larger than the return on foreign owned assets in US.

The last chapter examines the supply side of the illicit drug market, particularly the period non-pharmaceutical Fentanyl dissemination in New Jersey. New Jersey heroin market has been famous for supplying the highest average purity for the cheapest price in the country. However, especially after 2002 increasing interdiction efforts and close scrutiny in the customs decreased the availability as well as the average purity of the drug sold in the market. On the other hand the rise of the use and availability of the pain killers introduced an alternative to heroin which affected the inelastic demand as well as threatened the profit of the suppliers. In 2006, non-pharmaceutically produced Fentanyl mixed heroin bags sold in the market, which is a very strong opioid that is 40 times stronger than the heroin and very difficult to dose correctly.

In this paper we use zero-inflated negative binomial and negative binomial models to describe the Fentanyl overdose episode and argue that non-pharmaceutical Fentanyl overdoses were related to drug suppliers' efforts to respond to declining heroin purity

in the context of the increasing availability of close substitutes. We found significant evidence that the spatial distribution of the non-pharmaceutical Fentanyl mixed baggies are correlated with the availability of the close substitutes.

The three papers in this dissertation are linked by the use of econometric models to explain problems that are only explained descriptively in the literature. The underestimation in the international transactions documented and discussed in various papers however the papers here are the first to find statistically significant evidence about it, as well as estimate the implicit capital gain without any measurement bias. Similarly, the last chapter is the first to empirically analyze the supply side heroin market and Fentanyl episode in New Jersey.

Chapter 2

Application of Latent Factor Estimation on Capital Gains Calculation

2.1 Discussions on Global Imbalances

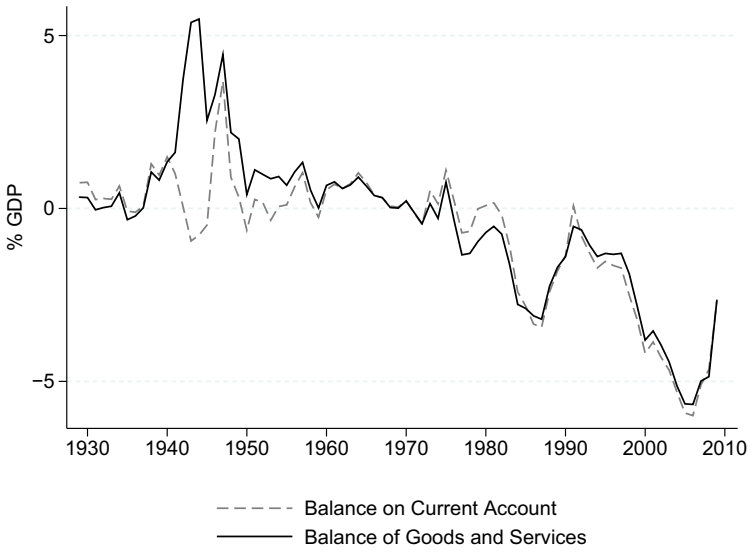
Global imbalances can be defined as the growth in the variation of the current account balance rates in the world encouraged by increasing globalization (Baclet and Vidon, 2008). In the center of these discussions lies the United States economy with current account deficit reaching 6% of its GDP and China whose current account surplus is about 10% of its GDP.

Deficit in its current account balance is not new to the US economy. Figure 2.1 shows the US current account balance and the trade balance as a percentage of US GDP since 1929. Before the 1980s, the second world war economy had periods of deficit where the largest one was about 0.9% in 1943. During this period there was a large trade surplus due to the war, however, this surplus was consumed by the unilateral spending mostly due to the Lend-Lease Program (Field, 2008) until 1945. The large share of unilateral spending continued under the Marshall Plan until 1951.

In the 1980's there was a sharp decline in the US current account balance partially explained by the Reagan tax cuts and decreased net national savings which led to increasing interest rates and the sharp appreciation of the US dollar (Frankel, 2006). During this period, Japan had a growing trade surplus and was the main lender to the US. Due to consecutive current account deficits the US net foreign asset holdings turned to negative in 1985 and US became a debtor nation for the first time after the first world war. The decline in net foreign asset holdings reached its highest in 1987 when the current account balance was recorded as $150 billion, or 3.3 percent of the US

GDP. After the US dollar started to weaken in the international markets, the current account balance got smaller and reached to zero by 1991, with the help of the transfer received due to the Vietnam War (Obstfeld and Rogoff, 2005).

Figure 2.1: Balance on Goods and Services: 1929-2009



Source:
Balance of international payments: 1790-1998. Table Ee1-21 in Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition, edited by Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright. 1998-2009, BEA International Transactions.

Overall, until the end of 1999 the deficit has rarely reached to 3% of the US GDP. The sharp increase in the deficit level since 2000 despite the weakening of the US dollar, has stirred discussions on the sustainability of this trend. In 2006, before the great recession, the US current account deficit was recorded as 6% of the GDP. This brought the questions regarding the current account reversals and its possible consequences.

It has been argued that the large current account deficit is bound to get smaller, and a possible sudden reversal is hanging over the world economy "as a sword of Damocles" (Obstfeld and Rogoff, 2005). Obstfeld and Rogoff (2005) predicted that a sudden reversal in current account balance triggered by a demand shock will lead to a large depreciation in the real effective exchange in the US dollar and an appreciation in the Euro.

Blanchard et al. (2005) do a similar analysis with imperfect substitutability between US assets and other assets and valuation adjustments through exchange rate changes, and predicts a large depreciation to obtain current account reversals. They explain the increase in the trade deficit and the dollar depreciation by both an increase in the demand for foreign goods as well as an increase in the demand for US assets. The increase in foreign demand for US assets is used as an explanation for the US trade deficit as well as the appreciation of the US dollar towards the end of 1990s.

Dooley et al. (2003) argue that depreciation of the dollar, low real interest rate and the current account deficit are a natural outcome of the division in the world economy where the US represents the core region, Asia represents the periphery trade account region and Europe represents the capital account region. They call this system as Breton Woods II. In this system, Asia, as the trade account region is the only one that seeks export led growth and applies capital and exchange rate controls. They argue that accumulated savings of this trade account region sustains the growing current account deficit in the core region. Unlike the capital account region countries the main motivation of the trade account countries is not the risk/return trade-off but the sustainability of their export led growth.

Caballero et al. (2008) provides a theoretical model that divides the world into 4 region: the US like countries , Eurozone, Japan and the Rest of the world. The rest of the world mainly covers emerging economies as well as high saving economies. These economies are argued to be the reason for the increase in demand for US assets. Different from the other theoretical papers, this paper sees the current global imbalances as a result of the current equilibrium in financial markets after a shock that crashed the capital markets in the rest of the world and distinguished the US economy with more financially developed markets . They find that the current deficit is sustainable as long as the asset demand from the rest of the world continues, where the asset demand is not restricted to the demand due to the accumulated reserves in the Asian countries.

Mendoza et al. (2009) also finds out the current state is the outcome of the financial integration and the different levels of financial development. They argue that “financial

integration was a global phenomenon, but financial development was not ". They compare the results of a transition from autharky to financial integration between the countries with different levels of financial development. They found out that there was a significant decline in net foreign asset holdings in countries with higher financial development.

How was the past current account reversal experience of the industrial counties? Chinn and Ito (2007) looks at the relationship between the budget balance and the current account balance. They estimate significant positive correlation between the two. In addition to that, they look into the argument about the difference in financial development attracting capital and affecting the saving rates by the supply of foreign funds. They found positive relation between the level of development in the capital markets and level of savings.

Is there any sizable past experience where the current account reversal came along with a sharp depreciation of the exchange rate as predicted in the literature? Croke et al. (2005), Freund (2005) look into the path of economic indicators like GDP growth, inflation, real exchange rate, real policy and long-term interest rates etc. during the past 23 episodes of current account reversals. They found no evidence of real exchange rate collapse, but found some examples of depreciation in nominal terms. The main reflection of the current account reversals is seen in the slowing growth rates.

Backus et al. (2009) does not agree with the doomsday scenarios. They point out the increasing divergence in the current account balances, and argue that the large US current account deficit happened along with the large surpluses observed in some of the industrial countries like Germany, Norway and Switzerland[1]. They explain the low savings rate by high net worth and high consumption correlation. They argue that the valuation gain as well as the existence of strong financial institutions creates a consumer confidence and the sustainability of the spending.

The current account balance that is discussed so far is one component of the balance of payments accounting which shows the balance in transactions of goods, services

[1]German, Norway, and Switzerland recorded 6.5%, 16% and 17% current account surplus in 2006.

and income with the rest of the world in a given period. The transactions of various financial claims are on the other hand recorded under the financial account component[2]. The outflows of funds (US foreign investments) during the period are recorded with a negative sign which could be considered as the import of foreign financial assets. Similarly, inflows of foreign funds into the US are recorded with a positive sign since it is US exports of financial assets (such as the sale of municipal bonds to foreign investors). Hence a deficit in current account or a surplus in the financial account show the net amount that the country owes to the rest of the world during that period.

$$\begin{aligned} BoP &= CA + FA + CapA \\ &= X - M + IncR - IncP + Inflows - Outflows + CapA \\ &= 0 \end{aligned} \tag{2.1}$$

The equation 2.1 summarizes the description above. Balance of payments is a way to keep track of the transactions with the rest of the world using the double entry bookkeeping accounting principle. It is based on the idea that the change in asset stock should be matched by a change in the liability stock. So, theoretically it should add up to 0. The current account, capital account and financial account are subcategories summarizing the type of the transactions on both the asset and liability sides, i.e. financial, non-financial etc. A good summary about the accounting foundation of the balance of payments can be found in Fieleke (1996).

The current value of all US foreign asset holdings and US assets held by foreigners are reported under the International Investment Position statement by the BEA. The net International Investment Position (net IIP, here onwards) summarizes the US foreign asset stock compared to the foreigners investment stock in the US. A country with a

[2] Previously, balance of payments consisted of current account and capital account, which included the financial assets and liabilities. According to the new definitions, the capital account is reduced to "... credit and debit entries for non-produced non financial assets and capital transfers between residents and non-residents." (IMF BOP manual, 2010) and financial assets and liabilities are reported under the Financial Account.

positive net IIP has lent to the rest of the world more than it borrowed and is called a net creditor. Similarly, a country that has a negative net IIP is a net debtor.

Change in foreign assets and liability holdings depend on the net inflows and outflows during the year. Any difference between the change in the foreign asset/liability position and the net flows are attributed to capital gains which are change in the market value of an investment due to price and exchange rate changes.

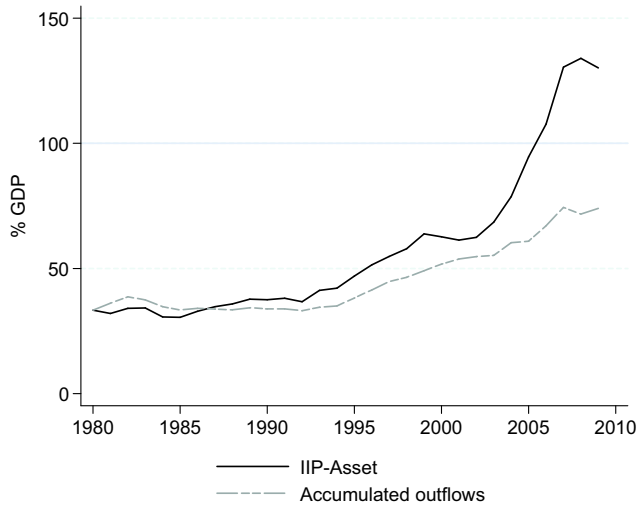
$$X_t = X_{t-1} + flow_t + CapG_t \tag{2.2}$$

The equation 2.2 shows the accumulation of an investment over time. The notation X_{t-1} shows the market value of the investment position (asset or liabilities) at the end of the previous period, $t-1$. During the period t, the net amount of financial flows received/sent is denoted by $flow_t$. Note that the net flows can be negative as well. If there is no change in the market value and exchange rates over time, then the equation reduces to the sum of the financial flows every period.

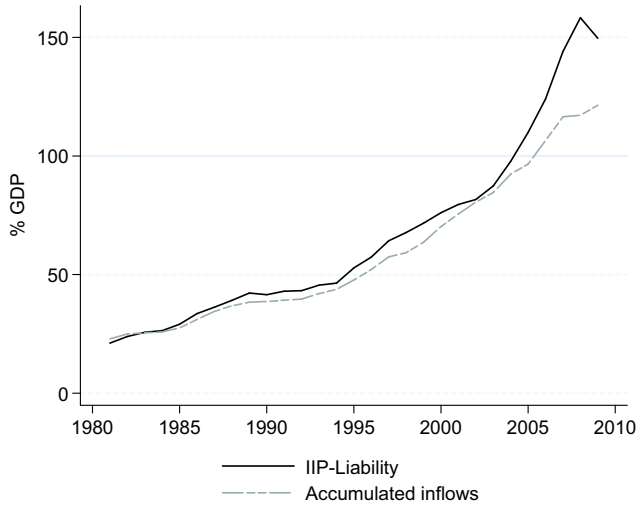
Figure 2.2 shows the accumulated flows as a percent of GDP starting in the 1980's up to 2009 in both foreign assets and liabilities. The first figure on US foreign assets show that until 1986, the value of accumulated flows eroded due to a negative value gain during the period. In 1981 and 1982 the recorded capital outflows were about 3.5% to 4% of the GDP however the annual change in the foreign asset holding were only 2.3% and 3.3 %, respectively. After this period, the sum of outflows diverges from the actual holdings significantly. This difference is biggest after 2000. The big difference after 2000 explained by the value gains related to portfolio investments which has a big share of foreign corporate stocks denominated in foreign currency . On the foreign held US asset side, the contribution of value gains is weak until 2003.

The accumulation of financial flows suggests that the difference between foreign holdings in US and US holdings abroad should be much larger. The net value gains, however, close the gap, and hence the net position looks smaller. This observation brought up questions regarding the contribution of these returns into the sustainability of the current account deficit as well as the stability of the net IIP (Backus et al., 2009,

Figure 2.2: International Investment Position of the United States at Yearend



(a) US-owned assets abroad



(b) Foreign-owned assets in the US

Source: BEA, Intentional Investment Position. Acc. net flows show the value of the cumulative flows after 1981 added on the investment position in 1980.

Gourinchas and Rey, 2007a, Hausmann and Sturzenegger, 2007, Higgins et al., 2007, Milesi-Ferretti and Lane, 2008, Obstfeld and Rogoff, 2005).

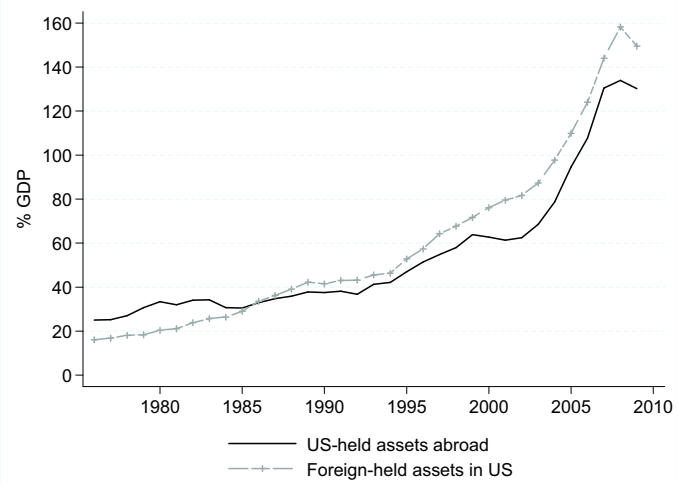
Another observation supported the arguments on the difference in the returns is related to the difference in income yields. Net foreign income (NFI) represents the income flow that is generated by the investment assets and the payments to the residents working abroad. It is reported within the current account balance.

Income received and paid on assets are expected to be proportional to the US owned foreign assets abroad and foreign-owned assets in the US, respectively. However, it has been noted that net foreign income of the US has been positive despite the consistent debt accumulation over time. Figure 2.3-a shows the US investment abroad against the foreign investment in the US divided by the US GDP. We see that the difference between the two became negative after 1985 when the consecutive current account deficits reached the highest level of the time, 3%. The figure b shows the income received and paid to GDP ratio. Contrary to expectations, the difference in income return on the US foreign assets and the one on foreign-held assets in the US has remained consistently positive. The rate of income return on US assets is significantly larger than the rate on US liabilities.

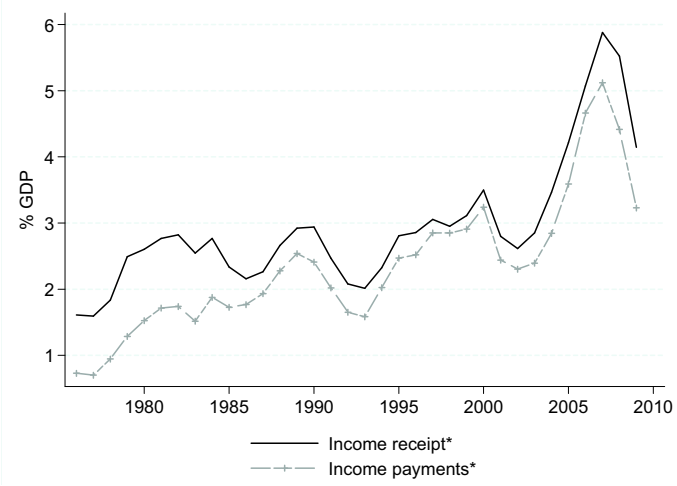
What can be said about the total return on US foreign assets compared to the return on foreign-held US assets? What is the source of this positive return differential? Are the reasons like portfolio composition and risk structure of the assets enough to justify the difference? How does the return differences change when the comparison is made within the investment categories like FDI, or debt securities? Can the return differential be used as a source of stability in the net international position?

In the next section, we will briefly analyze the asset composition of the US foreign investment and compare it with the asset composition of the foreign investment in the US. The comparison of the compositions is important in order to understand the discussions on return and value gains differences between the two.

Figure 2.3: Foreign Investment vs. Income



(a) International Investment Position



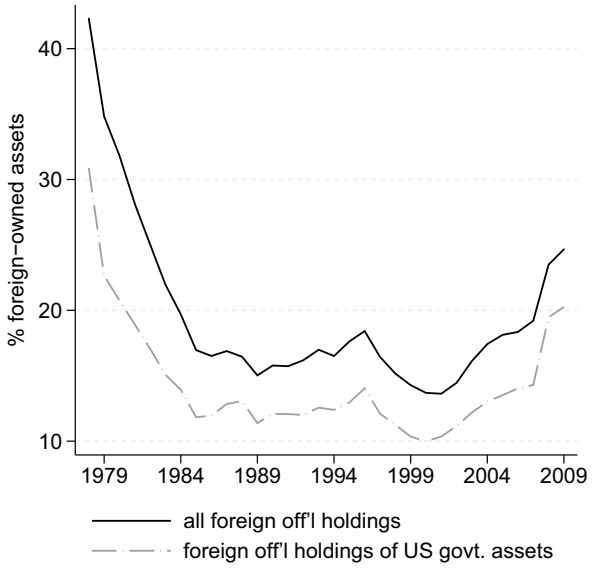
(b) Income Received vs. Income Paid

Source: BEA, Intentional Investment Position and International Transactions
Note: *Excluding the compensation of employees.

The US Investment Abroad versus Foreign Investment in the US

Understanding the portfolio composition is important in order to understand the relative risk structure of US foreign investment and foreigners investment in the US. High return differences naturally brings about differences in investment categories such as direct investment, debt investment or equity investment.

Foreign holdings in the US are mainly reported under two categories; foreign official assets and other assets. The foreign official asset holdings in the US declined significantly from 40% of the liabilities to less than 20% and remained stable around 15% until 2000. After 2000, we see a gradual increase again in the foreign official investment in the US. In Figure 2.4 we see that since 1980 a large share of these official holdings are invested in the US government assets.

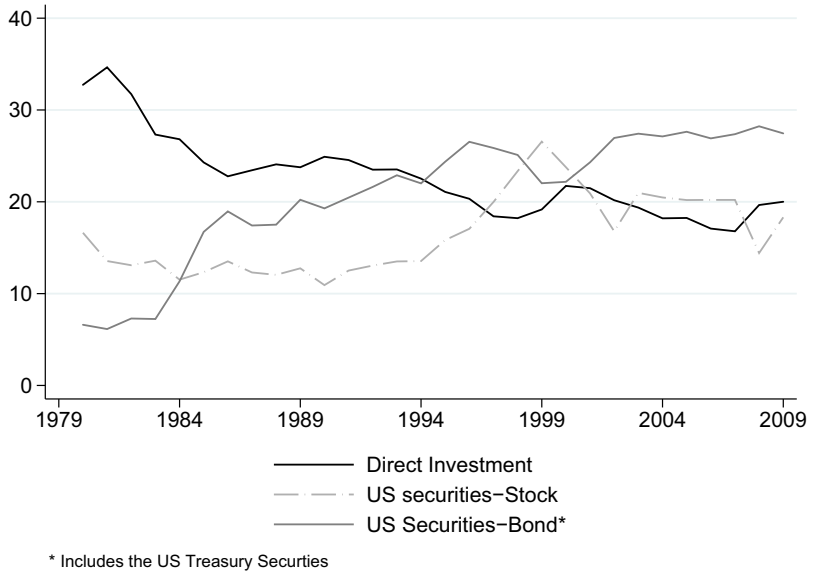


Source: BEA International Investment Position .

Figure 2.4: Share of Foreign Official Assets in Foreign-owned Assets in the US

Figure 2.5 shows the share of direct investment, the US corporate stocks, and US

debt securities including the treasury securities in foreign non-official investment portfolio. We see that the foreign private investment preference is shifting from direct investment to less risky debt securities.



Source: BEA International Investment Position .

Figure 2.5: Asset Composition of Non-Official Foreign Assets

The growing share of Asian economies has been pointed out in the literature. Table 2.1 summarizes the share of Europe[3] and Asia[4] within each US debt liability category. The first part compares the evolution of the share of European and Asian investors in the US corporate, treasury and agency debt over time. Note that these two groups cover about 90% of the foreign holdings of treasury as well as agency debt since 1985. Since the definition of Asia is very broad in the second part focuses particularly the share of China and Japan among the rest of the world in each of these categories.

[3]Total Europe (TIC Code: 19992) is used, which mainly includes Austria, Belgium , Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Bulgaria, Czech Republic, Hungary, Poland, Romania, and Russia

[4] Total Asia (TIC Code: 49999) is used which mainly includes Bangladesh, China, Hong Kong, India, Indonesia, Israel, Japan, Jordan,] South Korea, Lebanon, Malaysia, Pakistan, Philippines, Singapore, Syria, Taiwan, and Thailand

Among the other foreign investors in the US, Europe used to hold about one third of treasury and agency debt, and about 15% of the corporate debt in 1989. Similarly, Asia had more than half of the treasury and agency securities and about 11% of the corporate debt during the same period. During that time Japan had the biggest share in treasury and agency debt among the Asian economies, and China's share was basically zero.

Table 2.1: Share of Europe and Asia in US Debt Securities

		Corporate Assets (%)	Treas Assets(%)	Agency Assets (%)
Part I				
	1989	15.3	35.4	29.9
	1994	20	35.6	25.7
Europe	2000	35.9	33.4	37.3
	2006	56.5	18.4	26.4
	2009	64	17.7	13.2
	1989	11.6	55.0	55.2
	1994	15.6	54.3	53.1
Asia	2000	5.4	55.1	43.2
	2006	11.5	71.5	59.6
	2009	11.2	71.9	75.3
Part II				
	1989	0	0	0
	1994	0.1	3.8	0.5
China	2000	0	8.1	7.6
	2006	2.9	21.3	26.1
	2009	0.6	29.4	38.4
	1989	9.4	34.9	43.7
	1994	10.9	28.1	36.8
Japan	2000	3.2	25.2	16.5
	2006	5.4	31.3	18.9
	2009	6.2	25.1	18.5

Source: Cross-border portfolio holdings, Foreign (non-official) Portfolio Holdings of U.S. Securities, Treasury International Capital (TIC) system.
Note that Short-term securities are not included.

After 2000, this picture changed significantly. Asian share in treasury and agency

debt categories have risen to 70% in each category, and European investors share shrank to 17% and 13%, respectively. In corporate debt, however, the share of Europe has reached 64% in 2009, from about 15% in 1990s.

The share of China in corporate debt has been small since the 1980s. The highest share observed was about 2.9 % in 2006 which decreased back to 1% after the crises in 2007. China's share in foreign-held treasury and agency debt, however, grew tremendously, from 8% to about 30%, and currently it is greater than the share of Japan.

Currency composition of the US debt held by foreigners is not all in US dollars. Overall, about 15% of the long term debt is denominated in foreign currencies with the biggest share belonging Euros. This share increases to 25% if treasury securities are left out since they are all denominated in the US dollar. It is mostly corporate bonds that are denominated in foreign currencies.

Over the last 20 years, the composition of US foreign holdings has changed significantly as well. The table below summarizes the share of private and official US investment abroad. The official assets are categorized as official reserve assets and US government assets other than reserve assets. The table has two sections. The first section summarizes the share of each investment categories in the years 1981, 1991 and 2001.

Table 2.2: Composition of the US-held Foreign Assets

Year	Private Assets (%)	Official Reserve Assets(%)	Government Assets (%)
1981	80.49	12.44	7.08
1991	89.46	6.96	3.56
2001	96.58	2.06	1.36
2007	97.64	1.76	.599
2008	93.00	2.24	4.76
2009	96.73	2.72	0.56

Source: BEA International Investment Position.

The biggest share in US foreign holdings has been held by private investors since 1980s. This share has gone up from 80% in 1981 to more than 95% after 2001. On

the other hand, the share of official reserve assets and government assets decreased significantly since the 1980s. The overall US official holdings went down to 3.5% after 2000 from about 20% in the 1980s.

The second section shows the changes in the composition over the last three years which corresponds to the peak of housing bubble (2007) and afterwards. At the end of 2007, about 98% of the US investment was private investment. In 2008, we see a sharp decline in share of private investment and the US government holdings jumps to 4% from 0.5%. This is a big jump since the share of government assets has been stable around 1% since 2000.

The government assets has two categories, short term and long term assets. This increase is due to a jump in the large outflow of the US dollar due to temporary reciprocal currency arrangements, which are short-term dollar swaps extended by the US federal reserve bank for those countries who cannot meet the dollar reserve requirements.

In 2008, unlimited dollar funding agreements were made with major central banks like the European Central Bank, Bank of England, Bank of Japan etc. for the first time[5] Later, these bilateral currency agreements were extended to four major emerging market central banks, which are the Banco Central do Brasil, the Banco de Mexico, the Bank of Korea, and the Monetary Authority of Singapore[6].

A paper by Aizenman and Pasricha (2010) explores the reasons for why these four emerging countries were selected. They find out that the share of emerging markets in large US banks' balance sheet and their share in US trade have the biggest share in why these four countries were chosen. Due to these bilateral currency swap agreements, the US foreign currency holdings have increased about $500 billion in 2008[7].

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[5]See the Board of Governors of the Federal Reserve System Press Release, September 24, 2008, http://www.federalreserve.gov/newsevents/press/monetary/20080924a.htm

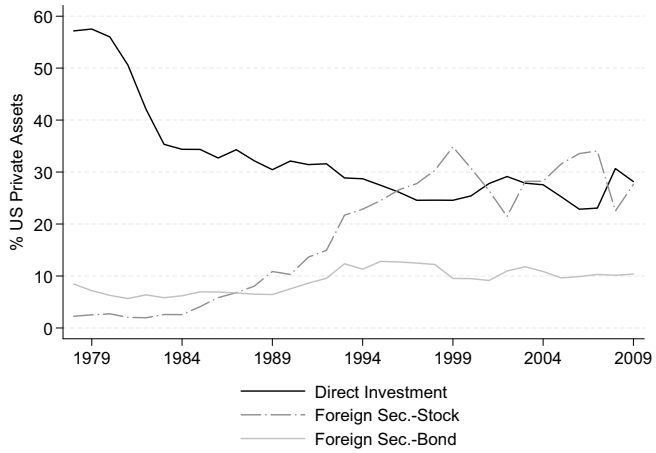
[6]See the Board of Governors of the Federal Reserve System Press Release,October 29, 2008, http://www.federalreserve.gov/newsevents/press/monetary/20081029b.htm

[7]The total number of central banks that the US federal reserve bank signed an agreement was 14 during the period. These central banks are; the Banco Central do Brasil, the Banco de Mexico, the Bank of Korea, the Monetary Authority of Singapore, the Reserve Bank of Australia, the Bank of Canada, Danmarks Nationalbank, the Bank of England, the European Central Bank, the Bank of Japan, the Reserve Bank of New Zealand, the Norges Bank, the Sveriges Riksbank, and the Swiss National Bank.

Surprisingly, even though the financial crisis at the end of 2007 was originated in the United States, the rest of world experienced a pressure in dollar demand, so the US Federal Reserve Bank was urged to act as a lender of last resort and extend these unprecedented credit swaps so that the US dollar preserved its reserve currency status during the financial crisis.

Along with the increase in the share of private holdings, the investment composition within private assets has changed as well. Figure 2.6 shows the composition of the US private assets portfolio from 1977 to 2009.

Figure 2.6: US-owned Assets Abroad: Private Assets



Source: BEA International Investment Position .

The share of the equity investment in the private investment portfolio has increased from about 2% in 1980 up to 27% in 2009. On the other hand the share of foreign direct investment has been reduced to half of what it was at the beginning of the 1980s. The overall share of risky assets (equity and FDI investment) in private investment has changed significantly after the boom in digital technology use such as the Internet and cell phones, and remained stable since the beginning of 1996 at around 55% of the US private investment. Note that, since the share of private assets increased dramatically over the years, the share of risky assets in the whole foreign asset holdings has increased as well.

As the investment in equity securities increases, the share of foreign currency denominated investment in US foreign holdings increases as well. That is why the capital gains have become more pronounceable over the last 10 years. In fact, we estimate a significant return differential for the period from 2002 till 2009 in chapter 3.

In reports on US portfolio holdings by the US Department of Treasury, we see that since 2003,oin average 74% of the US holdings of long-term foreign portfolio debt is denominated in dollars, which goes up to 90% for short term debt securities and the debt securities from developing countries. Note that more than 73% of the long term portfolio debt investment is made in developed countries.

2.2 Sustainability of the US Current Account Deficit and the Role of Capital Gains

The current account deficit has always been introduced as a saving and investment mismatch. In the national income accounting when the country invest/consumes more than the available amount of savings, the difference would be financed by borrowing from abroad. The correction mechanism includes increasing savings or decreasing consumption as well as exchange rate adjustments, so called "trade channel" in Gourinchas and Rey (2007b). In the same paper, the contribution of value gains based on exchange rate and price adjustments is introduced as another way to pay the accumulated external debt, which is called "valuation channel".

During the great recession financial side of the story and the excessive savings of the rest of the world[8] is stressed as one of the leading cause of the global imbalances and growing US external debt. So, the focus switched from low savings level in US to high savings level in the rest of the world. It was the increasing demand for US assets from the rest of the world (particularly Asian investors) that led the current account deficit to grow. Growing dependency of the US economy to the sustainability of international financial flows from the rest of the world triggered worries of "sudden

[8]Remarks by Governor at the Sandridge Lecture Bernanke (2005), "The global savings glut and the US current account deficit", 2005

stop" of financial flows (Calvo, 1998), which is used to describe the financial flows from developed countries to the emerging markets. Obstfeld and Rogoff (2005) predicted that in case of a sudden shock of that sort the dollar is expected to depreciate about 33%. As Serven and Nguyen (2010) also points out, the sudden shock happened however contrary to the expectations the US dollar has not been affected significantly.

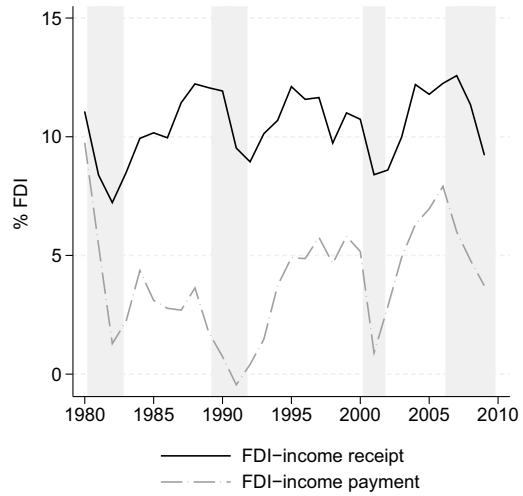
The data shows that investment in the US has always yielded a lower income return compared to the one on the US investment abroad. In his book, Cline (2005) decomposes income returns on private investment into direct investment, stocks, corporate bonds, bank claims and non-bank claims and shows that the persistent positive rate of income return is due to the positive net income return on foreign direct investment over the entire period. He finds that net income returns on other categories are not consistently positive during the same period.

The size of US direct investment holdings has always been larger than the size of the direct investment that US has received s from rest of the world. In 2009, despite a negative net foreign asset balance, the dollar amount of US direct investment was 1.5 times the direct investment in US from the rest of the world. So, it is not surprising that the level of income received on US FDI is larger. However, as is seen in the Figure 2.7-a, the difference in income received to FDI position ratio (income return) is large as well, with an average of 6% excess return from 1980 to 2009. The shaded areas shows the business cycle peak to trough periods. The income returns are highest in both assets and liabilities categories during the boom. Especially, we can clearly see the effect of dotcom and housing bubbles on FDI income returns in the US.

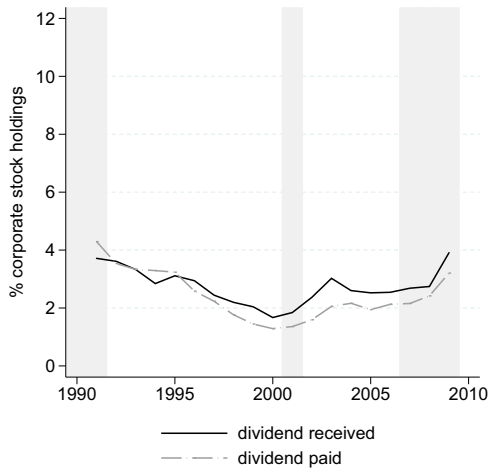
The figure 2.7 b and c shows the interest and dividend return on corporate bonds and stocks, respectively. The average income return difference is less than one percent on stocks and about two percent on bonds. After 2000, the major source of return in equity investment is obtained through value changes, which will be presented later.

How can we explain the difference? Is the return differential an illusion? There are studies which claim that the FDI investment income difference could be explained partly by a mismeasurement related to foreign investors motivation to avoid paying

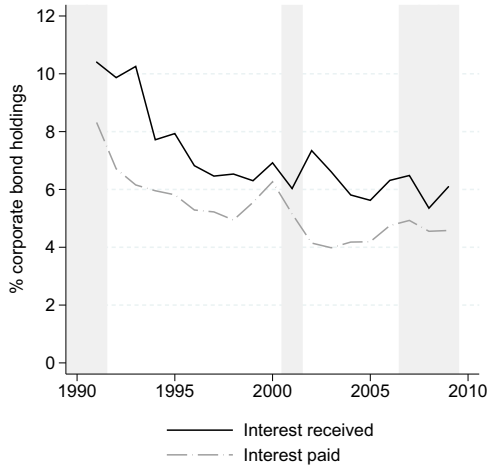
Figure 2.7: Income Received and Paid: FDI, Equity and Bond Securities



(a) Direct Investment Income



(b) Income on Corporate Securities-Dividends



(c) Income on Corporate Securities-Interest

Source: BEA, Intentional Investment Position and International Transactions
Note: *Rates are calculated as a ratio of income received in particular asset category and previous periods asset holdings. Other private investment includes all private investment except direct investment. The shaded areas show years that is listed in NBER peak to through dates.

income tax and reporting lower profit (Bosworth et al., 2007, Gros, 2006a,b). Gros (2006a) argues that foreign investors in US declare low profits, and show profit under mother company to avoid relatively high corporate income tax. They point out the fact that while companies investing less than 10% into US corporate equities earn close to the average rate of return in US, there is a significant drop in the return if they acquire more than 10% and classified as direct investment.The papers one of the main explanation is that the retained earnings which is counted as direct income in direct investment is reported close to zero by foreign investors where as US investors report a large retained earnings. Hence, the reinvested earnings recorded in income received in current account balance, as well as in the financial outflows, so that the balance of payments hold. Bosworth et al. (2007) argues that the multinational corporations using their foreign affiliates tend to report higher income from those countries with relatively lower income tax. Their paper show that the tax induced income shifting can account for one third of the FDI income return differential.

The paper by Hausmann and Sturzenegger (2007) argues that more than half of the investment income is coming from countries which have comparable or even higher corporate income tax, like Canada, and income generated from the low income tax countries is not large enough to account for the difference in FDI income return. The paper argues that the value of the US foreign assets are not captured correctly, due to the fact that intangible capital is not accounted for. The technical expertise, trademarks, and know-how are those intangible assets that generates a premium on FDI returns, like the return difference forgone to invest in a safer country. Corrado et al. (2006) estimates the business intangible capital investment in 1999 close to $1 trillion, and argue that this investment contributes to the growth of capital stock and GDP significantly.

Are the US investors more competent than the foreign investors? Curcuru et al. (2010) looks into the return difference in portfolio investments, specifically bond and equity investment. They find evidence that timing the switch from stocks to bond has a statistically significant effect on the return differences. The timing effect is defined as correlation between weight assigned to a portfolio investment category and next period

investment return. A positive correlation signals that the investment type chosen is rewarded by a high return next period. The analysis show significant negative correlation for foreign investors (especially from developed countries) investing in US and no significance for US investors. (Thomas et al., 2006) looks into the US investors portfolio in terms of the countries invested. The US investors portfolio found to have a higher excess return per unit of risk compared to the global benchmarks.

Income return constitutes only part of the investment return, the other part of it is the value gain ie. capital gain. How big is the share of value gains in total returns? As is shown earlier, the US net external balance benefits from the value gain significantly. Bureau of Economic Analysis calculates value gains under two categories, exchange rate changes and price changes. It has been argued especially exchange rate fluctuations has a significant contribution due the fact that most of the US foreign assets are denominated in foreign currency and the liabilities are in dollars (Forbes, 2010, Gourinchas and Rey, 2007a, Higgins et al., 2007, Tille, 2008). Contribution of currency fluctuations in to the return differentials has increased along with the scale of the foreign asset and liability positions.

So far there has not been a consensus about the contribution of the value gains in to the return differentials mostly because there has been measurement problems regarding the calculation of the value gains. There has been evidence towards consistent positive return differentials since as far as 1960's (Forbes, 2010, Gourinchas and Rey, 2007a, Meissner and Taylor, 2006) as well as no significant difference between the total return received (Curcuru et al., 2008).

Gourinchas and Rey (2007a) put together a quarterly international investment position dataset that targets the question if the US enjoys a special premium on its international investments for being a leading country in the international markets, or as they put it an " exorbitant privilege". They compute the quarterly total return on various categories of the US foreign asset and liability holdings and show that US assets received on average about 3% extra in real terms on assets relative to what it paid to the liabilities. Considering the different asset composition of US foreign investment

this difference does not look surprising. However, they show that this difference persists within each asset category as well and it to be largest when capital gains are included.

Hausmann and Sturzenegger (2007) and Meissner and Taylor (2006) estimate country specific yield privilege by defining the net investment income (NII) as a fraction on the net external asset (NFA). The yield privilege includes the excess return received on the foreign assets and the discount received on the return to the foreign-held assets. Formally,

$$NII = r^* NFA + [(r_A - r^*)A + (r^* - r_L)L] \tag{2.3}$$

where r^* is the average return in the world markets. Meissner and Taylor (2006) compares the exorbitant privilege of United Kingdom in the past and the exorbitant privilege of United States today. They estimates the average return as 2.3 % and the yield privilege as 0.5% of the GDP for US. They also show that this privilege is not unique to the hegemon and tends to decline as the investment portfolio becomes more leveraged. The paper by Hausmann and Sturzenegger (2007) follows the same definition. Assuming the rate of return and yield privilege constant, the change in NII over time is explained by the change in the NFA. Following Milesi-Ferretti and Lane (2008) (See also Milesi-Ferretti and Lane (2001b) and Milesi-Ferretti and Lane (2001a)), it is possible to model the change in NFA as follows [9]:

$$NFA_t - NFA_{t-1} = CA_t + KA_t + KG_t \tag{2.4}$$

$$\Delta NII = r^* CA_t + \alpha + \varepsilon \tag{2.5}$$

where CA, KA and KG shows the current account , capital account and capital gains respectively. So, the change in NII is decomposed into "typical yield" and yield privilege (α) and in a panel data setting the typical yield, r^*, as 5%. Using the typical

[9] Milesi-Ferretti and Lane (2001a) use B_t instead of NFA_t in their notation for net foreign asset position

yield, Hausmann and Sturzenegger (2007) derives the actual value of the US foreign investment and refers the difference between the measured and actual value as the dark matter.

Forbes (2007) discusses why foreigners still want to invest in the US assets despite the fact that the average return in US is less than the return from investing in the rest of the world. She finds that between the years 2002 and 2006 the US investors earned an average of 6.9% more abroad than the foreign investment made in US. When the exchange rate effect is discounted this difference becomes much less but still positive every year during the period. Her analysis shows that the effective, efficient and liquid market structure and strong institutions in US makes the US market attractive to the foreign investors.

Curcuru et al. (2008) shows that the total return calculations that uses implied capital gain (or value gain) are to be suspect because of internal inconsistency issues present in the revised data provided by the Bureau of Economic Analysis. This inconsistency originates from differences in the revisions made to the positions and the flows. Due to the difficulty in revisions the flow data is underestimated. They show that when the revised data is used the rate of return on international investment is overestimated mostly due to overestimation of the implied capital gains.

The result of the Curcuru et al. (2008) is also supported by the finding of Milesi-Ferretti and Lane (2008) where they conduct a similar analysis on the residual adjustment term which is the gap that completes the accounting between amount of total investment flow and the investment position after all the revision and valuation adjustments are done. They analyze the period from 1983 to 2006 in three sub-periods and find systematic pattern in the residual adjustment term which is attributable to the mismeasurement in the flows.

The next chapter is devoted to quantifying inherent biases and measurement errors in the BEA data discussed by Curcuru et al. (2008). We will estimate the rate of mismeasurement on the flows and look into the total returns using the corrected data. As Curcuru et al. (2008) is particularly addresses the overestimation in the work by

Gourinchas and Rey (2007a) we will use the quarterly net external position data that is constructed for that paper. The total return differentials calculated using the estimated value gains show that there is not a significant evidence on persistent positive differential since 1960's. It is also shown that the mismeasurement in capital flows could not be rejected. The results of the estimations using both datasets shows that the equity flows are underestimated. The results show that the actual flows are larger than the amount recorded.

2.3 The Role of Measurement Bias in Return Differentials

Every June, the Bureau of Economic Analysis(BEA) reports the preliminary estimations of year-end value of the US owned assets abroad and foreign owned assets in the US from the previous year. The details about the changes in positions from the previous year is also provided at the same time. These estimates for the most recent year is preliminary until the survey results come out.

The value that the assets were bought or sold is called the historical value. The value of these holdings does not stay constant and it has to be updated to get an accurate measure of the holdings. Quarterly balance of payments categories are recorded at the value of the transactions completed during that particular period. If the quarterly value changes can be estimated it could be possible to estimate quarterly assets and liabilities positions. The paper by Gourinchas and Rey (2007a) introduce a quarterly dataset that they put together this way and using the data they look into the differences between the return that US foreign assets receive and return that foreigners obtain investing in US including the income returns.

A naive way to estimate the US foreign asset and liabilities holdings would be to estimate the value gains and add it to the value of the holdings at the beginning of the period along with the new assets acquired. Formally,

$$\begin{aligned} IIP_t &= IIP_{t-1} + Flow_t + Val_t \\ &= (1 + kg_t)IIP_{t-1} + Flow_t \end{aligned} \tag{2.6}$$

Note that if the beginning and end of the period values, and the flows are known, this equation can be used to implicitly derive the annual rate of value gains. This definition, however, counts all the errors and omissions as a part of the capital gain. When the errors are negligible and random, the average value gain would not be affected by this generalization.

Curcuru et al. (2008) has shown that there is a systematic pattern in the error term due to the mismeasurement in the US investment flow abroad. They show that the foreign asset positions are usually under reported and receive a significant upward revision after the first publication. The revisions to liability positions however is not as big. Compared to investment positions data the flows receive a limited revision due to the difficulty in updating the past flows. They show that the difference in the scale of revisions to positions and flows tend to be interpreted as capital gain, and therefore the literature estimates that uses this *implicit capital gain* method are biased upwards.

This paper uses the *implicit capital gain* method taking the measurement problem into account. We show that the measurement bias is significantly different than zero. When the bias is taken into account the sizable return differential shown in the data by Gourinchas and Rey (2007a) disappears from 1975-2000. However, from 2000 onwards the return differential is significantly positive.

2.4 Calculating the Total Return Differentials

2.4.1 Estimating the Capital Gain on Foreign Asset and Liability Position

According to the Balance Payments and International Investment Position Manual (IMF, 2010) the foreign investment can be divided into four functional categories (five

for assets, reserves as the fifth category). These categories are direct investment, portfolio investment, financial derivatives and others. The portfolio investment includes equity and debt securities that are not included into any other categories. Estimating quarterly returns is challenging because it requires to estimate the quarterly value gains as well as the income gains that will match the end of period positions. Note that these returns also should be estimated for each functional category listed.

The foreign equity and debt portfolio of the US is involved many different countries, currencies and asset types. This diversity is one of the main difficulties in estimating the returns. While estimating the equity returns, Gourinchas and Rey (2007a) calculates the country weights which covers about 75% of the US equity portfolio in 2000. This coverage in debt equity portfolio goes up to 80% and 99% for long-term and short-term debt, respectively.

Similarly the calculations by Curcuru et al. (2008) covers 84% of the US equity portfolio and 80% of the US long-term debt portfolio in 2004. They do not take short-term debts into account which constitutes about 25% of US debt investment. In order to estimate the US foreign bond investment return, however, they pay attention to the currency composition differences between the developed and developing country debts as well as the weights of the different type of bonds (like treasury, agency and corporate bonds) foreigners holdings. The paper by (Thomas et al., 2006) show that US foreign investment portfolio actually beats the global benchmark indices, due to the differences in the portfolio compositions. So, simply using global indices might lead to different conclusions. The final total returns are calculated as the weighted average of related return indices that will mimic the US and foreign portfolio investment choices. As a result of their calculations, they reject the exorbitant privilege argument, and show that US does not always had a big positive gain in every asset category.

Why can't we simply take the change in the value of the position that cannot be explained by the new flows? As is mentioned earlier, every year in June, Bureau of Economics Analysis (BEA) publishes the preliminary values of the US assets abroad and foreign held assets as a part of the U.S. Net International Investment Position

at Yearend Report. Over the years, these estimations are updated based on the US cross-border holdings surveys published by Treasury International Capital system. The cross-border holdings surveys used to be conducted irregularly about every 4 to 5 years in the past for both international assets and liabilities and it has become regular after 2003 (Bertaut et al., 2007). Using the survey results, the old asset and liability positions are updated and posted as revised positions. The paper by Curcuru et al. (2008) shows that the preliminary estimations of the portfolio investment are undermeasured and significantly revised upwards after the surveys over the years. The table 2.3 is taken from that paper. It shows the average rate of revisions as a percentage of the intial position between 1990 and 2005.

Table 2.3: Pattern of Revisions in BEA's IIP Data

	Revisions-to		
		End-of-year Positions	Flows
Assets	Bond	24.6	3.6
	Direct Inv.	4.4	0.9
	Equity	46.3	1.2
	Total	10.3	1.0
Liab.	Bond	-8.4	-1.0
	Direct Inv	0.6	1.2
	Equity	4.8	-0.0
	Total	1.4	0.6

Note: These values are taken from Curcuru et al. (2008), table V, pp. 1513. Revisions to end-of-year position is the difference between the revised position as reported by BEA as of July 2007 and the end-of-year position as reported in the rightmost column of Table 1 of each original release of international investment position. Revisions to flows is the difference between flows reported in July 2007 vintage of the balance of payments and the original flows reported in column(a) of Table 1 in each original release of international investment position. All differences are reported as percent of the original beginning of the year position. Averages from 1990 through 2005 are reported.

First, note that the position data revised significantly but the flow data is not. For example, the average revision to the equity and debt assets were about 46% and 24%,

respectively. The average revision in equity and debt flows, however, were about 1% and 3%. Second, average rate of revisions in US investments abroad (assets) are much larger compared to the revision in foreign investment in US (liabilities). So, liability records are kept more strictly compared to the assets. Third pattern we observe in the table is that the revisions in equity investment categories are larger than the revisions in the debt categories.

Could it be that the flows do not require any revision? Technically, if the flow data is not complete than the balance of payments should not add up to zero. When the sum of all balance of payments accounts is not zero, the difference is added to "statistical discrepancy" which includes all the errors and omissions during the period. The article in Survey of Current Business by Landefeld and Lawson (1991) mentions that in 1980s large differences observed between the current account and the capital account (which used to include the financial account) continuously and that is attributed to the incomplete measure of flows. Therefore, new measures were suggested in 1992 to capture the international transactions better.

Another data that reports errors and omissions in the position data is published under the "Changes in Position" . The data presents the estimated total value adjustments divided in 3 categories; exchange rate adjustments, price adjustments and other adjustments. The errors and unexplained financial transactions are added to the other adjustments. However, the random nature of these errors are under question. When explaining the annual revisions Bach (2005) mentions about "incomplete coverage" in long-term bond transactions, which is accepted in the a report by the US Treasury Department [10] as the source of difference between surveys and the estimated positions. The paper by Milesi-Ferretti and Lane (2009) analyzes the other valuations data published by the BEA and found out that there is a systematic pattern, which can be partially attributed to the underestimation of flow data. The paper by Curcuru et al. (2008) argues that these misplaced inflows in valuation adjustments causes the significantly large capital gains especially in equity and debt investments.

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[10] *Report on U.S. Portfolio Holdings of Foreign Securities as of December 31, 2003* (2005)

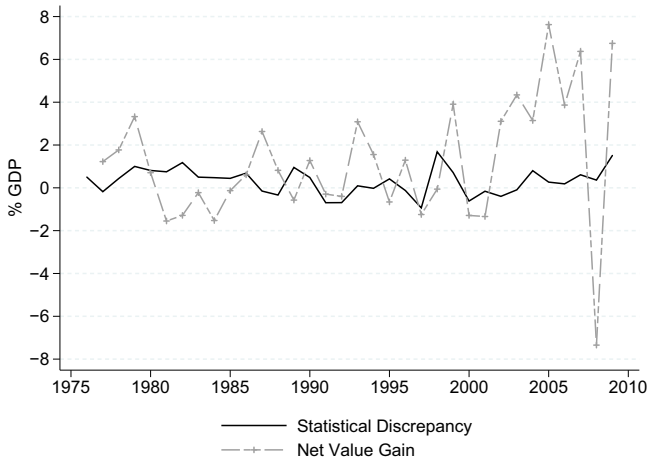
The statistical discrepency (SD) is usually kept away from the formal accounting equation, however the sum of current account, capital account and financial account hardly is equal to zero. If the flows are mismeasured would this be reflected to the SD in the balance of payments accounts? The sample correlation between the SD and the net value gain (NVG) in dollars for the period 1976-2009 is calculated as 0.35. Formally, SD and NVG is defined as:

$$CA_t + CapA_t + FA_t = -SD \tag{2.7}$$

$$NIIP_t - NIIP_{t-1} - FA = NVG \tag{2.8}$$

The figure 2.8 shows the annual SD published within balance of payments and compares it to the net value gain as percent GDP. Note that the NVG in the figure reflect both the systematic mismeasurement as well as the value gains received during the period. In fact in figure 2.2 the contribution of value gains can be observed in this figure as well. Especially for the periods 1980-85 and 2002-2007 the big divergence between the two series can be attributed to the value gains.

Figure 2.8: Net Value Gain and Statistical Discrepancy



Source: BEA international Transactions and international investment position.
Note: The Net Value Gain is the difference between the implicit capital gain on assets and implicit capital gain on liabilities. Statistical discrepancy is the amount that completes the sum of current account, capital account and financial account to zero.

Is it possible to estimate the weight of the mismeasurement in the net value gain? The argument is that the implicit value gain estimations are biased because it includes part of the flows that could not be captured during the revisions. A simple regression is not enough to capture the mismeasurement as well estimate the capital gains. The value gains are unobserved however we know that it is explained by price and exchange rate fluctuations. So, it is possible to model the capital gain as a latent variable and distinguish it from the usual errors and omissions.

2.4.2 Model and Data:

The general dynamic evolution of investment position is defined in equation 2.6 above. That model will be modified according to what we have been discussing so far, the observed flows are different then the actual flows. The equation below defines the actual investment positions (IIP) accumulation over time;

$$IIP_t = IIP_{t-1} + Flow_t + Val_t \tag{2.9}$$

where Val_t is the total value gain in period t and $Flow_t$ is the *actual net flows* during period t. Note that IIP, can be any foreign asset or liability category (i.e. equity, debt, direct investment or aggregate). We add the assumptions that the flows published, (FL_t), is a fraction of the true flows $(Flow_t)$.

$$Flow_t = \beta FL_t \tag{2.10}$$

The coefficient, β is a multiplier that shows the ratio between mismeasured flows and the actual flows. In the previous, section table 2.3 shows that the revisions to total foreign assets is about 10% whereas the revisions to total foreign asset flows is 1% . If the observed flows are less than the actual flows than β should be greater than one to the extent the flows are mismeasured (undermeasured) . If the observed flows are more than the actual (overestimation) than β should be less than one.

Combining the equations 2.9 and 2.10 above, taking the first difference and dividing by the previous period's position yields equation 2.12 which is the measurement equation of Kalman filter.

$$IIP_t = IIP_{t-1} + \beta FL_t + Val_t \tag{2.11}$$

$$iip_t = \beta fl_t + kg_t \tag{2.12}$$

The variable, iip_t, is the percentage change in international investment position from the previous period. The variable, fl_t shows the flow of investment received during the period to the previous position holdings, and kg_t is the ratio of the dollar value gain to the previous period investment position, i.e unobserved capital gain.

The capital gain captures the value changes in the current holdings over the period t, related to changes in market value or current value in dollar if denominated another currency. The measurement equation of the latent state variable, capital gain, will be defined as a linear function of the change in exchange rate, exr_t, and the return from the previous period. Formally,

$$kg_t = \alpha_1 + \alpha_2 exr_t + \alpha_3 kg_{t-1} + \nu_t \tag{2.13}$$

The coefficient α_1 is the average capital gain over the period without taking the exchange rate changes into account, α_2 shows the the effect of exchange rate changes on the capital gain, which is expected to be negative for US foreign assets, since a dollar depreciation would contribute to the dollar value of a foreign currency denominated investment. I used the Federal Reserve Bank Major Currency Index, which shows the weighted value of one US dollar against a set of country currencies, which are major trading partners of US.

In order to estimate the latent state, kg_t, Kalman filter will be used and the likelihood function generated by the filter will help to estimate the system parameters. The set of the parameters to be estimated are summarized as $\Theta = \{\alpha_1, \alpha_2, \alpha_3, \beta, \sigma_\nu\}$.

Note that, kg_t is the implicit capital gain without any bias related to the incomplete transaction flows, it will however include the general random errors and omissions. The parameter, σ_ν is the standard deviation of the error term, which is part of kg_t that is not explained by the exchange rate .

The mismeasurement argument will be tested using two different datasets. The first one is the quarterly net foreign asset position that Gourinchas and Rey (2007a) constructed where among other sources the revised international investment position is used as well. Curcuru et al. (2008) show that calculating the implicit capital gain estimations using this data yield unreasonably large numbers for equity and debt since it includes the unmeasured flows.

The second dataset is monthly estimates of US Cross-Border securities position data put together by Bertaut and Tryon (Bertaut et al., 2007). The second dataset reports the monthly US held equity and bond securities abroad as well as foreign-held US bond and equity securities in the US. This is a very detailed dataset that provides the cross-country investment positions and flows for each country. It also provides the bond liabilities by security level, namely treasury, agency and corporate bonds. This paper will estimate the capital gain for the aggregate debt and equity positions over the countries (country code is 69995, All Countries).

The second data is similar to the first data in the sense that the flows are published more frequently (monthly) than the positions (annually) and hence the authors estimate the value gain and possible errors and adjustments to obtain the position estimates in a given period.The difference of second data by Bertaut et al. (2007) is that they take into account the fact that the along with other things flows are systematically mismeasured, incorparate that into their calculations. These systematic differences other than value gains are gathered under "the gap", which is attributed to the fact that some of the transactions that shows up in position surveys are not captured in cross-border flows. The paper by Gourinchas and Rey (2007a) also mentions about this discrepancy, in their exercises these differences are added to third and fourth quarter value gains calculated. Chapter 4, explains the differences in bigger detail.

Results:

Table 2.4, below presents β coefficient estimates for the separate categories, using quarterly data by Gourinchas and Rey (2007a) (henceforth, GR data).

Table 2.4: Mismeasurement in flows: β

	Total	Debt	Equity
Assets	1.091*	1.398*	2.468*
	(0.30)	(0.10)	(0.39)
Liabilities	1.077*	1.295*	2.455*
	(0.21)	(0.14)	(0.54)

Source: Quarterly U.S Foreign Asset and Liability Position, 1973:1-2004:1, Gourinchas and Rey (2007a) .
Note: The first 7 years are burnt during the estimation. Hence, coefficients represent the period 1980:I-2004:I. Standard errors are reported under each coefficient in parenthesis. Star (*) shows significance at 10% level.

As expected, the β values are significantly larger than one for the equity and debt investment categories. The coefficient of the equity investments in general are larger than the debt category, which shows a the scale of mismeasurement is bigger in equity investments.

The table 2.5 below presents rest of the system coefficients as well as the standard deviation of the error term. Last row reports the corresponding natural logarithm of likelihood values. The first coefficient, α_1 shows the average rate of capital gain controlling for exchange rate changes. In all of the investment categories it is not significantly different than zero, except the debt liability categories. This shows foreigner investors bond holdings lost during this period on average about -1.6% in quarterly basis which is about 6% loss in annual terms. Although not significantly different than zero, the US bond holdings had a capital gain close to zero. Similarly, without exchange rate contribution average equity asset gain is less than the gain on equity liability, 0.8% and 1.3%, respectively.

The second coefficient, α_2, shows the effect of exchange rate on the rate of capital gain. It is estimated significantly negative in all US foreign asset categories. As

Table 2.5: Estimated Coefficients

	Liability			Asset		
	Debt	Equity	Total	Debt	Equity	Total
	(1)	(2)	(3)	(4)	(5)	(6)
α_1	-1.167*	1.336	0.626	0.024	0.793	0.964
	(0.66)	(1.05)	(0.63)	(0.37)	(1.19)	(0.69)
α_2	-0.21*	-0.125	-0.079	-0.562*	-0.924*	-0.214*
	(0.11)	(0.27)	(0.08)	(0.1)	(0.27)	(0.12)
α_3	-0.103	0.053	-0.022	-0.156*	-0.042	-0.112
	(0.1)	(0.1)	(0.1)	(0.09)	(0.1)	(0.1)
σ_ν	3.228*	8.37*	2.644*	2.917*	8.375*	3.615*
	(0.23)	(0.6)	(0.19)	(0.21)	(0.6)	(0.26)
logLikelihood	-251.29	-343.72	-231.94	-241.49	-343.76	-262.29

Source: Quarterly U.S Foreign Asset and Liability Position, 1973:1-2004:1, Gourinchas and Rey (2007a) .
Note: The first 7 years are burnt during the estimation. Hence, coefficients represent the period 1980:I-2004:I. Standard errors are reported under each coefficient in parenthesis. Star (*) shows significance at 10% level.

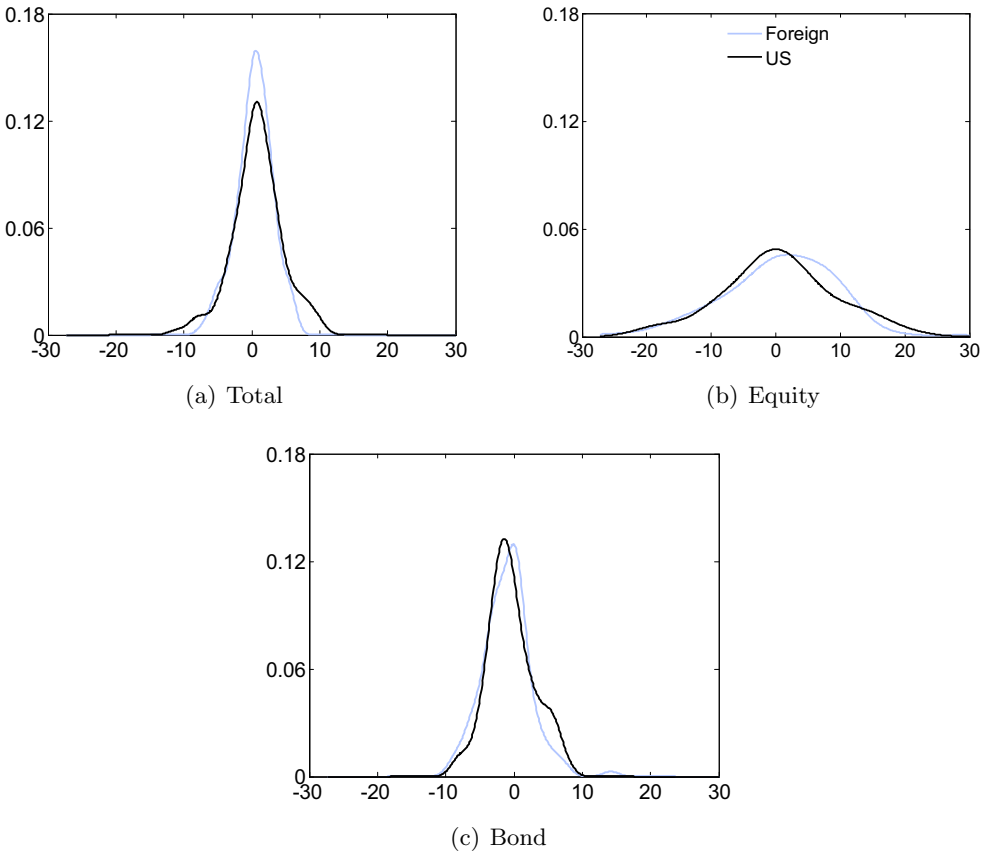
expected, a depreciation of dollar against other currencies, improves US foreign investment position denominated in foreign currencies in dollar terms. The US long-term foreign debt holdings are denominated almost all in dollars, if the country is a developing country, for a developed country it depends on th country. For example, most of the European countries borrow in euro, ie, half of the European long term debt holdings of US is denominated in Euro. This could be the reason for the low value of the estimated α_2 value of the debt assets compared to the equity assets which are mostly denominated in foreign currency.

In the US liabilities side, only the coefficient of debt liabilities are estimated significantly negative . About 15% of the US commercial debt (liability) is denominated in foreign currency. Also, the paper, Jorion (1991) finds significant negative correlation between the exchange rate and the long term government excess returns, and no significant relationship between stock market and exchange rate. This relationship is explained trough the relationship between interest rate and exchange rate.

Finally, the last coefficient α_3 which looks into persistence in returns, is not significantly different than zero except for the debt assets that US owned abroad. The

estimated standard deviations are significantly greater than zero. The volatility of the rate of capital gains are estimated to be the largest in equity investment category.

Figure 2.9: Rate of Capital Gains: 1980:1-2004:1



(a) Total

(b) Equity

(c) Bond

Note: Smoothed estimates are presented

Before looking into the average rate of gains, it would be useful to look at the histograms. The figure 2.9 shows the distribution of estimated implied capital gains, kg_t, for different investment categories. One common observation about the capital gains on US foreign holdings is that they have thicker tails. The distributions are centered close to zero. Large and positive returns has a bigger share on the distributions of US asset holdings, which is more clear in Equity and Bond categories.

The table 2.6 compares the averages of the estimated capital gain with the implied capital gains for the period 1980:I-2003:I. The reported values reflect the annualized nominal rates. The quarterly rates are annualized by continuously compounding. The

Table 2.6: Annualized Average Quarterly Returns, 1980:I-2003:IV

	Asset	Liability	Difference
Bond			
Implied Gain	4.12	0.66	3.46
Estimated Gain	0.93	-3.51	4.44
Equity			
Implied Gain	21.78	17.60	4.18
Estimated Gain	8.41	10.21	-1.80
Total			
Implied Gain	5.02	3.76	1.26
Estimated Gain	4.40	2.93	1.47

Source: Gourinchas and Rey (2007a) Quarterly US Foreign Asset and Liability Position. The implied capital gain is calculated by dividing the difference between change in position and flows by the previous years' position.

implied capital gains are larger than the estimated capital gains in every investment category. The biggest difference is in equity liability category. Simple implied capital gain estimates the rate of gain as 17% whereas the average estimated capital gain is 10.2%.

The implied capital gains suggest that the difference between the asset and liability return is consistently positive in every investment category. The asset and liability implied gain difference is positive and persistent even if the period is restricted to 1990:I -2003:IV period. The estimated capital gain is however do not show persistent positive returns between assets and liabilities, since the mismeasurement in flows are taken into account. In fact the average US equity return is lower during the period compared to the returns on equity liabilities.

Next, we will do the same analysis using a higher frequency, monthly data, put together by Bertaut et al. (2007) (BT data, here after). The monthly bilateral portfolio investment transactions are aggregated over all foreign countries. This data is restricted to portfolio transactions, in other words it will only presents the results for the equity and bond (debt) investments. The bond liabilities are available in agency, corporate and treasury categories. The total category will represents the sum of all these positions

and transactions.

The table 2.7 below shows the mismeasurement in the flows for monthly transactions, β. The equity coefficients both for asset and liability categories are significantly different than one. So, the equity transactions are significantly undermeasured. There is, however, no significant evidence of undermeasurement for bond transactions. The coefficient on total debt 0.63 suggest that the measured flows more than the actual flows at monthly levels.

The paper, Bertaut et al. (2007), carefully tabulates the adjusted flows, the change in the monthly position estimates and their valuation adjustment estimates. The flows are adjusted since there are transactions that are known to be not included into the transactions accounting, for example repayment of principle amount in asset backed securities or the transaction of non-marketable treasury bonds. Observed bond flows, FL_t, that is used in this exercise is the adjusted flows.

Table 2.7: Mismeasurement in flows- β

		Asset	Liability
Equity		2.12*	2.84*
		(0.68)	(0.71)
Bond		0.99*	0.63*
		(0.15)	(0.13)
	Agency		0.85*
			(0.07)
	Corporate		1.12*
			(0.13)
	Treasury		0.70*
			(0.09)

Source:Bertaut et al. (2007), Monthly Estimates of U.S Cross Border Security Position. US foreign liabilities and foreign assets, monthly 1998:1-2008:12
Note:Standard deviations are reported under each coefficient in parenthesis. Star (*) shows significance at 10% level..

The reason that triggered the return differential literature is that the accumulated flows fell short of explaining the observed value of the positions. In the BT data, however the debt inflows in all categories are consistently larger than the total change in the positions. So, the "GAP" in treasury, agency and corporate debt liabilities are shown

to be less than zero. This is not true for equity liabilities, US holding of foreign debt as well as the equity. So, this suggest that the adjusted debt inflows are overestimated and it shows up in the gap category.

The rest of the coefficients from that estimation are presented in the table 2.8 below. Average rate of capital gains controlling for the exchange rate changes is negative and significant for the bond liabilities. The US bond holdings received on average about 0.3% monthly without taking the exchange rate changes into account, which corresponds to about 3.6% annually. The total bond holdings of foreigners received a lower rate of 0.16%. Although insignificant, the average rate controlling exchange rate is larger for equities assets than that of equity liabilities during the period of 1998-2008.

Table 2.8: Estimated Coefficients: 1998-2008

	Liability					Asset	
	Bond				Equity	Bond	Equity
	Agency	Corp.	Treas.	Total			
α_1	-0.242*	-0.391*	0.04	0.168	-0.631	0.304*	-0.038
	(0.13)	(0.21)	(0.14)	(0.2)	(0.49)	(0.1)	(0.29)
α_2	-0.074	-0.189*	-0.065	-0.15*	-0.609*	-0.633*	-0.886*
	(0.06)	(0.07)	(0.07)	(0.06)	(0.22)	(0.15)	(0.46)
α_3	0.299*	0.133	0.075	0.042	0.086	0.021	0.134
	(0.1)	(0.09)	(0.09)	(0.09)	(0.08)	(0.1)	(0.25)
σ_ν	1.137*	1.287*	1.337*	1.127*	4.287*	1.658*	4.783*
	(0.07)	(0.08)	(0.08)	(0.07)	(0.26)	(0.09)	(0.09)
logLikelihood	204.28	220.65	225.68	203.08	379.42	254.06	393.88

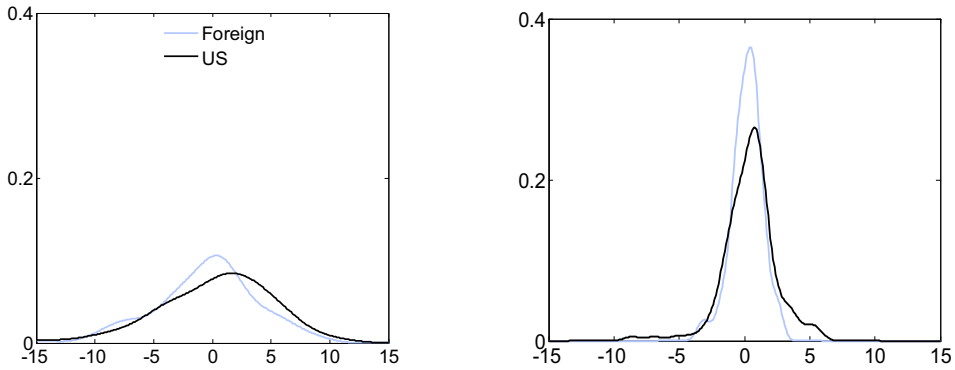
Source: Star (*) shows significance at 10% level.

The effect of exchange rate is significant in corporate bond holdings of foreign investors. According to this results a depreciation of the US dollar benefits the foreign investor in US. The previous estimation using GR data yields a similar significantly negative coefficient for bond liabilities. Approximately, one fifth of the corporate debt liabilities is denominated in Euro [11]. The size of the coefficient much smaller compared to the one estimated in asset category. Especially, the effect of change in exchange rate is close to one as is also estimated using the other dataset.

[11] See *Report on Foreign Portfolio Holdings of U.S. Securities as of June 30, 2008* (2009)

The coefficient α_3 shows the correlation between the current return and it first lag. We only see a significant persistence in agency bond. The volatility of the capital gain is estimated as expected with the highest values in equity investment category. Equity assets particularly have the highest volatility among the others. These values are consistent with the Curcuru et al. (2010) estimations. For the period January 1994 to December 2007 they estimated the volatility of the US investors foreign equity return and foreign investors equity return in US as 4.19% and 4.11% in monthly terms.

Figure 2.10: Rate of Capital Gains: 1998:1-2004:1



(a) Equity (b) Bond

Note: Smoothed estimates of the monthly rate of capital gains are presented

The figures 2.10 above compares the distributions of estimated equity and debt returns for asset (US) and liability(Foreign) positions. The total bond liability return is constructed aggregating the capital gain on treasury, corporate, and agency bonds. The US equity return is skewed to the left. The positive tail is thicker than the positive tail of equity liabilities. Return on bond liabilities has similarly thicker tails like in the GR data.

The next table 2.9 shows the average rates for implied gains and estimated capital gains. Different than previous table, the valuate gain estimates of Bertaut et al. (2007) also added to the table. In order to estimate the valuation changes they use various price indices like EMBI+ for local currency bond assets or US equity price index for equity liabilities. The valuation changes are reported in terms of dollars. These valuation changes to the previous period positions ratio are reported under “Value Changes”.

Table 2.9: Annualized Average Monthly Returns, 1998:1-2008:12

	Asset	Liability	Difference
Bond			
Implied Gain	4.77	-3.55	8.59
Estimated Gain	4.79	2.36	2.38
Value Changes	0.23	-0.08	0.31
Equity			
Implied Gain	5.53	3.11	2.35
Estimated Gain	1.03	-7.03	8.61
Value Changes	1.88	1.01	0.86

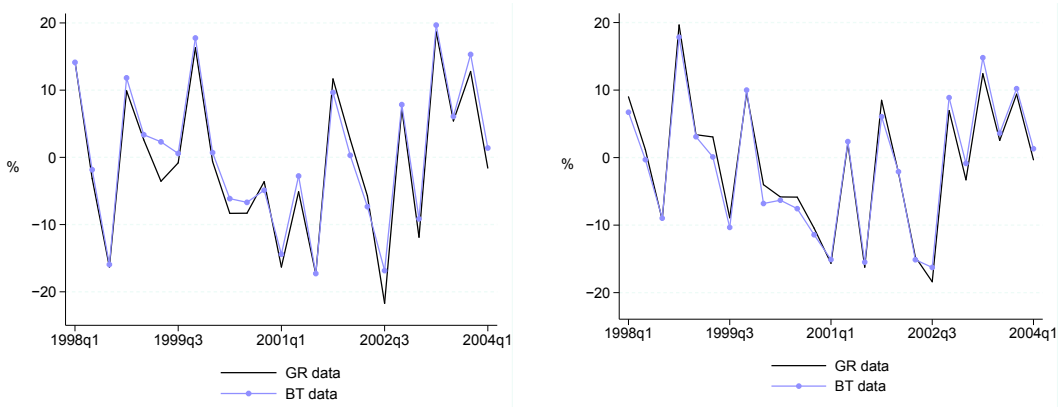
Source: Estimated rate of capital gains and implied capital gain between the years 1998:I and 2004:I using Bertaut et al. (2007). Annualized averages are reported.

For the US bond holdings the value change is 0.23% and the US equity holdings the rate is 1.88%. This paper, however estimates the gain as 4.8% on bond assets and about 1% for equity assets. For liabilities, the value change calculations found the rate very close to zero for bonds and about 1% for equities. The estimated capital gain, however, suggests that the equity return was about -7% during the same period, and the debt return was about 2.4%. So, there is a significant difference and no clear pattern between the three different capital gain calculations. One common result in all three of them is that the return on asset categories were larger than the return on liabilities.

The annual averages found from each dataset was different however the estimated quarterly rates are quite similar, especially for the equity asset and liabilities. The graphs below compare the estimated quarterly capital gains from GR data and BT data separately. BT data estimated monthly capital gains are continuously compounded to obtain quarterly returns.

The first set, figure 2.11 shows quarterly equity returns on asset and liability categories. The estimations in both graphs are almost identical having a correlation of 0.99 for both equity assets and liabilities. In equity, the difference in average rates is originated from one or two quarters that each data predict differently. These small differences when annualized can result in big differences in averages. The figure 2.12

Figure 2.11: Estimated Value Gains - Equity

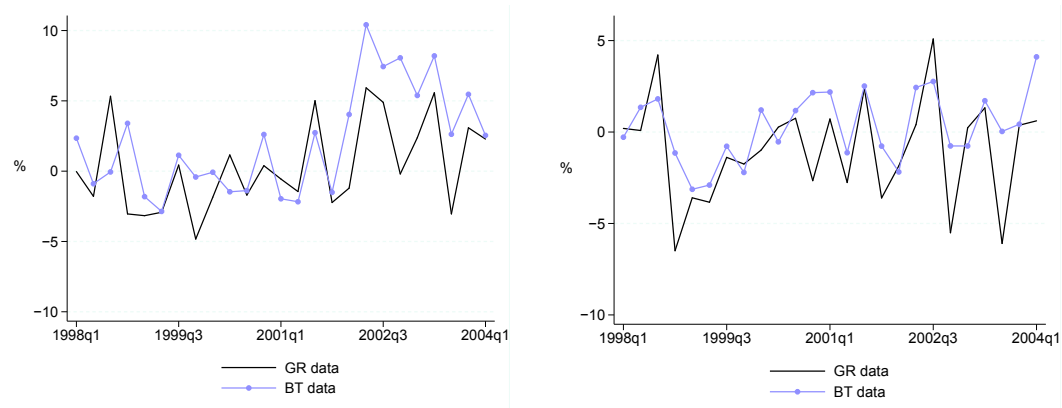


(a) Equity Asset (b) Equity Liabilities

Note: Quarterly estimated rates, 1998:1-2004:1. Only includes value gains, does not represent the income returns.

does the same type of comparison for debt investment return. Unlike the capital gains in equity investment we observe significant differences between the BT data estimations and GR data estimation.

Figure 2.12: Estimated Value Gains - Debt



(a) Debt Asset (b) Debt Liabilities

Note: Quarterly estimated rates, 1998:1-2004:1. Only includes value gains, does not represent the income returns.

We should note that the underlying debt asset categories included in each data is different in the sense that the BT data is only restricted to long-term portfolio debt. GR, however, includes the official holdings as well as the short term bonds for the value

gain estimations. For the value gain calculations the short term bonds are assumed to be a quarter of the bond positions. No valuation adjustment was made for the shot term holdings. This difference, however, is especially reflected to the variation in the estimated series.

The equity investment is a better way to compare the two datasets since the asset type covered is pretty similar. Also, the value gain estimation is more straightforward in the sense that it is a weighted average of the stock market return indices from the countries invested. To the extent that the country coverages match the equity returns are expected to be similar. This expectation includes the total return estimations of the Curcuru et al. (2008), where they chose the weights using bi-lateral portfolio holdings. The graph that compares estimated capital gains for equity asset and liabilities for GR data, BT data and the total return computed by CDW data will be provided in the Appendix.

2.5 Returns Differential:

The main motivation of this paper was to estimate the capital gains which is a controversial part of the positive return differentials discussions. The estimation that we presented above took the mismeasurement in investment flows into account and calculated the capital gains under that assumption. The table 2.10 presents the capital gains on equity investment for both assets and liabilities.

In GR data, the difference in returns is not consistently positive every year, however there average difference between the years 1998-2004 is close to zero. The data on the first quarter of 2004 is not included (annualized one quarter suggests that the difference for 2004 was 17%) since the rest of the data is calculated continuously compounding the quarterly rates. In the previous section we have seen that the quarterly capital gains estimations for equity category is similar. This similarity persist when the rates are annualized.The difference in BT data however much more sizable compared to the difference in estimation by GR data. In fact for the same period, 1998-2003 BT data suggests that the average return differential was 1.53%.

Table 2.10: Equity Investment 1998-2008

	GR data			BT data		
	Asset	Liability	Difference	Asset	Liability	Difference
1998	0.45	4.62	-4.17	1.3	3.36	-2.06
1999	3.37	1.55	1.82	5.79	0.44	5.35
2000	-5.27	-6.56	1.29	-4.3	-8.05	3.75
2001	-7.48	-5.94	-1.55	-6.79	-6.05	-0.74
2002	-5.05	-7.64	2.58	-4.45	-6.70	2.25
2003	5.60	5.09	0.51	7.39	6.77	0.62
2004				3.42	1.28	2.14
2005				4.12	-0.73	4.85
2006				5.06	0.26	4.8
2007				3.70	-1.12	4.82
2008				-14.57	-11.14	-3.43

Source: GR data, Gourinchas and Rey (2007a). BT data, Bertaut et al. (2007). The rates are obtained by continuously compounding the quarterly and monthly estimations.

After 2003 until the end of 2007, the difference in asset and liability gains is large. So, US asset holdings actually received significantly larger return difference in foreign investment. This is the period the US dollar depreciated significantly. The trade weighted exchange index show that from the beginning of the 2003 to the end of 2007 dollar lost about 17 % of its value.

Table 2.11: Debt Investment
Estimated Capital Gain: 1998-2004

	GR data			BT data		
	Asset	Liability	Difference	Asset	Liability	Difference
1998	0.07	-0.57	0.64	1.18	0.43	0.76
1999	-2.64	-2.65	0.01	-1.00	-2.26	1.26
2000	-0.51	-0.67	0.15	-0.09	0.99	-1.09
2001	0.15	-0.85	1.00	-0.75	0.69	-1.43
2002	2.31	-0.54	2.85	7.46	0.54	6.92
2003	1.95	-1.09	3.04	5.40	0.35	5.05
2004				1.27	1.26	0.01
2005				-0.36	0.67	-1.03
2006				2.38	2.26	0.12
2007				2.59	1.94	0.65
2008				-5.25	-0.59	-4.66

Source: GR data, Gourinchas and Rey (2007a). BT data, Bertaut et al. (2007). The rates are obtained by continuously compounding the quarterly and monthly estimations.

The picture is different in the debt investment side. Annual rates are less consistent

between the two datasets. The GR data shows that the difference has always been positive. Even during the period of crises like 2001 and 2002, the US foreign holdings received higher returns. The BT data suggests that the long-term portfolio debt return was significantly large for those years. The effect of dollar depreciation from 2004 to 2007 is not present in the differences

2.6 Concluding Remarks

This paper is focused on the capital gain estimations using two different datasets. The most commonly used method, implicit capital gain has shown to estimate the asset returns excessively large compared to the liability returns. As a result, the return differential estimated using this method are biased upwards and incorrectly leads to the conclusion that US asset returns are larger than then US liability returns.

Our estimations show statistical evidence on the incomplete measurement of financial transactions, which is more significantly present and larger in the equity investment compared to the debt investment.

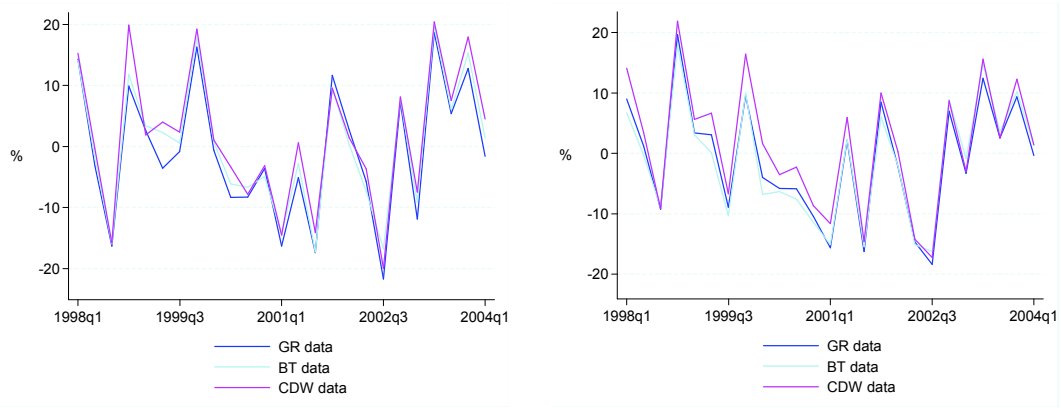
The US foreign investments are significantly affected from the dollar fluctuations. Due to the foreign currency denominated US foreign equity investment, the dollar depreciation after 2003, added on the average about 4% extra on the returns. It was however less effective on long-term debt holdings.

The implied capital gain versus estimated capital gains comparisons showed that implied gain which is the difference between the change in the positions and the flows, was over estimating the returns. Taking the misplace flows out of the value gains, decreased the capital gains to the rates suggested by Curcuru et al. (2008). In fact, the estimated capital gains on equity assets become more comparable to their monthly portfolio return estimates.

Appendix

This appendix presents quarterly capital gains for equity investment for the period 1998 to 2004. The figures below show the capital gain estimates using BT data and GR data presented in the paper, as well as the monthly weighted portfolio investment returns constructed by Curcuru et al. (2008).

Figure 2.13: Value Gains on Equity in the Literature



(a) Equity Asset (b) Equity Liabilities

Note: Quarterly rates from 3 datasets, 1998:1-2004:1. GR data and BT data shows estimated value gains, CDW data shows the weighted averages of the total return indices constructed by Curcuru et al. (2008). For BT data nad CDW data the monthly rates are continuously compunded to obtain quarterly rates.

Except a handful of quarters we see that quarterly returns are very similar in the asset category. In liability investment CDW data returns are closer to BT data returns. First of all CDW returns uses the monthly bilateral positions in the BT data to calculate the country weights in US and foreign portfolios. In addition to that, the liability returns weights also take into account the preference of foreign investors between treasury, agency and corporate bonds. Note that the estimated capital gain on BT data is different than the authors value gain estimates when constructing the monthly portfolio holdings data. For details please go to table 3.7.

Chapter 3

Estimating Capital Gains using data at Multiple Frequencies

The rest of the world has been generously lending to the US over the last decade and the US keeps borrowing more, despite accumulating net liabilities that have reached to 20% of its GDP as of 2009. Is it the relatively high return that motivates the foreign investors? Studies that look into the returns on US foreign assets and the foreign liabilities find that rate return on US foreign investment is larger. Various questions came along with that observation:

Does the US receive a special premium when investing abroad and a special discount for borrowing from the rest of the world since the US dollar is the international reserve currency (Gourinchas and Rey, 2007a, Meissner and Taylor, 2006)? Could this excess return help sustain future current account deficits (Eichengreen, 2004, Krugman, 2007, Obstfeld and Rogoff, 2005)? If the US receives a higher rate per unit risk investing abroad, then why do people invest in the US (Forbes, 2010)?

In chapter 2, two different, previously constructed datasets are used to estimate the widely discussed undermeasurement of international transactions (Bach, 2005, Curcuru et al., 2008, Gros, 2006a,b). These estimation results suggest that equity flows are undermeasured, and the actual flows are significantly larger than the observed flows. The evidence for debt liabilities depends on the dataset used. Overall, when the mismeasurement is taken into account the consecutive large positive return differentials are only pronounceable for the period after 2004,during which time the US dollar lost about 15% in the weighted major currencies index.

In this paper we estimate the quarterly asset and liability positions along with the rate of returns on those estimated positions. The paper is similar to Bertaut et

al. (2007), Gourinchas and Rey (2007b), and Gourinchas and Rey (2007a) in using a higher frequency transactions data to estimate the asset and liability positions at that frequency. The common target is to construct US international positions and extracting information on the value gains. Unlike these papers, however, this paper uses international positions and transactions data, and estimates the quarterly value gains using a model that takes the mismeasurement in the transactions data into account as well as the international positions. We find significant evidence on undermeasurement of asset flows. Once that is taken into account the average return differential decreases to 1.25% for the period of 1985 to 2008, which is almost half of the amount found in the literature.

Section one will discuss the models and methodology applied in the two papers by Bertaut et al. (2007), and Gourinchas and Rey (2007a). Section two introduces our model. Section three presents the results and section four concludes.

3.1 Estimating Quarterly Investment Positions

Every July, the Bureau of Economics Analysis (BEA) publishes preliminary estimations of US assets abroad and foreign held assets in the US under the International Investment Position (IIP) category. These positions are revised as more information through the cross-border holdings surveys are released. The international transactions data, however, is published at the end of every quarter.

The paper by Gourinchas and Rey (2007a), uses both BEA and Federal Reserve Flow of Funds data for positions and BEAs U.S. International Transactions data for flows. They use this data to estimates various categories of quarterly investment positions. Specifically, the international investment positions are separated into four functional categories, direct investment, equity investment, debt investment and other investment categories. Accumulation of each of these categories is modeled in the following way:

$$PX_t = PX_{t-1} + FX_t + r_t^x PX_{t-1} \tag{3.1}$$

where PX_t is the market value of the foreign investment position (US or Foreign), FX_t

is the net flows during the quarter and r_t^x is the estimated dollar capital gain for the given category, which is unknown. The fourth quarter position estimates are matched to the IIP end of year position estimates. The difference is added to the value gain adjustments of the last two quarters.

The capital gain, r_t^x, is calculated using various return indices related to the investment categories and countries, these indices were averaged using the country weights in the US portfolio. Since these returns are calculated in dollar terms, the currency denomination of each category is also taken into account.

There are two underlying assumptions which are later shown to be not reliable in these position estimates. First, the flow data, FX_t, does not reflect the actual amount of flows, and second, the discrepancy that appears between the estimated position and the IIP publications are related to this mismeasurement rather than the estimation mistakes in valuation adjustments. Therefore the return estimations are significantly biased upwards, which leads to a 3% extra return differential between assets and liabilities (Curcuru et al., 2008).

The other paper by Bertaut et al. (2007), follows a similar way to estimate monthly cross-border securities positions, but takes into account that the flows are measured with error. They use infrequently (annual after 2002) published Treasury International Capital Systems (TIC) surveys and monthly cross-border securities transactions data. The difference between the accumulation of the monthly transactions and published survey positions are divided into "valuation adjustment" and "the gap" categories. Formally, the actual and observed flows are modeled as follows,

$$S_t = (1+\pi_t)S_{t-1} + N_t \tag{3.2}$$

$$\hat{S}_t = (1+\hat{\pi}_t)\hat{S}_{t-1} + \hat{N}_t \tag{3.3}$$

where S_t is the actual position, N_t is the actual flows and $(1+\pi_t)$ is the actual value gain. The notations with hat are the same variables however values observed with some error. Like Gourinchas and Rey (2007a), this paper uses various return indices to

estimate the end of period value gains. In addition to that, it assumes that the value gains as well as the flows are estimated with some error. The relation between the actual and observed values are defined in the following way:

$$(1+\pi_t) = (1+\hat{\pi}_t)(1+\varepsilon_t) \tag{3.4}$$

$$N_t = (1+\beta_t)\hat{N}_t \tag{3.5}$$

where ε_t is the measurement error related to the valuation adjustment calculations.

If the survey positions were observed at the end of every period then the gap between the actual and estimated position would be measurement error related to the value gain estimations and the fraction of the flows which are not captured:

$$S_t - \hat{S}_t = S_{t-1}(1+\hat{\pi}_t)\varepsilon_t + \beta_t\hat{N}_t \tag{3.6}$$

However, since the position surveys are not monthly, the previous period position, S_{t-1}, is actually not observed and hence the gap evolves with mismeasurement accumulated from the previous survey. Note that only the gap, which accumulates all errors from those missing months is observable. Bertaut et al. (2007) carefully calculate the weight of each period, and add each periods share to the estimated position. So, the monthly position estimates proceed as follows:

$$\tilde{S}_t = (1+\hat{\pi}_t)\tilde{S}_{t-1} + \hat{N}_t + \eta_t \tag{3.7}$$

where η_t is period t's estimated share in the gap. Note that η_t is a function of the unknown parameter β_t and ε_t, which are assumed to take values -0.01 to 0.02.

In this paper, we will apply a latent factor analysis on a mixed frequency data and estimate the quarterly capital gain as well as the mismeasurement in flows. The main difference of this work from the previous chapter is that it directly uses the annual investment position data and quarterly transactions data, and estimates the unobserved

quarterly capital gains. The next section will introduce the model and briefly explain the method.

3.2 The Model

This paper applies the model described in Mariano and Murasawa (2003) to the estimation of quarterly international investment positions (IIP). Change in investment position from the previous year is written as a sum of unobserved quarterly changes :

$$IIP_t - IIP_{t-4} = \Delta IIP_t^* + \Delta IIP_{t-1}^* + \Delta IIP_{t-2}^* + \Delta IIP_{t-3}^* \tag{3.8}$$

$$\Delta IIP_t^* = IIP_t^* - IIP_{t-1}^* \tag{3.9}$$

where the t subindex represents the end of a given quarter. The quarters where the change in investment positions from the previous quarter is unobserved, are denoted with a star. The quarter to quarter change in investment position depends on the net flows during the period, $Flow_t$, and the dollar value gain, Val_t. Note that the discrepancy due to errors and omissions are assumed to be part of the value gains[1]:

$$\Delta IIP_t^* = Flow_t + Val_t \tag{3.10}$$

The revised international investment data, IIP_t, reflects the true value of investment position at the end of the quarter t, however, the financial flows, $Flow_t$, are mismeasured even after the revisions due to the dynamic nature of the financial transactions (See Curcuru et al. (2008)). Similar to the model in the previous chapter, observed flows, FL_t, will be assumed to be a fraction of the true flows, $Flow_t$:

$$Flow_t = \beta FL_t \tag{3.11}$$

[1]The errors and omissions here correspond to the random measurement errors which are assumed to have zero mean

Combining equations 3.9, 3.10, and 3.11, and dividing by the annual GDP of the previous year yields:

$$\Delta^4 iip_t = \beta(fl_t + fl_{t-1} + fl_{t-2} + fl_{t-3}) + kg_t\lambda_t + kg_{t-1}\lambda_{t-1} + kg_{t-2}\lambda_{t-2} + kg_{t-3}\lambda_{t-3} \tag{3.12}$$

where $\Delta^4 iip_t$ is the change in the position compared to the same quarter a year ago divided by the previous year's annual GDP. The change is composed of the accumulated flows and value gains. For simplicity, the measurement error, β, is assumed to be independent of time. If β is estimated as larger than 1 than the actual flows are larger than what is reported, so flows are underestimated. If it is less than one than the flows are overestimated.

The capital gains, kg_t, in this chapter will be estimated as a percent of the quarterly US GDP. Since in equation 3.9 annual GDP was used in the denominator, the weights λ_t are used for the transition. These weights are the ratio of quarterly GDP to the GDP of the previous year. The λ_t values fluctuate around 0.25.

Note that here the latent state variable includes capital gains and three additional lags. The transition equation of kg_t is modeled to reflect the exchange rate gain/loss. The constant aims to capture the average gain related to price changes. So, the quarterly capital gain is defined as:

$$kg_t = \alpha_0 + \alpha_1 r_{EXR,t} \times iip_{-1} + \alpha_2 kg_{t-1} + \nu_t \tag{3.13}$$

where the second term on the right hand-sight shows dollar value gain (as percent GDP) if the entire position were denominated in foreign currency:

$$r_{EXR,t} \times iip_{t-1} = \frac{exr_{t-1} iip_{-1}}{exr_t} - iip_{-1} \tag{3.14}$$

The exchange rate, exr_{t-1}, is the Federal Reserve Board Major Currencies Index, which is a "...weighted average of the foreign exchange values of the U.S. dollar against a subset of currencies in the broad index that circulate widely outside the country

of issue" (See Loretan (2005)). The iip_{-1} is a ratio of previous years international investment position to GDP of that quarter. Note, that the ratio will be constant for different quarters of a year. In this setting, when the US dollar depreciates in value ($exr_t < exr_{t-1}$) the gain in equation 3.14 becomes positive. So, the coefficient α_1 is expected to be estimated significantly positive for US assets.

The last part of the equation 3.13 ν_t denotes the errors and omissions in the capital gain estimations, which is assumed to have normal distribution with zero mean and variance, σ_ν.

The list of parameters of the state-space system to be estimated are as follows: $\Theta = \{\beta, \alpha_0, \alpha_1, \alpha_2, \sigma_\nu\}$. The maximum likelihood factor analysis on the mixed frequency series, described in Mariano and Murasawa (2003), will be used to estimate the system coefficients as well as the latent factor, kg_t [2].

3.3 Results

The results are reported in the Table 3.1 below. The maximum likelihood estimation uses the data from 1979 first quarter to 2007 fourth quarter. Since the next two years are extremely unstable, they are left out of the estimation. The capital gains, however, are calculated for those years as well using the estimated coefficients presented in the table. Note that, the capital gains are defined as the ratio of dollar value gain to quarterly GDP. So, the values presented in table are in percent quarterly GDP.

Table 3.1: Estimated Coefficients 1983:I-2010:II

	β	α_0	α_1	α_2	σ_ν
Assets	1.331*	0.139	0.185*	0.671*	1.699*
	(0.19)	(0.26)	(0.06)	(0.12)	(0.35)
Liabilities	1.079*	0.087	0.062	0.114	2.485*
	(0.07)	(0.45)	(0.07)	(0.69)	(1.49)

Standard errors are reported under each coefficient in parenthesis. Star (*) shows significance at 10% level. The data covers 1979:I-2007:4.

The β coefficient estimates the average mismeasurement in flows about 30% for

[2] The details of this estimation can be found in the Appendix

assets and about 8% for liabilities. The estimated coefficient is significantly larger than one for assets. Average capital gain without the exchange rate effect, α_1, is estimated larger for assets however both coefficients are insignificant. As expected, the exchange rate effect is significant and positive for capital gains on assets.

The estimated value gains and annual income/received paid on assets/liabilities are combined to estimate the total returns. Table 3.2 below shows the average rate of returns on previous asset and liability holdings for the period 1999-2009.

Table 3.2: Capital Gains and Total Returns 1999-2009

	Value Gain			Total Returns		
	Asset	Liability	Difference	Asset	Liability	Difference
1999	4.08	-0.83	4.91	9.8	3.74	6.05
2000	-8.06	-3.73	-4.33	-2.23	1.08	-3.32
2001	-7.04	-3.12	-3.92	-2.43	0.19	-2.61
2002	-0.82	-4.25	3.43	3.59	-1.26	4.84
2003	8.36	1.29	7.07	13.14	4.36	8.78
2004	4.85	2.13	2.72	10.23	5.6	4.63
2005	7.53	-1.53	9.07	13.23	2.38	10.85
2006	6.56	3.53	3.03	12.87	8.43	4.44
2007	4.76	0.34	4.41	11.03	5.01	6.02
2008	-15.56	-8.37	-7.19	-10.53	-4.8	-5.73
2009	11.91	3.77	8.14	16.38	6.49	9.89
Total	1.51	-0.98	2.49	6.82	2.84	3.99

Value Gains are calculated as the estimated dollar value gains on the previous position. The total return includes the dollar value of income received/paid as well as capital gains. Formally, $ValueGain_t = \hat{kg}_t \times gdp_t/IIP_{t-1}$, where gdp_t is quarterly GDP.

This period has seen two bubbles, with peaks in March 2000 and December 2007 and collapsed afterwards. The economy started to recover from the first collapse around the beginning of 2002. In 2003, the dollar started to depreciate against the major currencies. This depreciation was reflected in the value gains on US foreign holdings. In 2003, the value gain on the US foreign holdings was about 8.4% which becomes 13% when the income yield is added in as well.

Forbes (2007) uses the revised data and estimates the total returns on total assets as 23% for the same period which we think includes the mismeasurement bias. This table however agrees with her findings that the positive return differential did exist

from the first peak to the second peak. The recession periods, however, hit the US investments abroad worse than it did the foreigners' investments in US. This might be related to the differences in investment composition of the portfolios. The foreign investors mostly holds low risk, long-term US debts, whereas about 70% of US foreign securities portfolio is invested in equities.

Figure 3.1 shows the estimated value gains from 1985 to 2009. The average difference between asset and liability gains over this period has been around 1.25% of the total holdings. The largest difference was 9% in 2005. The largest loss that US had relative to the return on foreign liabilities was in 2008, -7%, which is followed by -5% during the 1997 Asian financial criss.

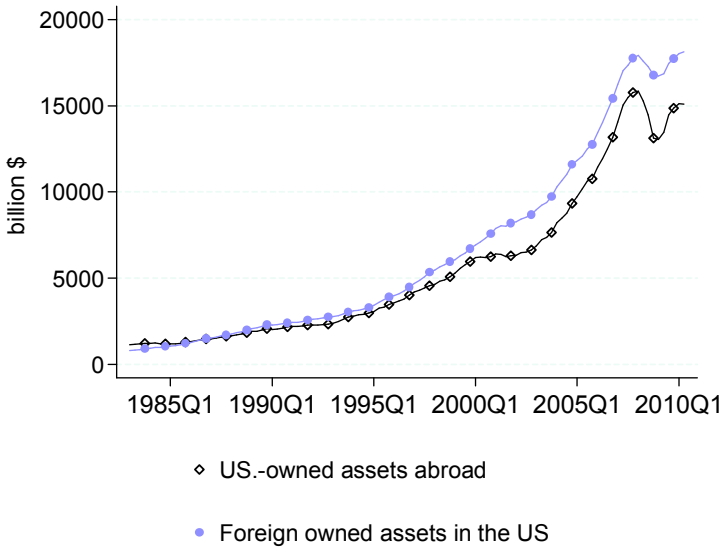
Figure 3.1: Return Differential: Assets vs Liabilities

Source:Authors Estimations

Is the return large enough to support the consecutive US current account deficit? As is argued in the literature over the years both the size of the value gains and the volatility has increased along with the change in scale and the composition of foreign investments. In 2006, the US had the largest current account deficit, which was 6% of the US GDP. On the other hand in 2006, the US foreign asset holdings were about 100%

of GDP and during that year, according to our estimations, average value gains was about 6% of these holdings. The return differential has become more of a value transfer from the rest of the world to the US as the currency denomination of US holdings changed.

Figure 3.2: US Foreign Assets and Liabilities, Quarterly



Source:Authors Estimations and International Investment Position, BEA

One of the results of this paper was to estimate the quarterly investment positions. Figure 3.2 shows the estimated quarterly asset and liability positions compared with the values published by BEA. The points show the BEA values and there is no gap between these values and estimated position for fourth quarter.

3.4 Concluding Remarks

The total returns on US foreign investment have increased over the last few years as the scale of the foreign holdings reached to more than 100% of US GDP. The income received on US foreign assets being consistently larger than the income paid to foreign investors was a puzzling observation since the foreigners' investment holdings in the US are significantly larger than US asset holdings abroad. In addition to that, the large value gain estimations especially using implied value gain method suggested that US

enjoys a significant yield privilege.

This paper estimates the value gains using a model that takes into account the fact that investment flows are not measured correctly. We estimate that this mismeasurement is significantly large for US assets compared to the liabilities. According to the results, on the average 30% of the quarterly flows are not captured despite the revisions and corrections. It has been long argued and recently documented by Curcuru et al. (2008) that these mismeasurement could go up to 120% in equity categories. These missing flows however tend to be interpreted as part of the implied value gains, which is change in assets holdings less the net flows.

The value gains estimated without the mismeasurement shows that the difference in returns to foreign asset and liability holdings was actually large and positive only after 2003. For the period of analysis, we show that difference in the annual returns could be large and negative. On average we find the US assets returns are about 1.5% larger than the US liability returns, which is much smaller than the values suggested in the literature.

We also add the income gain into each category and compare the total returns. The significant difference between the two investment categories are mostly driven by this income yield, until 2002 and there is a significant contribution by the value gains after that until the end of 2007.

Appendix

The estimation in this paper follows that of Mariano and Murasawa (2003). The measurement and transition equation is specified earlier as:

$$\begin{aligned} \Delta^4 iip_t &= \beta(fl_t + fl_{t-1} + fl_{t-2} + fl_{t-3}) + kg_t + kg_{t-1} + kg_{t-2} + kg_{t-3} \\ kg_t &= \alpha_0 + \alpha_1 r_{EXR,t} \times iip_{-1} + \alpha_2 kg_{t-1} + \nu_t \end{aligned}$$

The univariate state-space model, following the two equations above is:

$$y_t^+ = \mu_t^+ + H^+ s_t + w_t^+ \tag{3.15}$$

$$s_t = a_0 + a_1 z_t + \nu_t \tag{3.16}$$

Since $\Delta^4 iip_t$ is observed only at the end of each year, or once every three months, those quarters where the dependent variable is not observed will be replaced by a random draw, z_t, from normal distribution with mean 0 and variance 1:

$$y_t^+ = \begin{cases} \Delta^4 iip_t, & \text{if } \Delta^4 iip_t \text{ observable} \\ z_t, & \text{otherwise} \end{cases}, \; H^+ = \begin{cases} [1\ 1\ 1\ 1], & \text{if } \Delta^4 iip_t \text{ observable} \\ 0, & \text{otherwise} \end{cases}$$

$$\mu_t^+ = \begin{cases} \beta F_t, & \text{if } \Delta^4 iip_t \text{ observable} \\ 0, & \text{otherwise} \end{cases}, \; w_t^+ = \begin{cases} 0, & \text{if } \Delta^4 iip_t \text{ observable} \\ z_t, & \text{otherwise} \end{cases}$$

where $F_t = fl_t + fl_{t-1} + fl_{t-2} + fl_{t-3}$.
Note that the state variable, s_t and H is a $4x1$ vector. So, the equation 3.16 is :

$$\begin{pmatrix} kg_t \\ kg_{t-1} \\ kg_{t-2} \\ kg_{t-3} \end{pmatrix} = \begin{pmatrix} \alpha_0 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} \alpha_2 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} kg_{t-1} \\ kg_{t-2} \\ kg_{t-3} \\ kg_{t-4} \end{pmatrix} + \begin{pmatrix} \nu_t \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{3.17}$$

The likelihood function that is used includes the probability of z_t as well.

$$f(y_T^+; \Theta) = f(y_T; \Theta) \prod_{t \in A} f(z_t) \tag{3.18}$$

where y_T only includes the y_t observed every three months. The maximum likelihood is performed using equation 3.18 instead which is "equivalent up to scale" (Mariano and Murasawa, 2003). Once Θ is estimated, the latent factor, capital gain is estimated using the Kalman filter.

Chapter 4

Supply-side Response to Declining Heroin Purity : Fentanyl Overdose Episode of 2006

with Katherine Hempstead

Drug control policy in the United States has tended to prioritize the interruption of supply over demand reduction efforts such as prevention and treatment. Traditionally, interdiction efforts have been focused on relatively small number of popular and potent substances - heroin, cocaine, and to a lesser extent, marijuana. These efforts continue, yet in the last decade, several new developments have complicated drug control efforts.

One major shift is the increasing popularity of "non-organic" substances which are manufactured from easily obtained chemicals, most notably methamphetamine, but also XTC and PCP. Another trend is the increasing availability of prescription opioids, which have been diverted into the illegal drug market in various ways.

These more recent developments have increased the sophistication and flexibility of the drug market, and suggest that in this environment, supply interdiction may have new and unintended consequences. We argue that the fentanyl overdose episode in New Jersey was a result of a sustained decline in heroin purity since 2002. New Jersey used in general has the highest heroin purity level in the nation, however, partially due to enforcement activities average market purity dropped significantly in recent years. The imperative to increase the potency of the heroin supply was heightened by the increased availability of prescription opioids, a close substitute for heroin, and the ability to manufacture fentanyl was facilitated by technological change and the use of the Internet. The outcome was an eight month period of elevated overdose in a number of U.S. cities, resulting in more than one thousand deaths.

The objective of this paper is to describe the economic aspects of this incident and argue that non-pharmaceutical fentanyl overdoses were related to drug suppliers' efforts to respond to declining heroin purity in the context of the increasing availability of close a substitute. While the empirical evidence supporting the existence of this relationship in some markets is convincing, it should be noted that fentanyl was not universally mixed with heroin in all drug markets in the North East. For example, the pattern we observe in Philadelphia and Camden and the surrounding area does not occur in New York City and the Newark area, although the trends in the heroin purity are essentially the same in both markets. This may be attributable to differences among drug sellers in access to fentanyl, and perhaps in their predisposition to risk. We also argue that market differences in the availability and the use of prescription opioids are significant.

The effect of supply reduction efforts on the consumption of illegal drugs has been addressed in the literature (Manski et al., 2001, Reuter and Robert, 2001). In general, supply reduction efforts result in moderate declines in consumption, which are difficult to assess due to the underground nature of the market and questions regarding the data collected (Caulkins, 2007, Horowitz, 2001). Some studies of illegal drug markets focus on evaluating the effect of supply reduction on consumption via increasing prices (Caulkins, 1998, DiNardo, 1993). Becker et al. (2006) studies the effect of supply reduction efforts on suppliers under different demand elasticity assumptions from a theoretical perspective. Smithson et al. (2004) used the Australian heroin drought to measure the effect of supply reduction on ambulance calls and enrollment in methadone treatment programs. Weatherburn et al. (2003) found that heroin users in Australia during this period substituted cocaine for heroin to a certain extent. A recent paper by Dobkin and Nicosia (2009) studies the effects of government restriction of methamphetamine precursors on the consumption of methamphetamine.

This analysis makes a number of contributions to the literature on drug markets. First, we focus on a sustained and fairly widespread reduction in supply, as the decline in heroin purity was experienced throughout the eastern half of the United States between approximately 2001 and 2007. Second, unlike most of the literature which

focuses on demand, this study examines the supply side response to purity decline. Third, unlike much of the previous literature, our analysis includes consideration of prescription opioids, which are close substitutes for heroin. Fourth, our data sources are unique. Our use of richly detailed unpublished medical examiner data allows us to trace the trend in substances ingested by overdose decedents, allowing the analysis of substitution. Additionally, we use unpublished heroin purity data obtained from the Drug Enforcement Agency (DEA) to supplement our estimates of the trend in heroin purity. Finally, DEA data on retail pharmacy orders of opioids are used to enhance our analysis of the availability of substitutes.

This paper is organized in the following way: Part 1 provides some background on heroin markets and prescription opioids. Part 2 discusses the price elasticity of heroin demand conditional on the prescription opioid availability. Part 3 summarizes 2006 fentanyl overdose episode in New Jersey and discusses the link between prescription drug availability and fentanyl related overdoses during that year. Part 4 presents the empirical evidence and Part 5 concludes.

4.1 Background: Heroin Market in United States

Since 2002, there have been two significant trends in the heroin market in the northeastern United States; declining purity and the increasing availability of a close substitute, prescription opioids. Heroin prices and purity depend in part on the origin of the drug. In the east coast of the United States, South American (SA, hereafter) heroin dominates the market, whereas in the west coast Mexican heroin is widely sold. The Drug Enforcement Agency (DEA) conducts the Domestic Monitoring Program, a surveillance project in which they make quarterly street level purchases in most major cities where they monitor the heroin market. This surveillance data shows a decline in the average purity of South American heroin for the U.S. as a whole in recent years, (although as mentioned, South American heroin is sold primarily in cities east of the Mississippi).

Table 4.1 above shows the trend in average purity and price per milligram pure observed in South American heroin in the US between 2001 and 2006. As can be seen,

Table 4.1: South American Heroin: Purities and Prices

	2001	2002	2003	2004	2005	2006
Percent Pure (percent)	49.7	46.0	41.8	32.5	37.3	36.1
Price per pure milligram (in dollar)	NA	0.72	0.77	1.00	0.81	1.04

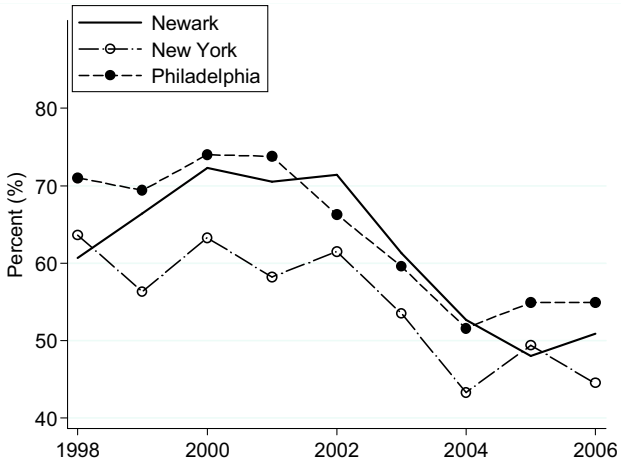
Notes: See National Drug Threat Assessment 2009. South American retail heroin purity by percentage, 2001-2006. Price per milligram of pure heroin in dollars.

purity declined and the price per milligram pure rose, with the highest price, 1.04, recorded in 2006. New York City, Newark, and Philadelphia have traditionally had the purest SA heroin in the country, yet data collected under the Domestic Monitoring Program reveals that in these areas there was also a decline in purity during these years.

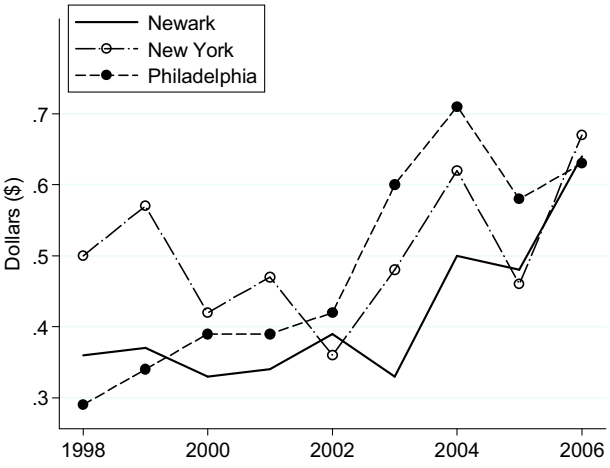
Figure 4.1 shows the average purity and the price of the samples collected in Newark, New York, and Philadelphia. In New Jersey, heroin is provided in two somewhat distinct markets, South Jersey is basically supplied by Philadelphia, while North Jersey's heroin originates from New York City. The DEA conducts its Domestic Monitoring Program in Philadelphia, Newark, and New York, as well as several dozen cities in other areas. As can be seen in Figure 4.1-a, purity declines were similar in these three cities. Since 2002, the average purity of SA heroin in this region decreased from approximately 70 percent to 50 percent.

Figure 4.1-b shows the trend in price per milligram pure for these three cities over the same period. Over the last 8 years the price of heroin increased substantially, from about 35 cents to 65 cents per milligram pure. This increase reflects the relative stability in the market price of heroin, despite purity declines.

The decline in heroin purity is attributed mainly to a reduction in heroin production in Columbia. Additionally, since 2002 improved interdiction efforts may have led to changes in trafficking patterns, as SA heroin is increasingly likely to be transported by Mexican drug cartels across the U.S.-Mexican borders rather than arriving on the East Coast. Since approximately 2007, heroin purity has stabilized, as increased production in Mexico has compensated for the continued decline in South American production,



(a) Average Rate of Purity



(b) Price per Pure Milligram

Figure 4.1: Heroin Purity and Price Levels in 3 Major Cities

Notes: DEA, Heroin Domestic Monitoring Program. Annual averages from selected cities: Newark, New York and Philadelphia.

although at a level which is still below that observed in 2000 or 2001[1].

4.2 Elasticity of Demand for Illegal Drugs and the Role of Prescription Opioids

Elasticity of demand is affected in part by the availability of close substitutes. Given its highly addictive and unique nature, one would expect the demand for heroin to be relatively inelastic.

Most studies of the price elasticity of demand for heroin have found that users respond to price changes in the market. In fact, the sign of this response is estimated consistently as negative (Jofre-Bonet and Petry, 2006, Manski et al., 2001, Petry and Bickel, 2002, Saffer and Chaloupka, 1999, Silverman and Spruill, 1977). However, findings regarding the degree of the price elasticity of demand are not consistent. Results from recent studies have ranged from elastic, (i.e. greater than one in absolute terms), to inelastic, (i.e. less than one in absolute terms).

Petry and Bickel (2002) study the price and income elasticity of demand among polydrug abusers that are in treatment for heroin addiction. In an experimental setting, participants were asked to spend a given amount of imitation money on the available drugs: heroin, Valium, cocaine, marijuana, and alcohol. The price elasticity of demand for heroin was found to range between -0.86 and -1.26, and was more elastic at higher prices. The cross price elasticity results showed that Valium was chosen as a substitute for heroin as price level increased. A recent study by Jofre-Bonet and Petry (2006) analyses the results of a very similar experimental study and estimates the price elasticity of heroin as -0.917 among heroin addicts. Another study by Saffer and Chaloupka (1999), combined the DEA's STRIDE data with National Household Survey on Drug Abuse for the years 1988, 1990 and 1991, and estimated the price elasticity of heroin as -0.94.

These studies, however, were conducted with two experimental conditions that are not particularly applicable to actual drug markets. The purity of the drug was known

[1]See http://www.usdoj.gov/ndic/pubs31/31379/heroin.htm

to users, and there were no close substitutes available. Unlike most other goods, in the market for illegal drugs, fluctuations in purity rather than price matter most to consumers. Caulkins (2007) provides a good survey about the characteristics of the illicit drug market. Like Levitt and Venkatesh (2000) he also points out that the price of illicit drugs at the retail level is quite stable. The buyer pays a fixed price for a bag which is expected to have some level of purity. The purity of the drug is the most important aspect of its quality, but can only be known after use.

Second, prescription opioids represent a fairly close substitute for heroin. In the study by Jofre-Bonet and Petry (2006), it was shown that heroin addicts chose Valium over other alternatives such as cigarettes, alcohol and cocaine, as a substitute for heroin. While Valium may have been the closest substitute for heroin available to subjects in this study, present day heroin users have closer substitutes such as oxycodone, which would be expected to affect the price elasticity of demand for heroin.

Wagstaff (1989) summarizes bended demand curves where either demand is elastic at low price ranges due to occasional drug users (The Blair-Vogel demand curve) or at very high levels of price, where addicts cannot afford to pay (The White-Lusetich demand curve). It is also mentioned, that in case of the availability of substitutes, supply side interdiction efforts might effect the market for substitutes.

In recent years, the availability and use of a variety of prescription opioids has increased dramatically Manchikanti (2007). Paulozzi et al. (2006) studies the trend in overdose from illicit and prescription drugs, and shows that the share of fatal overdoses from prescription drugs exceeded that from street drugs by 2002. Prescription drug abuse related emergency department visits jumped by 73% between 1999 and 2002, compared to 14% and 18% increase in heroin and cocaine related visits. This would imply that the actual price elasticity of demand for heroin is greater than in an experimental setting with no close substitutes. It would also be expected that heroin suppliers are aware of the increased availability of close substitutes.

Yet it should be noted that heroin is also a substitute for prescription opiates, and many users of prescription opiates ultimately find that heroin is cheaper and more

reliably available. Experts from the treatment community note that once prescription opiates users switch to heroin, they rarely return completely to prescription opiates, due to the greater intensity of the high from heroin, and may continue to use heroin and prescription drugs in combination (NDIC, 2008).

Due to the "experience good" nature of illicit drugs, the relationship between price, which is conventionally measured as dollar per milligram pure and supply is more complicated than in the case of other goods. The paper by Galenianos et al. (n.d.) shows that the reason why drug sellers sell drugs with positive purity is explained by the possibility of a long-term relationship with the customer. In general, there is little opportunity for consumers to differentiate the available supply in terms of quality through variations in price. As has been shown in a number of studies (Caulkins, 2007, Wendel and Curtis, 2000) at the retail level there is "conventional pricing", so the price of a baggie sold is fixed. However, the purity is not fixed. Hence, drug sellers cannot compensate addicts for low purity by reducing prices. In the case of inelastic demand, unsatisfied customers would not result in a drop in demand. However, if substitutes are available, sellers would be motivated to seek alternative ways to improve their drug quality.

Since buyers do not know about the quality of the product before consuming it, sellers have an incentive to try to convince consumers that their product is the most potent on the market. Traditionally, heroin sellers accomplish this attempt at product differentiation through logos on the packages in which the drug is sold. Drug sellers "brand" their baggies with logos suggestive of potency, such as "Die Hard", or "R.I.P.".

In the long run, consumers will know whether or not these marketing claims are accurate. If they are, the use of the logos will help sellers obtain repeat business, and through "word of mouth" communication among drug users, attract new customers who have heard good reviews of the product. The importance of both drug baggie labeling and communication among addicts about drug quality has been described well in Wendel and Curtis (2000). In general, baggies serve primarily to direct consumers to products that are at the top of the market standard, and to help them avoid products

that are particularly bad (Wendel and Curtis, 2000).

4.3 Fentanyl Related Overdoses in 2006

Given the emergence of close substitutes and the conventional attempts at product differentiation in the heroin market, it is understandable that heroin sellers would be motivated to attempt to increase the potency of their product in the face of declining purity. In 2006, the availability of highly potent fentanyl provided such an opportunity.

Fentanyl is a very powerful synthetic opioid that is frequently used in hospital settings for anesthesia. It is estimated to be at least forty times more potent than heroin and other prescription opioids (Hull et al., 2007). Since 1990, it has been available with a prescription in various forms like transdermal patches or lollipops for the treatment of serious chronic pain, most often prescribed for late stage cancer patients. Prescription fentanyl has been diverted to the illicit market to a certain extent, although not as widely as much more commonly prescribed substances such as oxycodone. There have been reported fatal overdoses associated with the misuse of pharmaceutical fentanyl due to crushing, heating and inhaling the patches, or the use of multiple patches (Hull et al., 2007, Kuhlman et al., 2003). However such cases resulted in only a few dozen overdose deaths a year in New Jersey during the years 2004 through 2006, out of a total of approximately nine hundred overdose deaths per year.

Beginning in approximately April 2006, there was a marked increase in emergency calls received regarding drug overdoses in multiple states including New Jersey, Maryland, Illinois, and Pennsylvania. These overdoses were ultimately found to be linked to non-pharmaceutical fentanyl manufactured by clandestine laboratories in powder form. Packets of heroin mixed with fentanyl were confiscated by the DEA and other law enforcement agents in various locations. During this period Chicago and Philadelphia observed the highest number of fentanyl related overdoses, 349 and 269 decedents, respectively (MMWR, 2008).

The figure 4.2 shows fentanyl related overdose deaths in New Jersey as a percentage of the total number of overdoses between 2004 and 2007.

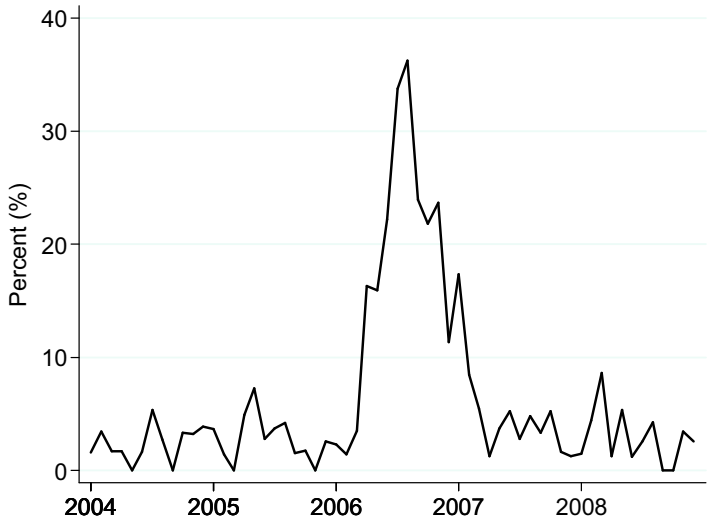


Figure 4.2: Fraction of Overdoses related to Fentanyl Consumption
Source: New Jersey, Office of the State Medical Examiner. Notes: Share of Fentanyl related overdoses in total number of overdoses in a month.

In New Jersey, non-pharmaceutical fentanyl was first identified in the drug market in April 2006. Fentanyl-related overdoses occurring before then were related to misuse of pharmaceutical fentanyl, as described above. As can be seen, starting in April 2006, there was a large increase in the number of fentanyl related overdose deaths in New Jersey. In August 2006, the peak of the fentanyl episode, more than one third of overdose deaths in the State were fentanyl related. Nationally, more than 1000 people died of fentanyl related overdoses in 2006 (MMWR, 2008).

The retail distribution of "synthetic heroin" comprised of fentanyl or a fentanyl analogue mixed with heroin or perhaps just with a cutting agent has long been a theoretical possibility, and has occurred several times in the past, although on a much smaller scale. In the 1980s a fentanyl-based drug marketed as "China White" caused about a dozen deaths in California [2] . Subsequently, there were several other very small episodes in various places, including New York, Philadelphia, Maryland, Pittsburgh and New Jersey (Henderson, 1991, Hibbs et al., 1991, Kronstrand et al., 1997, Smialek et al., 1994). These cases resulted in very few deaths, and were connected to corrupt chemists attempting to manufacture synthetic heroin, but were not connected with major drug

[2]See *Synthetic Heroin Seen As Cause in 18 Deaths*, The New York Times, December 25, 1988, p.143

distribution operations.

Previous episodes of synthetic heroin overdoses were small in scale in part due to difficulties in manufacturing large quantities of fentanyl. The extent of the episode in 2006 was mostly due to the ready availability of the inputs and the development of a new, relatively simple method of fentanyl production - "The Siegfried method" - which was disseminated on the Internet[3]. This method does not require special equipment or a high degree of technical knowledge. Before the 2006 incident, the distribution of N-phenethyl-4-piperidone (NPP), the main substance used to produce fentanyl, was not regulated. After the fentanyl outbreak the dissemination of NPP was restricted [4].

Despite the ease of production, the correct dosing of fentanyl requires professional equipment and knowledge, as one gram of fentanyl is equivalent to about seven thousand street doses (MMWR, 2008). Due to this high potency, mixing fentanyl with other drugs or a cutting agent creates a high potential for overdoses, as evidenced in the episode of 2006.

Initially, sellers of heroin enhanced with fentanyl marketed their product using distinctive baggie logos, and distributed free samples to consumers in some cities. The publicity surrounding the overdose deaths paradoxically attracted users to the product, making public health messages relatively ineffective in containing the episode. Ultimately, pressure from law enforcement in the form of enhanced sentencing laws, bans in the availability of ingredients, and raids on fentanyl labs led to the suspension of this practice and thus the spate of fentanyl-related overdose deaths came to a fairly abrupt halt in the late fall of 2006(MMWR, 2008).

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[3]See http://opioids.com/fentanyl/synthesis.html , a very dedicated website on Fentanyl production using Siegfried Method. It includes the links to off-shore pharmacies. First suggested link on Google (by March 4, 2009)

[4]For restriction of the NNP distribution in New Jersey see Federal Register, Rules and Regulations, *Control of a Chemical Precursor Used in the Illicit Manufacture of Fentanyl as a List I Chemical*, July 25, 2008, vol. 73, no. 144, p.43355-43357

4.4 Empirical Results

4.4.1 Data

While both declining heroin purity and fentanyl overdose were characteristic of a number of Northeastern states and cities, our empirical analysis focuses on New Jersey, due to the availability of detailed data. Our information on trends in heroin purity in New Jersey comes from the drug monitoring program (DMP) of DEA. While New York City, Newark, and Philadelphia are regularly monitored by DEA, during the 2006 fentanyl episode, DEA conducted supplemental heroin surveillance in Atlantic, Camden, and Mercer counties in South Jersey, which are not usually part of the DMP sampling frame. The purity data collected during this period is still too sparse to construct separate series at the subregional levels. So, we use a monthly purity series that is representative of New Jersey, by combining DMP data with this unpublished DEA purity data collected only during the 2006 Fentanyl episode.

Our main source of information on fentanyl consumption comes from New Jersey medical examiner data. It is acknowledged that fatal overdoses represent only a sample of drug use, and probably not a representative sample. Yet mortality data are comparatively rich. Non-fatal fentanyl overdoses treated in the hospital are difficult to identify, due the lack of detailed toxicological testing. New Jersey hospitals as a rule do not engage in extensive testing in the event of drug overdoses, since the mode of treatment (administration of Narcan) is unlikely to vary as the result of testing, and many overdose patients do not have generous insurance payers. Medical examiner data, on the other hand, provides complete toxicological results for all substances found in the decedent, and includes the blood concentration of most substances found. Additionally medical examiner data provides basic demographic information about the decedent, the time and place where the body was found, and includes a brief narrative synopsis that describes the scene, and often includes information about drug paraphernalia found.

The Table 4.2 provides some basic information about characteristics of drug overdoses in New Jersey. In 2006 there were 980 fatal overdoses in total, of which 19% involved in either fentanyl alone or fentanyl combined with heroin. In both overall and

Table 4.2: Characteristics of Fatal Drug Overdoses, New Jersey 2006

	Total	Fentanyl Only	Fentanyl & Heroin	Heroin Only	Other
	N (Rate)	N	N	N	N
Total	980 (11.24)	93	86	354	447
Mean Age	40	37	34	39	42
Male(%)	77	84	87	81	71
Non-Hispanic White (%)	70	78	79	70	68
Non-Hispanic Black (%)	20	11	11	19	25
Hispanic(%)	8.6	10	9	11	6
Positive for Cocaine (%)	50	53	57	43	54
Positive for Oxycodone (%)	25	22	22	20	31
Nanograms fentanyl per ml blood	-	17	23	-	-

Source: New Jersey Office of the State Medical Examiner.
Notes: Includes all cases meeting case definition occurring between Jan 1 and December 31, 2006. Nanograms fentanyl/ml blood shows the averages. Age, 5 cases missing information. Race, 6 cases missing information. Rate, calculated per 100,000 resident population

fentanyl related overdose cases, a large proportion of the overdose decedents are male and non-Hispanic white with an average age around 37. Half of the fentanyl related overdose decedents tested positive for cocaine and more than one fifth of them tested positive for oxycodone.

In 88% of the cases in 2006, the blood toxicology analysis provides information about the blood concentration of fentanyl, measured in nanograms per milliliter. The average fentanyl found in decedents' blood is approximately 20 nanograms per milliliter. The therapeutic quantity associated with a fentanyl patch is approximately 6-7 nanograms per ml. and a common rule of thumb is that in the absence of other drugs, levels above 20 nanograms/ml. are considered toxic (Ellenhorn, 1997).

4.4.2 The Model

Our goal is to show that the distribution of non-pharmaceutical fentanyl was related to heroin purity, especially in those markets where close substitutes were available. An important question pertains to the level of information asymmetry present in these markets. Our main claim is that the purity decline put more pressure on heroin suppliers in markets where consumers had easy access to a close substitute. This claim is based on

the assumption that consumers are relatively less likely to be informed about prescription drug availability in other regions. Of course other factors like regional differences in preferences could also be a reason for not seeking an alternative to heroin.

As discussed above, medical examiner data provides the location of the body and its residential address. Our data shows that more than 80% of the decedents overdose in the same municipality that they live. This percentage is even higher for fentanyl related overdoses in 2006. The rest of the decedents mostly are residents of other states. This is consistent with the idea that most addicts only have information about the markets and products close to where they live.

The availability of close substitutes in the heroin market creates an incentive for suppliers to increase the potency of their heroin baggies due to preexisting established market prices. In a heroin market with an elastic demand, unhappy customers can switch to a prescription opioid substitute, resulting in a loss of customers and profits for the seller. In a market where demand is inelastic, a decrease in heroin purity (increase in the value of pure gram) would cause a small consumption loss which can be explained by less frequent use, or addicts seeking drug treatment. The availability of prescription opioids is therefore an important characteristic of the heroin markets.

We use two measures for the availability prescription opioids. One comes from the medical examiner data, and is the proportion of overdoses with positive toxicology for prescription opioids in each New Jersey county in 2004. This measure reflects the availability of the substitute, and also reflects the preferences of consumers.

The other measure uses DEA ARCOS[5] data, which measures retail pharmacy orders for oxycodone at the level of the three-digit zip code. ARCOS provides summary information regarding pharmacy orders of various controlled substances in every state in US. We use grams of oxycodone distributed in each 3-digit zipcode area in New Jersey in 2004. Oxycodone is a prescription opioid which is prescribed to chronic pain patients and its abuse has been growing significantly over time (Cicero et al., 2005). Our expectation is that in those areas where there were more oxycodone orders, fentanyl

[5]Automation of Reports and Consolidated Orders System, Drug Enforcement Administration, Office of Diversion Control, Reporting Period 2004.

related overdoses were higher as well. In both instances we chose 2004 to avoid possible endogeneity problems.

Our dependent variable is the number of *non-pharmaceutical* fentanyl related fatal overdoses observed in a heroin market i during month t. A heroin market in our study is defined in two different ways; as a county and a 3-digit zipcode area. Toxicological testing for fentanyl is expensive, and requires use of special equipment. This testing was not routinely performed before April, 2006. Therefore, we have nine months of data, as the fentanyl episode had essentially concluded by the end of 2006.

The general approach for estimating the expected number of count data is Poisson regression, which has the strict requirement of the mean and variance being equal, or equidispersion. In our sample, the average number of monthly overdoses in a county is 0.94, with a variance of 5.49. In 3-digit zip code area the average is the same and the variance is even higher, 6.9. This is partially because of the excess number of zeros in the data. When we omit the zero counts in a month and county (3-digit zipcode area) the sample variance to mean ratio is still much larger than one, 3.54 (4.05).

In our sample, 72-76% of the total observations are zero in the geographical areas used in this study. In South Jersey, some 3-digit zip code areas cover multiple counties. Fentanyl overdoses were highly concentrated in the southern part of the State. Therefore, fentanyl related overdoses are more clustered when we use 3-digit zip code to define a heroin market. For example, in 4 out of 21 counties no fentanyl related overdoses were observed during this 9 month period, as compared with 7 out of 20 in 3-digit zip code areas.

Due to the evidence on overdispersion and the high number of zero observations, we use a negative binomial regression and compare the results with the zero-inflated negative binomial regression. The negative binomial model is obtained assuming that the Poisson mean, which is a non-linear function of heroin purity and county specific factors is perturbed by an unobserved Gamma process. A convenient property of a negative binomial is that the Poisson specification is nested within it. So in the case

when the overdispersion parameter is zero, the model reduces to the Poisson regression[6].

The unobserved heterogeneity due to individual and time dependent factors is taken into account this way. Due to possible serial correlation within each region we report cluster-robust standard errors in both specifications. The zero-inflated regression models excess zero counts as a mixture of sampling from zero state and sampling zero outcome from negative binomial process. Zero-state refers to those regions where it is unlikely to observe heroin consumption over the year. These regions inflate the number of no-fentanyl related overdoses cases because there is no heroin market in those areas or consumer is not interested in heroin. Hence, we cannot explain these zero cases with fluctuations in heroin purity or availability of close substitutes. In short, if we did not observe a fentanyl related overdose, then either we are sampling from a region that is a zero-state region or we are sampling from a region with a functioning heroin market but whose outcome for that month was zero.

The probability of a region being zero-state might depend on various different factors. We used economic and demographic variables such as racial distribution, the proportion of urban population, median incomes, and unemployment rate. Among these variables we found the concentration of households with an annual income of $ 200,000 and over, significantly increase the probability of sampling from zero-state. We do not consider this result particularly surprising because people with higher income are known to take better care of their health. A similar correlation is also found between the median income level of a county or 3-digit zip code area and the expected number of fentanyl related overdoses.

4.4.3 Estimation Results

The objective of the empirical analysis is to show that monthly fluctuations in heroin purity and the supply of oxycodone were significantly related to the distribution of

[6]In NegBin II model (Cameron and Trivedi, 1998) the conditional variance of the counts is modeled as follows, were α is the overdispersion coefficient:

$$Var\left(Fent_{it}/X\right) = \alpha^2 E\left(Fent_{it}/X\right) + E\left(Fent_{it}/X\right)$$

Table 4.3: Descriptive Statistics of the Related Variables

	County Mean (Sd)	3-digit Zipcode Mean (Sd)
$POD04_i$	13.4 (11.7)	14.1 (14.9)
$ArcosOxy04_i$ *		58.6 (62.3)
$MedianIncome_i$ *	64.9 (14.4)	53.2 (16.3)
$ProportionWhite_i$ (%)	68.6 (17.1)	68.1 (19.2)
$ProportionBlack_i$ (%)	12.2 (9.1)	16.4 (12.6)
$ProportionHispanic_i$ (%)	13.2 (9.9)	15.6 (11.1)

Source: Median income and race/ethnicity distribution is obtained from Census 2000. $ArcosOxy04_i$ is from the Office of Diversion Control, Reporting Period 2004. $POD04_i$ is from the New Jersey Office of the State Medical Examiner.
Notes: *in thousands. $POD04_i$ is average number of prescription related overdose counts in 2004. $ArcosOxy04_i$ is retail oxycodone distribution, grams weight in thousands.

non-pharmaceutical fentanyl, here proxied with fentanyl-related overdoses.

Our general regression model can be summarized in the following equation:

$$E\left(Fent_{it}/X\right) = exp\left(\alpha_0 + \alpha_1 \ln Pure_{t-1} + \alpha_2 \ln Pure_{t-1} \times S_i + \alpha_3 CS_i\right)$$

The expected number of fentanyl related overdoses, $Fent_{it}$, depends on the monthly fluctuation in heroin purity in New Jersey, $Pure_{t-1}$, spatial differences in availability of substitutes during months of low heroin purity, $\ln Pure_{t-1} \times \ln S_i$ as well as county specific variables, CS_i.

Table 4.3, summarizes descriptive statistics for the variables used in the regression. The region specific variables are presented both at county and 3 digit zip code levels, except the retail drug distribution, ARCOS, which is only available for 3 digit zipcode areas. New Jersey has 21 counties and 20 3-digit zipcode areas, which define regions which are mostly, but not completely, similar. The economic and demographic statistics related to New Jersey counties and 3-digit zipcode areas are taken from Census 2000. Average number of prescription related overdoses in New Jersey, $POD04_i$ comes from the past medical examiner data, which reports an annual average of 13 prescription overdose decedents in a New Jersey county and/or 3-digit zip code area.

Table 4.4: Fentanyl related Overdoses, at County Level

Dependent Variable: $Fent_{it}$				
	ZINB		NegBin II	
	1	2	1	2
$\ln Pure_{t-1}$	-2.236*	1.502	-2.403*	1.092
	(0.95)	(2.07)	(0.98)	(1.85)
$\ln POD2004_i$	1.085**		1.026**	
	(0.29)		(0.34)	
$\ln Pure_{t-1} \times \ln POD2004_i$		-1.439**		-1.357**
		(0.35)		(0.45)
$ProportionWhite_i$	0.032	0.029	0.059*	0.057*
	(0.03)	(0.03)	(0.02)	(0.02)
$MedianIncome_i$	-0.037+	-0.036+	-0.056*	-0.055*
	(0.02)	(0.02)	(0.03)	(0.02)
$Constant$	-3.786	-0.828	-5.107**	-2.360
	(2.38)	(2.80)	(1.97)	(1.75)
Log Likelihood	-189.96	-190.88	-195.09	-196.18

Notes : $+, *,$ and $**$ show 10%, 5% and 1% significance, respectively. The robust standard errors are presented in parentheses.

The $ARCOSOxy04_i$ show that the grams of Oxycodone ordered in New Jersey in 2004 changes from region to region and has an average of 59,000 grams per 3-digit zipcode.

Tables 4.4 and 4.5 show the estimation results from zero-inflated negative binomial (ZINB) and negative binomial regressions (NegBin II). In the first table, the availability of prescription opioids is measured by the number of prescription related overdoses in 2004, $POD04_i$. The results in the second table shows the estimated coefficients when the availability of close substitutes is controlled using ARCOS data, which more directly measures the supply of prescription opioids.

In Table 4.4 above, the results from the ZINB regression and the NegBin II are similar. The estimated coefficient on purity shows the elasticity of the expected number of fentanyl related deaths to the percentage changes in heroin purity. According to the results, a 10% decrease in purity in a given county increases the expected number of deaths about 21-24%. The estimated elasticity of the expected number of fentanyl overdoses to prescription related overdose deaths in 2004 is significant and positive as expected, which suggests that the supply of prescription opioids is related to the

Table 4.5: Fentanyl related Overdoses, at 3-digit Zipcode Level

Dependent Variable: $Fent_{it}$				
	ZINB		NegBin II	
	1	2	1	2
$\ln Pure_{t-1}$	-2.781**	4.737*	-2.743**	4.313+
	(0.84)	(2.20)	(0.85)	(2.41)
$\ln ArcosOxy04_i$	1.424**		1.323**	
	(0.28)		(0.32)	
$\ln Pure_{t-1} \times \ln ArcosOxy04_i$		-1.916**		-1.767**
		(0.38)		(0.43)
$MedianIncome_i$	-7.352*	-6.954*	-7.338*	-6.962*
	(3.43)	(3.27)	(3.19)	(3.04)
$Constant$	-4.173*	1.262	-3.844*	1.293
	(1.91)	(2.11)	(1.96)	(2.08)
Log Likelihood	-171.789	-173.523	-175.323	-176.913

Notes: $+, *,$ and $**$ show 10%, 5% and 1% significance, respectively. The robust standard errors are presented in parentheses.

dissemination of fentanyl, as measured by fentanyl related overdoses.

The joint effect of heroin purity and the availability of close substitutes is found to be significant at the 1% level. The results in this table show that the availability of prescription opioids changes the magnitude of the effect of heroin purity. The estimated coefficient significantly confirms that the effect of a decrease in purity would have a bigger effect on those markets where prescription drugs are more common.

In order to control for market specific heterogeneity we used various demographic and economic variables available from Census 2000. The proportion of the local population that is non-Hispanic white and the median income level are two factors whose effects are significantly different than zero, at least within one standard deviation. Controlling for median income level, markets with higher non-Hispanic white population have a higher chance of observing fentanyl related overdoses. Similarly, median income level of the market is negatively correlated with the fentanyl related overdoses.

The estimated effect of heroin purity on fentanyl-related overdoses is higher when we use 3-digit zip code regions. In Table 4.5, the effect of 10% decrease in purity is estimated as 26-28%. The availability of the prescription drugs in the market measured

by retail oxycodone orders is significant at more than 1%. Similarly, the joint effect of heroin purity and availability of close substitutes has a significant effect on expected fentanyl related overdoses. As expected, markets with high oxycodone orders are affected more by a decrease in heroin purity. At the 3-digit zip code level, the proportion of the population which is non-Hispanic whites and median income level are highly correlated, 0.76. In order to avoid collinearity we omitted $ProportionWhite_i$. The effect of median income, however, is still negative and significant.

Table 4.6 shows the actual frequencies of the count data along with the predicted probabilities[7] of the observed counts using the estimated coefficients from the tables above. The first part of the table shows the predicted probabilities from table 4.4, the second part shows those from the table 4.5. Underneath the predicted probabilities the estimated overdispersion parameter, α, Likelihood Ratio (LR) test regarding the significance of α and the Vuong test statistics is reported from each regression.

In part one, zero-inflated negative binomial specification estimates the α quite low, around 0.5, however the likelihood ratio test on α being zero is significantly rejects the null at 1%. The level of overdispersion in our data is related to intermarket heterogeneity in addition to the high number of zero-counts. By rejecting the likelihood ratio test we reject the use of zero-inflated poisson regression which only takes into account the overdispersion related to excess number of zeros.

The Vuong statistics (Vuong, 1989) compares the probability distribution under zero-inflated negative binomial specification to the one under negative binomial specification. The asymptotic distribution of the statistics is standard normal distribution. Positive significant values of the statistic will prefer zero-inflated over negative binomial distribution, and the negative significant values will chose otherwise. For an extensive discussion on model selection see (Greene, 1994) and (Cameron and Trivedi, 1986).

The Vuong statistics in part one and part two slightly favor the zero-inflated model to the negative binomial with a p-value of 9 % and 6 %, respectively. However when we compare the predicted frequencies with the actual frequencies we see that negative

[7]Cameron and Trivedi (1998, See), the predicted probabilities are computed as follows: $\hat{p}_j = \frac{1}{N}\sum_{i=1}^{N} Prob(Y_i = j/X)$, where $j = 0, 1, 2..., max_i(Y_i)$ and N is the total number of observations.

Table 4.6: Actual vs. Predicted

	Dependent Variable: $Fent_{it}$				
	Actual	ZINB 1	ZINB2	NegBin II-1	NegBin II-2
Part I - POD04					
0	71.43	72.04	71.90	71.40	71.35
1	12.70	10.87	11.07	12.94	13.01
2	5.29	5.44	5.52	5.30	5.33
3	2.12	3.17	3.16	2.81	2.82
4	1.59	2.07	2.03	1.72	1.72
5	1.06	1.46	1.41	1.15	1.15
6	1.59	1.08	1.03	0.82	0.82
7	1.59	0.82	0.78	0.62	0.61
8	2.65	2.40	2.35	1.96	1.92
Alpha		0.47 (1.17)	0.48 (1.06)	2.59 (1.14)	2.65 (1.13)
$LR-test\ of\ equidispersion$		14.18[0.00]	14.25[0.00]	154.21 [0.00]	156.77 [0.00]
Vuong		1.35 [0.09]	1.41 [0.08]		
Part II - ARCOS					
0	75.56	73.39	73.76	74.60	74.74
1	9.44	12.13	11.81	11.25	11.11
2	4.44	5.25	5.13	4.68	4.65
3	1.67	2.81	2.76	2.55	2.53
4	1.67	1.69	1.67	1.59	1.57
5	0.00	1.10	1.09	1.08	1.06
6	0.56	0.75	0.75	0.77	0.76
7	2.22	0.54	0.54	0.57	0.56
8	0.56	0.40	0.40	0.44	0.43
9	1.11	0.31	0.31	0.35	0.34
10	2.78	1.05	1.07	1.31	1.30
Alpha		3.08 (0.57)	3.25 (0.61)	3.32 (1.76)	3.56 (1.73)
$LR-test\ of\ equidispersion$		20.60[0.00]	23.24[0.00]	139.73 [0.00]	152.64[0.00]
Vuong		1.54 [0.06]	1.52 [0.06]		

Note: Standard errors are provided in parenthesis', p-values are provided in brackets.

binomial does at least as well as the zero-inflated model, especially in predicting the probabilities of observing up to 4 cases including zero overdose cases.

In both Part I and Part II, the negative binomial specification predicts the frequency of zero observations as good as the zero-inflated model. This shows that the market specific heteroskedasticity explains the differences in fentanyl distribution. There is a big variation in number of overdoses observed from county to county in a year, but every county in the past years had at least one heroin overdose case. Our analysis show that the differences between these heroin markets and the consumers could be very well explained by the differences in the availability of close substitutes and income level.

4.5 Concluding Remarks

We argue that the adulteration of heroin with illicitly manufactured fentanyl in 2006 was a supply side response to both declining heroin purity and the growing availability of a close substitute, prescription opioids. While this response may have been economically rational, the consequences were tragic, as more than one thousand fatal overdoses occurred.

The combination of declining heroin quality, growing competition from a close substitute, and the dissemination of a technological innovation led some drug distributors to risk the manufacture and sale of a product whose potency they could not successfully control. While enhanced sentencing and bans on precursors ultimately contributed to the cessation of the illegal manufacture and distribution of fentanyl, suppliers' incentives to maximize market share while minimizing the cost of bringing drugs to the illegal market will undoubtedly remain. The fentanyl overdose episode provides another example of the growing difficulty of effective drug control in an environment in which supply interdiction is a decreasingly effective strategy.

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