



**Spreadsheet Modelling and Analytics
Final Report**

Group 7

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COR1305: Project ‘STOP THE BURN’

1. Problem statement and justification

The Monetary Authority of Singapore (MAS) issues approximately 100 million pieces of new notes annually for the Chinese New Year and other festive events (MAS, 2021). In this project, we are solely focusing on the Chinese New Year and the circulation of S\$2 notes during this period.

During Chinese New Year, money is usually given to friends and families in the form of hongbaos (red packets). This leads to a rise in demand for new notes, especially S\$2 notes. However, a large proportion of these S\$2 notes are returned back to MAS after the festive period. This leads to an excess of physical notes in circulation, far suppressing circulation demand. To curb this excess supply, the \$2 notes are incinerated. The production, transportation and destruction of these notes are wasteful in terms of cost and resources, not to mention environmentally detrimental as well.

Our project aims to help MAS optimise the amount of \$2 notes to print during the Chinese new year to reduce the number of notes they have to incinerate on a yearly basis.

2. System Scope

One way to reduce the carbon footprint of producing and incinerating banknotes would be to extend the shelf-life of banknotes. Singapore has done just that by switching its lowest three denominations (\$2, \$5 and \$10 notes) from paper to polymer, which last 2.5 times longer than their paper counterparts (Wang, 2016).

We will be setting the number of new notes being printed as an input variable. The printed notes will be used for one of four different purposes:

1. New banknotes will replace the notes held in storage as a contingency buffer.
2. New banknotes will replace existing notes in circulation nearing the end of their shelf life.
3. New banknotes will be used to increase the money supply whenever there is a sustained/trend increase in demand for banknotes (such as a growth in income).
4. The remaining new banknotes not fulfilling the first three purposes will be considered as an excess of the usual circulation and assumed to be used only for CNY exchanges.

For purposes 1 and 2, it is assumed that the money supply (M) stays constant as the new banknotes act as a replacement for existing banknotes. For purposes 3 and 4, the newly printed banknotes aid in increasing the money supply circulating in the economy. The change in money supply will be denoted as ΔM .

Zooming in on purpose 4, most of the notes which are used in excess of circulation happen during CNY, when hongbaos are exchanged constantly amongst loved ones. After the festive period, a large portion of the banknotes will be deposited by people into their bank accounts. The banks receiving these excess banknotes will then return them to MAS. A small portion of red packet money will still remain in the money supply circulating in the economy.

When we asked MAS (refer to email screenshot), a spokesperson explained that the 20% of \$2 banknotes deposited immediately after CNY will be reissued for the following year's CNY as they are in near-mint condition. The remaining 80% will be used to replace other banknotes nearing the end of their shelf-life. The old and unfit banknotes removed from circulation will then be destroyed.

3. Performance measures and their evaluations

We will incorporate the following performance measures within our model:

1. **Excess Notes:** The Excess Notes in any period are defined as the excess Money Printed minus the change in Money Demand in that period. By way of example, if 100 notes are printed by the MAS and the demand for notes increases by 50, there are 50 excess notes which are returned to MAS at the end of that period. Our model tracks all these variables on a monthly basis.
2. **Total Cost of CNY Notes:** The total cost of CNY notes includes the cost of printing, storing and destroying excess notes exclusively for CNY which fail to be used for replacement or new money demand. We define excess notes as the number of notes in excess of money demand in a month. From these excess notes, 20% are sieved for the next CNY while the remaining are stored as long as the current storage does not exceed capacity.

When the number of excess notes exceeds the demand for replacement money in storage, then some storage notes are destroyed early. Storage notes are only destroyed in advance when they exceed maximum storage capacity. Storage capacity is defined below. The cost of printing excess notes for CNY is the sum of the cost of printing and destroying the storage notes which need not have been destroyed at that point in time. The cost of all excess notes being printed or destroyed is not considered in the CNY cost. The reasoning is that as long as the excess notes replace older storage notes and circulation, they would be printed eventually. Our model minimises this cost while fulfilling the demand for \$2 notes during CNY.

Storage capacity is defined as 1% to 10% of the active money supply in the previous period. If the amount of notes falls below the required storage capacity, it increases money demand. The cost of burning and printing CNY notes is defined as the cost of burning and printing 1 note multiplied by the notes that exceed maximum storage capacity in any period.

Cost of printing excess notes for CNY = Quantity of notes in excess of storage x (Cost of printing + Cost of Destroying) + Cost of storing x CNY notes saved for next year

4. Data Collection and Analysis

Our model uses two sets of data for its primary analysis: Money Supply and Money Demand for \$2 notes. Data specifically for the \$2 SGD denomination is not publicly available, hence we began by utilising data for overall currency notes in circulation and taking a varying percentage of it to identify the amounts of \$2 notes in demand and in circulation through the various times of the year. Money supply (M_0) comprises multiple series named 'Money Supply in Circulation' and 'Money Supply in Active Circulation' retrieved from Computer and Enterprise Investigations Conference (CEIC) data. These series are then combined to fill in missing values within each other and allow a longer time period for our analysis. We assume the difference between the total currency in circulation and currency in active circulation equals the currency in storage held by MAS as a contingency buffer and will use it to find the average percentage of the active money supply held in the contingency buffer for our decision model.

The Money Demand will utilise real GDP and real GDP growth data, also retrieved from CEIC, to estimate the demand for new money in each period and consecutively the excess notes printed. We also retrieved the costs of printing currency notes from the Federal Reserve's website and proportionately assumed the other costs. The accuracy of these costs is trivial as they're not fundamental to the model's performance and can be changed easily. The shelflife of the notes was retrieved from BBC.

We also included methods to find hongbao demand, which include extrapolating average hongbao payments per married couple, and then simulating the data, and subsequently the \$2 notes, for the rest of the population over time, to find the demand for \$2 notes during the CNY period.

5. Decisions and Alternatives

The main decisions that can be made by the use of our model are the ideal number of \$2 notes to print to prevent excess in that period, keeping additional notes from the previous period in mind. By finding out this value, we can use this number to print exactly that amount of \$2 notes needed, no matter the period, to optimise the printing and minimise the burning. Subsequently, this will minimise the cost of burning to as good as minimum, because there is no wasted cost of burning such notes, and replacement and replenishment of existing notes is also kept to a minimum, aside from regular restocking.

6. Assumptions

It's important to note that we assume Chinese New Year is the only major event that significantly impacts the money supply, discounting events like Formula 1 for the sake of simplicity. Therefore, the changes in money supply are attributed solely to the Chinese New Year and the standard Year on Year volume that is introduced into the economy. These are the assumptions we made for our model:

- CNY is the sole major event of the year that changes the money supply
- No major events were considered in this project, such as the Global Financial Crisis and COVID-19.
- MAS incinerates the notes in the storage supply by first replacing them with newly-printed notes
- Note amount in storage remains within 1% to 10% of the previous period's money supply
- All excess supply of \$2 currency notes is utilised for CNY
- Based on historical data, we assumed 70% of the notes in circulation and those being printed are \$2 notes
- Only notes replaced on a monthly basis are affected by generic wear and tear
- The cost of monthly storage and burning a \$2 polymer note is 10 cents and 5 cents respectively
- The year-on-year adoption of e-hongbaos is assumed to be at 5%

7. Trade-offs, scenarios and sensitivity analyses

The key trade-off we observe is between short-term printing costs and long term burning, printing and storage costs. Assume a scenario where the model is run, and MAS discover that they need to print 100m worth of \$2 notes in the next month to accommodate demand over the next year, until the next CNY. They must then generate funds to print this volume in the short-run, and despite it reducing their costs in the long run by minimising storing, printing and burning that occurs outside whatever is necessary, they would have to decide what is the best choice to make now, by weighing up the opportunity cost of such a decision. In this area, it makes sense to conduct a trade-off analysis, to determine the best course of action moving forward.

One area we believe needs further analysis is the range of hongbaos (in total monetary value) given by married Chinese couples. The range was large, but we attributed it to the variance in different family dynamics and income. Perhaps, sensitivity analysis could be conducted by constructing a normal distribution and evaluating the mean number of \$2 notes given by standard hongbaos. The standard deviation could subsequently be attributed to varying income stages, and therefore be averaged, evening out the variance.

8. Results (tabulation, charts) and implications

We can see two key results based on the model. The first key result is how many notes should be printed every year for CNY. The second key result is how many \$2 notes a married couple needs in accordance with the number of family members they have.

(Screenshots of these results have been added to the appendix.)

Implications of the Analysis - The results of excess notes that need to be printed at any given time can indicate to MAS the surplus or shortage they are currently running in the economy, and subsequently the future course of action for notes to print. These are subject to simulated hongbao demand and overall predicted Money Demand within our model.

9. Model limitations, lessons learnt and conclusions

One limitation is that there is a lack of data about money demand therefore this model is only as accurate as the data we had access to. As such, we had to simulate it alongside using established economic research to derive our data. As mentioned previously, multiple assumptions were also made, such as printing, storage and incineration costs for the polymer notes as well as the average amount given to each family member. Each family dynamic varies based on the number of family members as well as the earning income of the married couple. Higher-income married couples with fewer family members tend to be more generous in giving bigger hongbaos to their loved ones than lower-income married couples with more family members.

From this project, we have learnt that the demand for newly-printed \$2 notes during the CNY period will be significant albeit at a lower rate than in previous years. This could be attributed to the rise of people using e-hongbaos. In the foreseeable future, there will still not be full adoption of e-hongbaos by Singaporeans as there will be some who will still use physical hongbaos due to traditional preferences, especially the older population.

10. Member's role and external party contact details

Akshay - Initial primary searching and correspondence with MAS - tabulated formula and scope of work. Also finalised the cost optimisation section and processed data into pivot tables.

Bharat - Main macro and VBA coder, worked to extract and process raw data and generated formulas. Developed the base excel sheet to kickstart the analysis.

Dhruv - Processed raw data, and initiated formulae for excess note calculation. Assisted in generating assumptions and increasing the model's accuracy. Presented the proposal and developed influence diagrams.

Erica - Did the simulated data table for hongbao demand, conceptualised and designed the dashboard including the graphs used, presentation style and colour scheme. Developed the main formulation process for hongbao simulation, and subsequent formulas.

Tze Ying - Worked on the report, slides excluding model demos, and created mock Q&A to simulate potential questions.

MAS Details

Sherry THENG

Corporate Communications Division

Monetary Authority of Singapore

Email: webmaster@mas.gov.sg

11. Citations

BBC. (2020, January 4). *Millions of plastic £5 and £10 banknotes replaced due to damage*. BBC News. Retrieved April 4, 2022, from <https://www.bbc.co.uk/news/uk-50989914>

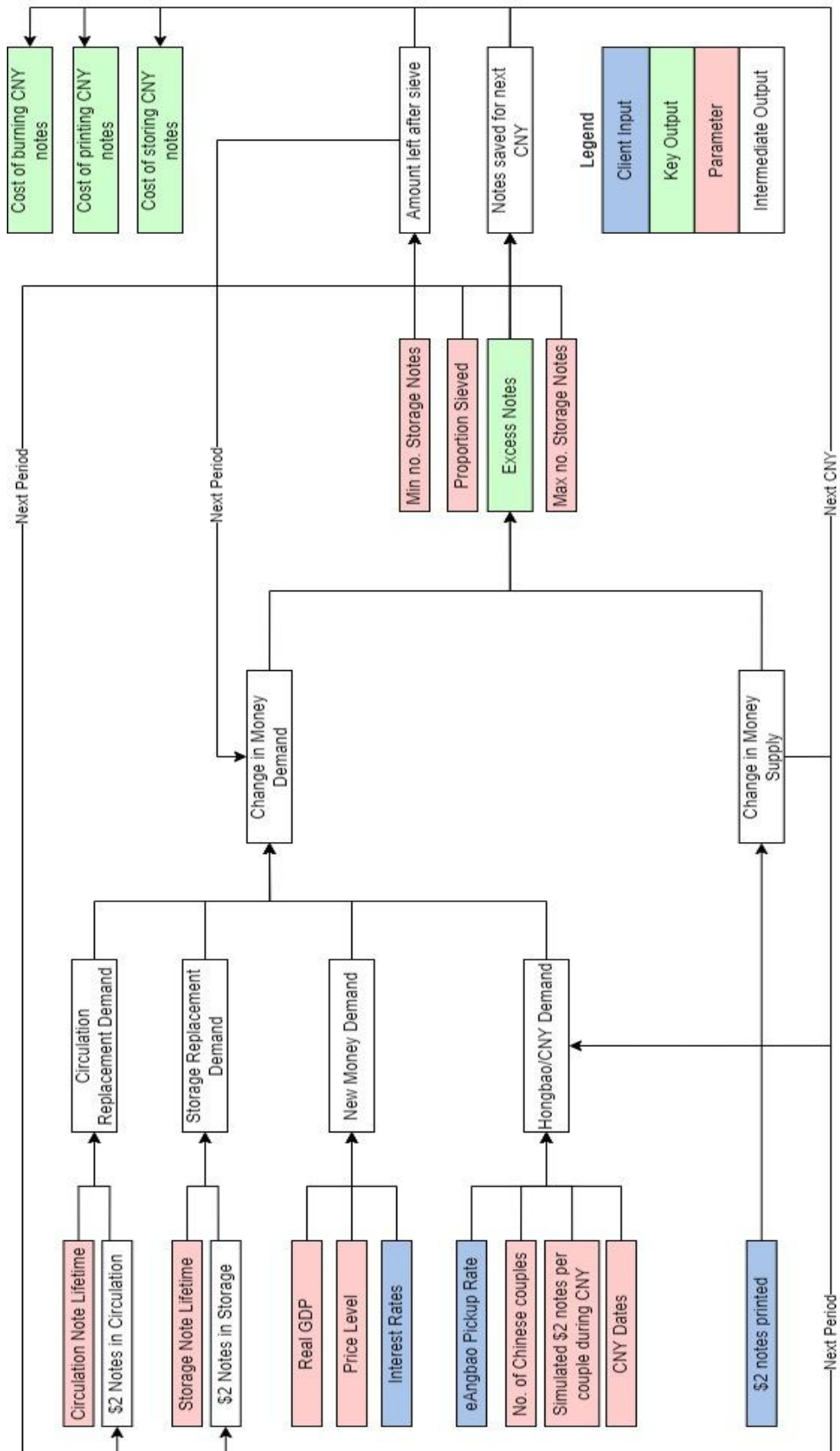
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Federal Reserve. (n.d.). *FAQs - How much does it cost to produce currency and coin?* Board of governors of the Federal Reserve System. Retrieved April 4, 2022, from https://www.federalreserve.gov/faqs/currency_12771.htm

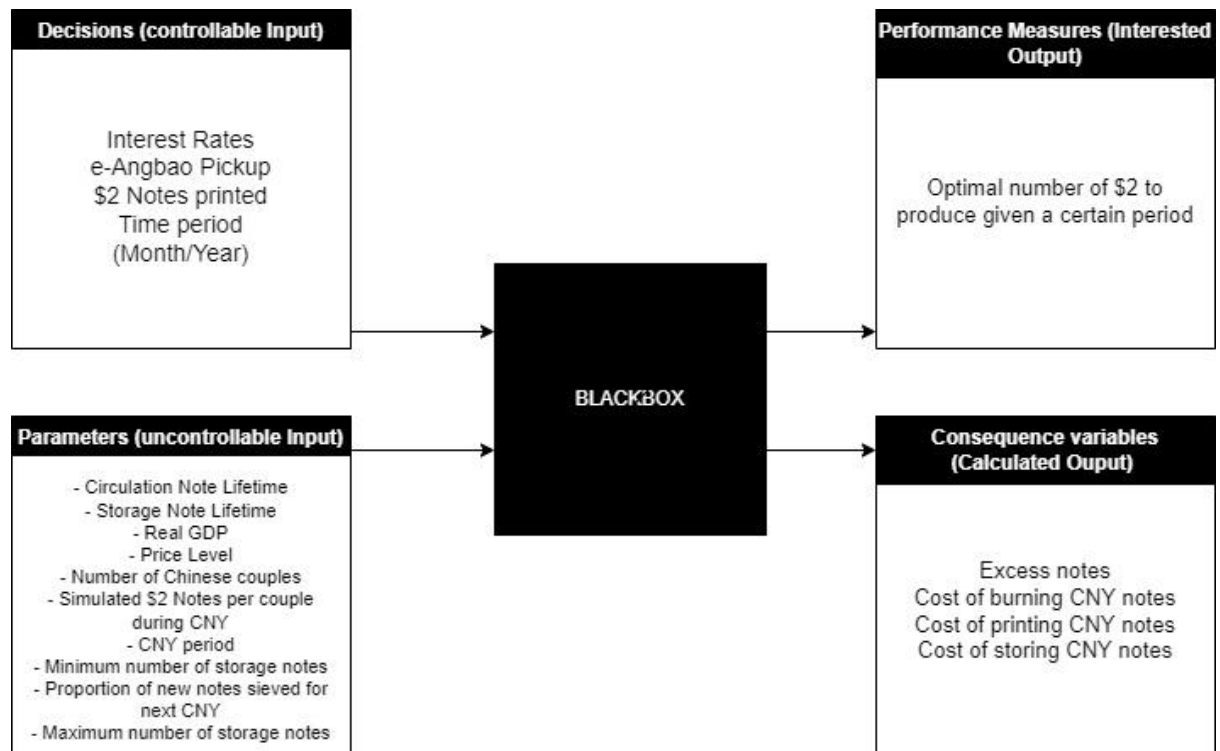
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12. Model Sketches

Influence Diagram



Blackbox



Appendix

Enquiry to Monetary Authority of Singapore

Enquiries on Banknotes printed for Chinese New Year

↩ ⏪ ⏩ ↪



📧 Akshay BRYAN <akshayb.2021@accountancy.smu.edu.sg>

Wednesday, 16 February 2022 at 1:00 PM

To: webmaster@mas.gov.sg; press_officer@mas.gov.sg; Cc: 📧 Erica TAN Ruilin; 📧 YANG Tze Ying; +2 more ▾

Hi,

My name is Akshay and I am an undergraduate student from the Singapore Management University. I am currently doing a spreadsheet modelling group project about the recent rise of online payments with my team members (CC'ed in this email). More specifically, we would like to understand and study the trends of e-hong baos being exchanged during the Chinese New Year period and its impact on the demand for new banknotes over the past few years.

From our research thus far, we were only able to find that MAS prints out approximately 100 million pieces of new banknotes each year. Hence, we were wondering if you could kindly provide us with information on how many new banknotes, in each denomination, are produced specifically for Chinese New Year and how many are returned to the banks and eventually to MAS to be incinerated over the past 12 years (2010 to 2022)?

We hope that you would kindly provide us with the data as it will be highly beneficial for us to understand the rising trend of online payments.

Thank you.

Regards,
Akshay Bryan

Reply from Monetary Authority of Singapore

Enquiries on Banknotes printed for Chinese New Year

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📧 webmaster@mas.gov.sg <webmaster@mas.gov.sg>

Monday, 21 February 2022 at 1:46 PM

To: 📧 Akshay BRYAN

Case Reference Number: MAS-2022-02-01021

Please quote the entire highlighted text should you need to contact MAS on this matter.

Hi Akshay Bryan,

Thank you for your email.

While MAS issues approximately 100 million pieces of new notes yearly, only the \$2 notes issued during Lunar New Year (LNY) are in excess of circulation demand as we observed that a large proportion is returned to MAS after LNY. The new notes of the remaining denominations issued for LNY are used to replace unfit notes withdrawn from circulation and meet increase in circulation demand. Based on the trend of past few years' LNY new notes exchanges, 60% – 80% of the new notes issued were \$2 denomination and we have seen reduction since 2018.

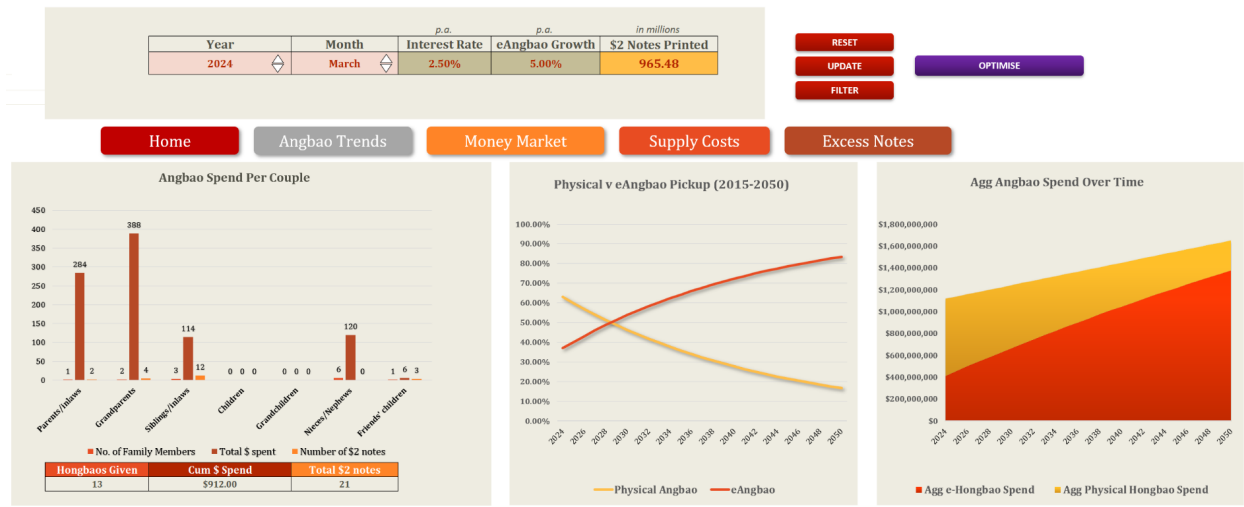
We do not have information on the quantity of newly issued notes (i.e. exchanged during the LNY period) that are subsequently returned by the public after the LNY. For the \$2 notes deposited immediately after LNY, MAS will sieve through them and harvest about 20% as Good-As-New notes to reissue in the following year's LNY. The remaining used notes that are still fit for normal circulation, will replace unfit notes withdrawn from circulation or older notes kept in storage, both of which are then destroyed.

Best regards,
Sherry THENG
Corporate Communications Division
Monetary Authority of Singapore
Email: webmaster@mas.gov.sg
Website: <https://www.mas.gov.sg>

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Results (tabulations, charts)

Angbao Trends



Bottom left graph: Hongbao Spend per couple

This graph simulates 1 married Chinese couple’s expenditure on Hongbaos given a certain time period. Details like the number of Hongbaos given out, total amount spent, and the total number of \$2 notes used.