

Modelling the Counterfeiting of Bank Notes: A Literature Review

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- *Ensuring that the threat of counterfeiting remains low is critical to maintaining the public's confidence in bank notes as a means of payment.*
- *In the past 50 years, Canada has experienced two major episodes of counterfeiting at levels that threatened public confidence. The Bank of Canada has since developed a comprehensive anti-counterfeiting strategy that has brought counterfeiting under control and that supports public confidence by staying ahead of counterfeiters.*
- *Research that models the behaviour of relevant parties—the counterfeiters, the merchants and the central bank—helps to improve our understanding of their respective decisions: whether or not to produce counterfeit notes, whether or not to verify and accept bank notes offered, and what level of security to apply to bank notes. This research also sheds light on the importance of policies against counterfeiting.*

In June 2011, the Bank of Canada unveiled its new \$100 and \$50 notes to the public. The Bank's new series of polymer bank notes, which incorporates innovative security features that are not only easy to verify but also difficult to counterfeit, marks a significant advance in counterfeiting deterrence.

Issuing new, more-secure bank notes is one of four components in the Bank's comprehensive anti-counterfeiting strategy, which was developed during the most recent episode of high levels of counterfeiting.¹ At the episode's peak in 2004, the number of counterfeit notes detected per million notes in circulation reached 470, which was the highest among industrialized countries. The high levels of counterfeiting threatened to undermine Canadians' confidence in using bank notes. The anti-counterfeiting strategy developed by the Bank and its partners has been very effective. By 2010, detected counterfeits had dropped to 35 parts per million. Recent survey results suggest that bank notes continue to be an important means of payment in Canada, and thus it is important for the Bank to continue to ensure that Canadians can use bank notes with the highest confidence.²

This article aims to contribute to our understanding of counterfeiting and its policy implications by reviewing the literature on the subject. We begin by discussing the general characteristics of counterfeiting. We then briefly review several models of counterfeiting and study their implications for the incentive to counterfeit, social welfare and anti-counterfeiting policies. This research is still at an early stage, and more work is necessary before these models can be used to explain many of the observed characteristics of counterfeiting.

¹ For a description of the Bank's four-part anti-counterfeiting strategy, see Bank of Canada (2011, 16).

² According to a 2009 survey of Canadian consumers, nearly half of all transactions are conducted with bank notes, accounting for 20 per cent of the total value of transactions (Arango, Hogg and Lee, forthcoming).

Stylized Facts About Counterfeiting

Analysis of the available data on counterfeiting in Canada and other countries can provide a general understanding of the problem, as well as facilitate our discussion of recent research. Counterfeiting is usually measured in terms of the number of counterfeit notes detected in circulation in one year, typically in comparison to the total number of genuine notes in circulation, or parts per million (PPM).³

Counterfeiting tends to be episodic

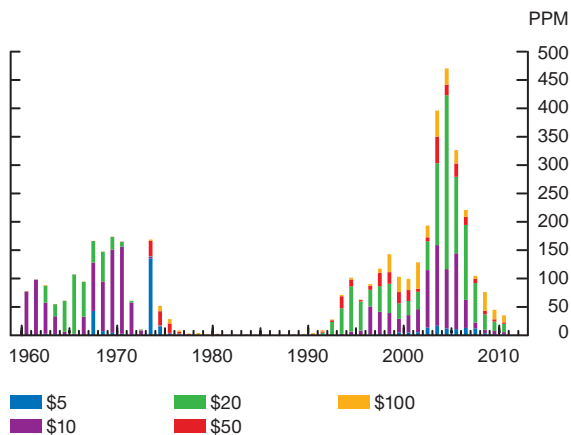
Since 1960, Canada has experienced two major episodes of increased counterfeiting (**Chart 1**).⁴ During the first episode, from 1960 to around 1975, counterfeiters targeted mainly \$5, \$10 and \$20 notes. Toward the end of this episode, however, the counterfeiting of \$50 and \$100 notes began to rise, even as counterfeiting in general was trending down. From 1976 to 1991, counterfeiting remained subdued.

The second major episode of counterfeiting activity began in 1992, with counterfeiters initially targeting \$20 notes. Around 1996, the number of bogus

\$10 notes began to rise rapidly, and this was soon followed by an increased number of counterfeit \$100 notes. The counterfeiting of \$10 notes increased substantially following the issue of a new series of \$10 notes in 2001 whose security features were not sufficient to deter counterfeiters. Also in 2001, a new and highly deceptive \$100 counterfeit note began to be passed in considerable numbers, and the resulting publicity heightened the public's concern about counterfeiting.⁵ Since the peak of the counterfeiting problem in 2004, the Bank's anti-counterfeiting strategy has been successful. In particular, the security features of the new series of bank notes issued between 2004 and 2006 were considerably improved, and the less-secure notes previously issued were aggressively withdrawn from circulation. By 2010, the number of counterfeit notes detected annually had dropped well below the Bank's current medium-term target of 50 PPM, suggesting that the most recent counterfeiting episode may have ended.

By 2010, the number of counterfeit notes detected annually had dropped well below the Bank's current medium-term target

Chart 1: Counterfeit Canadian bank notes passed for every one million genuine notes in circulation, 1960–2010



Sources: Bank of Canada and the Royal Canadian Mounted Police

³ A preferred measure would be the outstanding stock of counterfeit notes in circulation, which would better reflect the extent of the counterfeiting problem. Unfortunately, such a measure cannot be observed directly. Chant (2004) discusses various methods of estimating the stock of counterfeits in circulation.

⁴ Chart 1 also depicts the number of counterfeit notes detected for each denomination as a ratio of the total number of genuine notes in circulation. For a discussion of the counterfeiting of various series of Canadian bank notes, see Moxley, Meubus and Brown (2007).

Given the episodic nature of counterfeiting, it would be important to understand what factors lead to a sharp rise in counterfeiting, and what anti-counterfeiting policies are effective in preventing and reducing it.

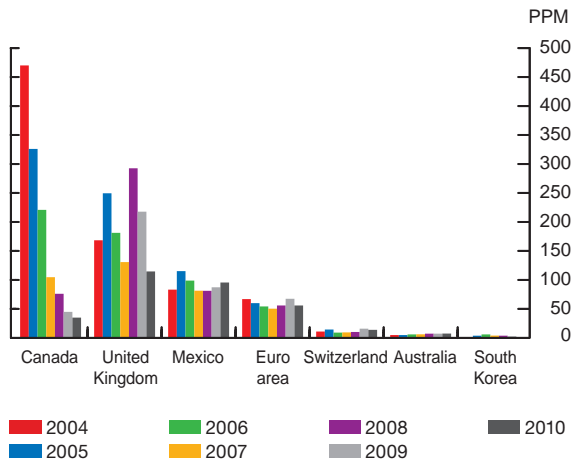
Counterfeiting tends to vary across countries

In recent years, counterfeiting has been a problem in Canada, the United Kingdom, Mexico and the euro area, while remaining at low levels in Switzerland, Australia and South Korea (**Chart 2**).⁶ Indeed, in some countries, such as Australia, counterfeiting has been almost negligible for the past 20 years. The differences may lie with the security features of the current bank notes, the deterrence efforts of law-enforcement authorities, the extent of

⁵ The number of counterfeit \$20 notes detected during the second episode was also relatively high. Since the early 1970s, the \$20 note has become the most popular denomination in circulation, and demand rose sharply in the mid-1990s because it is the main denomination dispensed by automatic teller machines. It now accounts for over 40 per cent of all notes in circulation.

⁶ Many countries, including the United States, do not publish their counterfeiting data in a form that facilitates comparisons across countries.

Chart 2: Counterfeit bank notes passed for every one million genuine notes in circulation in selected countries



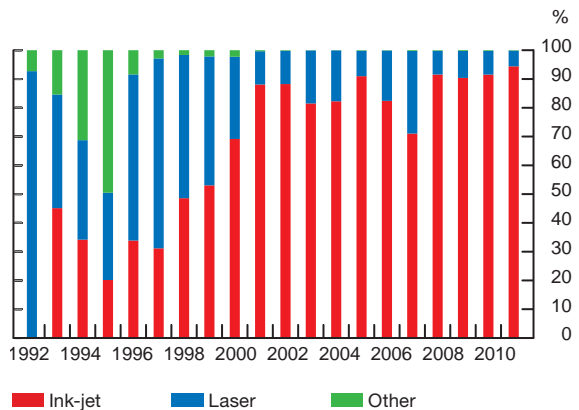
Source: Authors' calculations based on information available on websites of central banks and law-enforcement agencies

criminals' access to counterfeiting technology or the publicity that successful counterfeiters receive. Understanding why some countries have experienced a more serious counterfeiting problem than others and what factors explain this difference across countries could be instructive.

Counterfeiting tends to change with technology

Advances in security technology allow the central bank to produce more-secure notes, but other technological innovations can enable counterfeiters to produce higher-quality counterfeits at a relatively low cost. Prior to the 1980s, the production of counterfeits required engraved plates and offset presses that necessitated expensive, large-scale operations. Counterfeiting was therefore usually part of organized criminal activity, and large numbers of counterfeit notes were produced at a time. Police often seized large quantities of uncirculated counterfeits. The availability of colour copiers, and later of personal computers with scanners and ink-jet and laser printers, heightened the potential threat. Over 99 per cent of counterfeits detected in Canada are now produced by colour printers and copiers (**Chart 3**). Moreover, the share of uncirculated counterfeits seized by law-enforcement authorities relative to counterfeits passed into circulation has been low. It would therefore be interesting to study how technology affects the behaviour of counterfeiters and merchants, as well as the security design of bank notes.

Chart 3: Share of counterfeits by printing method



Source: Royal Canadian Mounted Police

Models of Counterfeiting

There has been almost no empirical work on counterfeiting because of the limited availability of counterfeiting data and related statistics. We therefore focus our discussion on theoretical studies that model the behaviour of the relevant economic agents. To date, there have been only a small number of these studies. They can be grouped into two categories—partial-equilibrium and general-equilibrium models—depending on how money is introduced.⁷

Partial-equilibrium models

Models in the first category do not explicitly specify the demand for money. It is assumed to be exogenous and does not depend on the actions of agents in the model. These models are therefore referred to as partial-equilibrium models. They are used to study the interactions of counterfeiters, merchants and the central bank, and often derive implications that can be compared with actual counterfeiting data. We review two studies that use this approach.

Lengwiler (1997) models the strategic interaction between a central bank and counterfeiters. He finds that it is optimal for a central bank to choose a design with a high level of security for high-denomination notes because the expected cost of producing a secure note is relatively small compared with the expected losses to those accepting counterfeits. If genuine notes are very costly to counterfeit, then forgeries are not profitable. In contrast, the expected

⁷ The term “money” usually refers to the medium of exchange used to facilitate transactions between individual parties. In this article, money refers to bank notes issued by the monetary authority.

losses to consumers from counterfeits of low-denomination notes are small compared with the cost of producing secure notes. The central bank therefore produces less-secure low-denomination notes, and counterfeiters respond by forging a large number of these notes. The study implies that central banks tend to issue more-secure high-denomination notes, and thus counterfeiting rates are higher for low-denomination notes.

The denominations that are most counterfeited tend to change over time

Empirical support for Lengwiler's main findings is mixed. In the United States, it is true that the security features of \$1 bills have been changed only slightly in the past few decades. Contrary to Lengwiler's assertion, however, their very low face value also makes them unattractive to counterfeiters. In Canada, some previous series of bank notes did have better security features on the high-denomination notes, consistent with Lengwiler's argument. However, in the *Canadian Journey* series issued from 2004 to 2006, all denominations carry the same security features. Moreover, the denominations that are most counterfeited also tend to change over time. For example, \$10 notes were the most counterfeited in the early 2000s, when they were less secure than others, which supports Lengwiler's findings. Since 2008, however, the counterfeiting of \$100 notes has been higher than that of other denominations, which contradicts the argument that low-denomination notes are more often counterfeited.

Quercioli and Smith (2009) investigate the strategic interaction between merchants and counterfeiters in an environment where counterfeiters select the quality of counterfeit notes to produce and merchants verify the notes offered to avoid counterfeits. The security level of notes is given, since the central bank is not explicitly modelled. High-quality counterfeits are less likely to be detected but are more costly to produce. Counterfeiters also face expected costs of legal punishment. Verification by merchants is imperfect and costly, and a greater effort by merchants results in better detection.

Quercioli and Smith find that the behaviour of merchants and counterfeiters varies with note denomination. They derive three main implications from their model. First, there is no counterfeiting of low-denomination notes, since the expected gain is not large enough to cover the expected costs.

Counterfeiting occurs only in the case of high-denomination notes. Second, merchants choose to exert more effort when verifying high-denomination notes because the losses from accepting counterfeits are larger. At the same time, counterfeiters also produce higher-quality counterfeits for high-denomination notes, since the marginal gain to quality is higher. While both verification effort and counterfeit quality increase as the denomination of the notes rises, the authors find that the rise in counterfeit quality can dominate the increase in the verification effort under certain conditions. In other words, the ratio of passed counterfeit notes to all counterfeit notes (seized and passed) rises with the denomination. Third, the authors find that the counterfeiting rate, measured as the fraction of counterfeit notes to the total notes in circulation, displays a hump-shaped distribution across denominations, which is consistent with available counterfeiting data.

If people think that only high-denomination notes are counterfeited, they may avoid them and use more low-denomination notes

While the above analyses derive interesting and useful implications regarding counterfeiting, some of which are consistent with the stylized facts, both studies assume that the demand for money is fixed and thus will not influence the decision to counterfeit. However, if people think that only high-denomination notes are counterfeited, they may avoid them and use more low-denomination notes. In this case, counterfeiters may prefer to produce low-denomination counterfeits because they are more easily passed. Indeed, when a large number of \$100 counterfeit notes were detected in Canada in 2001, up to one in ten retailers in some regions displayed signs informing customers that they would no longer accept \$100 notes. Counterfeiters likely found it more difficult to pass \$100 counterfeits and thus might have had less incentive to produce them. This suggests the need for a more complete modelling approach, which we discuss in the next section.

General-equilibrium models

Models in the second category are referred to as general-equilibrium models because the model environment that generates money as the medium of exchange is explicitly specified, and the demand

for money depends on the interactions of agents in the model.

The relatively few general-equilibrium models of counterfeiting share certain common features. There are two types of money: (i) genuine money, which is supplied by the monetary authority and lasts forever; and (ii) counterfeit money produced privately, which may last for one or more time periods. In each period, buyers and sellers have a chance to meet and trade. If buyers do not have genuine money, they can produce counterfeit money at a cost. Sellers will accept genuine money, but they may or may not accept counterfeit money. If sellers refuse to trade with buyers that use counterfeit money, they will have to wait until the next period to meet another buyer.

Once counterfeiting has been established as an equilibrium outcome, the model can be used to study [its] effects and the effectiveness of policies

An important first step in modelling counterfeiting in a general-equilibrium framework is to examine whether both genuine and counterfeit money will be accepted in equilibrium, given the economic environment of the model. In this case, some buyers use genuine money while others decide to produce counterfeit money. Sellers accept money as payment, even though there is a possibility of receiving counterfeits. Once counterfeiting has been established as an equilibrium outcome, the model can be used to study the effects of counterfeiting on social welfare and to assess the effectiveness of policies in reducing counterfeiting.

In earlier models by Kultti (1996), Green and Weber (1996), Williamson (2002), Monnet (2005), and Cavalcanti and Nosal (2007), counterfeiting is defined as the private provision of money. Counterfeit money can last for more than one period and so will have value if people are willing to accept it as a medium of exchange. Sellers may knowingly accept counterfeit money in a bilateral trade when there is a shortage of genuine money.⁸ This is because they may have to

⁸ Earlier models of money tended to assume that money is indivisible in the sense that an agent can carry only one unit of money in each period, and thus there could be a shortage of money. Wallace and Zhou (1997) constructed a model to explain the currency shortages that were common in many parts of the world until the mid-nineteenth century. While a shortage of money is unlikely in modern economies, the development of private digital money, such as Facebook credits and Bitcoins, could reflect a shortage of “money” in other areas of trade, particularly online commerce, in which bank notes are not accepted.

wait a long time before they meet a buyer with genuine money, and they expect other sellers to accept counterfeit money in such a situation.

Monnet (2005) argues that central banks should aim to reduce counterfeiting, even if counterfeit money has positive value as private money. In his model, genuine notes are less costly to produce than counterfeits because of factors such as economies of scale. Thus, from a social-welfare viewpoint, it is better to have trades intermediated by genuine money. He also finds that if the cost of counterfeiting is low, more counterfeits will be in circulation, and thus the money stock will rise. Counterfeiting can therefore lead to inflationary pressures, and high inflation can impose a large social cost.⁹

In practice, however, society does not consider counterfeits as private money. Private money is issued by a reputable private institution, such as a commercial bank, and is backed by the issuer’s assets. Its design differs from that of government-issued money and so is easily identified. In contrast, counterfeiters aim to produce notes that look like government-issued notes so that unsuspecting merchants will accept them. It is against the law to produce and pass such counterfeits. Therefore, sellers will not accept or recirculate counterfeits if they know the notes are fake. One way to capture these features in a model is to assume that counterfeit money can last for only one period and will be completely confiscated by the authorities at the end of each period. Counterfeit money therefore has no value because it cannot serve as a medium of exchange. Thus, it can pass to sellers only when they do not recognize that it is a counterfeit.¹⁰

For counterfeiting to exist as an equilibrium outcome when counterfeit money cannot circulate across periods, the method that buyers and sellers use to trade with each other is critical. In Nosal and Wallace (2007) and Li and Rocheteau (2011), a buyer can make a take-it-or-leave-it offer to the seller, which specifies the quantity of goods traded and the amount of money paid. Both papers find that counterfeiting does not occur in a monetary equilibrium because buyers holding authentic notes can signal that they are using genuine money by offering to pay a small sum of money in exchange for a very small quantity of goods. No counterfeiter will make

⁹ Friedman (1960) also argues that counterfeiting and the private issue of money can lead to inflation.

¹⁰ The inability to recognize even poor-quality counterfeits can occur in situations where cashiers are inexperienced or where they choose not to verify notes.

such an offer because the gain from the trade is too small to cover the cost of counterfeiting. Therefore, no one will produce counterfeits. Li and Rocheteau (2011) also consider the case in which both buyers and sellers take turns to make a take-it-or-leave-it offer to the other party. When sellers make the offer, they are willing to trade with a buyer even when they cannot verify the quality of money, since the buyer may be holding genuine notes. Thus, counterfeits can exist alongside genuine money in equilibrium. Fung and Shao (2011) consider a model environment in which sellers post offers to attract buyers, and buyers search for sellers based on these offers. In this case, sellers will not be able to use their offers to screen buyers, and all sellers will post the same offers.¹¹ As a result, counterfeiting can occur in equilibrium since a seller will attract both counterfeiters and buyers with genuine money.

*A policy that deters counterfeiting
is needed to maintain the public's
confidence in money*

According to Nosal and Wallace (2007), the threat of counterfeiting itself can have a significant negative impact on the economy. The possibility of counterfeiting threatens the use of money in equilibrium when no one is willing to accept money as a medium of exchange. Therefore, a policy that deters counterfeiting is needed to maintain the public's confidence in money. Li and Rocheteau (2011) argue that, while counterfeiting does not pose a threat to the acceptance of money as a medium of exchange, it lowers the volume of economic transactions, since sellers are concerned about receiving counterfeits. This, in turn, will reduce production and further decrease economic transactions. Anti-counterfeiting policies can prevent these effects by mitigating the threat of counterfeiting.

Policies against counterfeiting

In addition to the direct losses experienced by sellers who accept worthless notes, counterfeiting has indirect costs for society, such as the costs of producing more-secure notes and providing effective law enforcement, as well as the potential loss of confidence in bank notes.

¹¹ Sellers also face a capacity constraint since they can serve only a limited number of buyers in each period. Buyers may therefore have to take into account how likely it is that they will be served by the seller they visit. If buyers do not pay attention to this constraint, as in Guerrieri, Shimer and Wright (2010), counterfeiting may not occur.

Green and Weber (1996) study the effectiveness of introducing a new series of bank notes that is very difficult to counterfeit, such as one with advanced security features. Only old-style money can be counterfeited at some cost. The old-style money in circulation is gradually replaced by new-style money, as is done in the United States. The authors find that the introduction of new-style money may not always be effective in reducing counterfeiting because sellers may knowingly accept counterfeits (e.g., if there is a currency shortage, as explained earlier). Nevertheless, if counterfeits are too costly to produce, they will eventually go out of circulation. Thus, if old notes are not immediately withdrawn when a new series of more-secure bank notes is issued, additional anti-counterfeiting measures, such as enhanced law enforcement that increases the cost of counterfeiting, are also needed to effectively reduce counterfeiting.

Many of the other studies considered in this article also discuss the importance of policies against counterfeiting, and their insights can be summarized as follows:

- (i) Policies aimed at raising the cost of counterfeiting, such as increased bank note security or enhanced law enforcement, can reduce the incentive to produce counterfeits. Policies aimed at improving note verification by merchants and withdrawing counterfeit notes from circulation can also stop these notes from entering into circulation or from being recirculated.
- (ii) The implementation of anti-counterfeiting measures is crucial, even when the level of counterfeiting is low, because the threat of counterfeiting can affect the public's acceptance of bank notes as a means of payment, as well as reduce production, economic transactions and social welfare.
- (iii) A comprehensive anti-counterfeiting strategy that encompasses a range of measures, including the regular issuance of a new series of bank notes, is more effective in deterring counterfeiting than any one single measure.

Conclusion

This article has summarized some relevant insights from studies that model counterfeiting. The policy implications of these studies support our understanding of counterfeiting and the Bank's comprehensive anti-counterfeiting strategy.

Many of the questions raised by the stylized facts derived from the experience with counterfeiting

remain unanswered, however. Future research using general-equilibrium models of counterfeiting with less-restrictive assumptions would be useful in addressing these matters. It would also be very helpful to have more data available for empirical

work. Such work would help us to better understand why counterfeiting episodes break out and why experience varies across countries. It would also improve our ability to assess the effectiveness of various policies against counterfeiting.

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