# E-Payment Systems and Cryptocurrency Technologies

https://course.ie.cuhk.edu.hk/~ftec4004

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# Acknowledgements


- The slides used in this lecture are mostly adapted from the following sources. The copyrights and contribution of the original authors are hereby acknowledged and recognized:
  - **The Electronic Payment Systems course by Prof. Michael Shamos, CMU**
  - World Payments Report 2019, Capgemini Research Institute
  - McKinsey&Company, “Global Payments 2018: a dynamic industry continues to break new ground”, Oct 2018.
  - John Hill, Fintech and the Remaking of Financial Institutions, Academic Press 2018
  - Speech by Thomas J. Jordan, Chairman of the Governing board, Swiss National Bank, “How money is created by the central bank and the banking system,” Jan 16, 2018, https://www.bis.org/review/r180118c.pdf
  - Eswar Prasad, “Central Banking in a Digital Age: Stock-taking and Preliminary Thoughts,”, April 2018, https://www.brookings.edu/wp-content/uploads/2018/04/es_20180416_digitalcurrencies.pdf
  - Vivien Lee and David Wessel, “Digital Currencies: Five big implications for central banks,” May 2018, https://www.brookings.edu/blogAcademic Press/up-front/2018/05/21/digital-currencies-five-big-implications-for-central-banks/
  - Robert E. Litan and Martin Neil Baily, Editors, Moving Money: The Future of Consumer Payments, Brookings Institution Press, 2009.
  - Banking and Electronic Fund Transfer, OCDE, OCED, 1983.
  - Brett King, Breaking Banks -The Innovators, Rogues, and Strategists Rebooting

# Course Objectives

- Understand money and its movement
- Understand foreign exchange
- Learn how money is made electronic
- Learn the role of Electronic Payments in emerging economy
- Understand the technical principles and system architecture of electronic payment systems/ technologies
- Understand how major types of payment systems work; appreciate and be able to analyze and compare their risks and advantages

# Course Outline

- Introduction to Money and Banking
- Automated Clearing and Settlement
- *Quick Recap on Crypto Basics which enable Secure Payment Systems*
- Overall Landscape of E-payment Systems
- Credit Card system
- P2P payment systems, e.g. Paypal
- Stored-Value Facilities (SVFs), e.g. Smartcards, RFID, NFC, Octopus card
- Digital Wallet and Mobile Payment Systems
- Crypto-currencies and related Technologies, e.g. Blockchains, Bitcoin, Ethereum, Smart Contracts,
- Central Bank Digital Currencies (CBDC)
- Time-permitting: Failed E-Cash/ Micro-Payment Protocols

# Lecture Outline

- Nature of money
- What is a payment?
- What is a payment system?
- Desirable properties of money
- Payment system requirements
- Payment risks
- What banks do
- Foreign exchange

# What is Money ?

# What is Money ?

- A Medium of Exchange
- A Unit of Account (pricing of services and goods)
- Storage of Value

# Money Supply in the U.S.

**Used**

- By households and businesses
- To make payments and to be held as short-term investments

**Components**

- **M1** = coin and currency in circulation, plus checking accounts
- **M2** = M1 plus short-term liquid assets

**Context**

- The Fed uses M1 and M2 as a standardized way of defining money in the economy


As a share of the total values shown above, M1 dropped from 26% in 1980 to 20% in 2010.[1]

1. See PowerPoint file for technical note.

# U.S. Money Supply - Components

**M2**

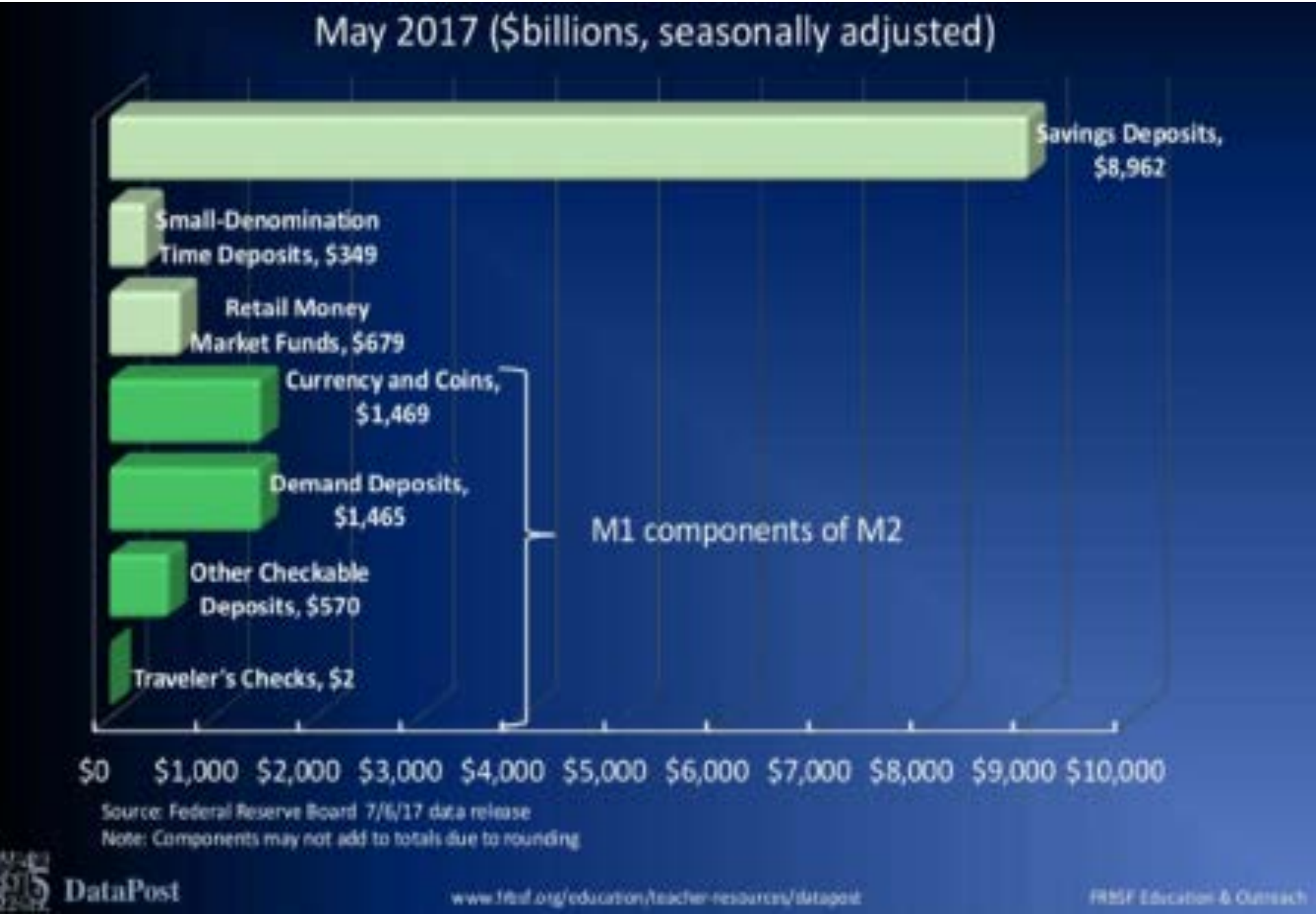
- Savings Deposits
- Time Deposits
- Certain CDs
- Money Market Deposit Accounts
- Money Market Mutual Funds
- Includes M1

**M1**

- Coin
- Currency
- Demand Deposits
- Travelers Checks


DataPost

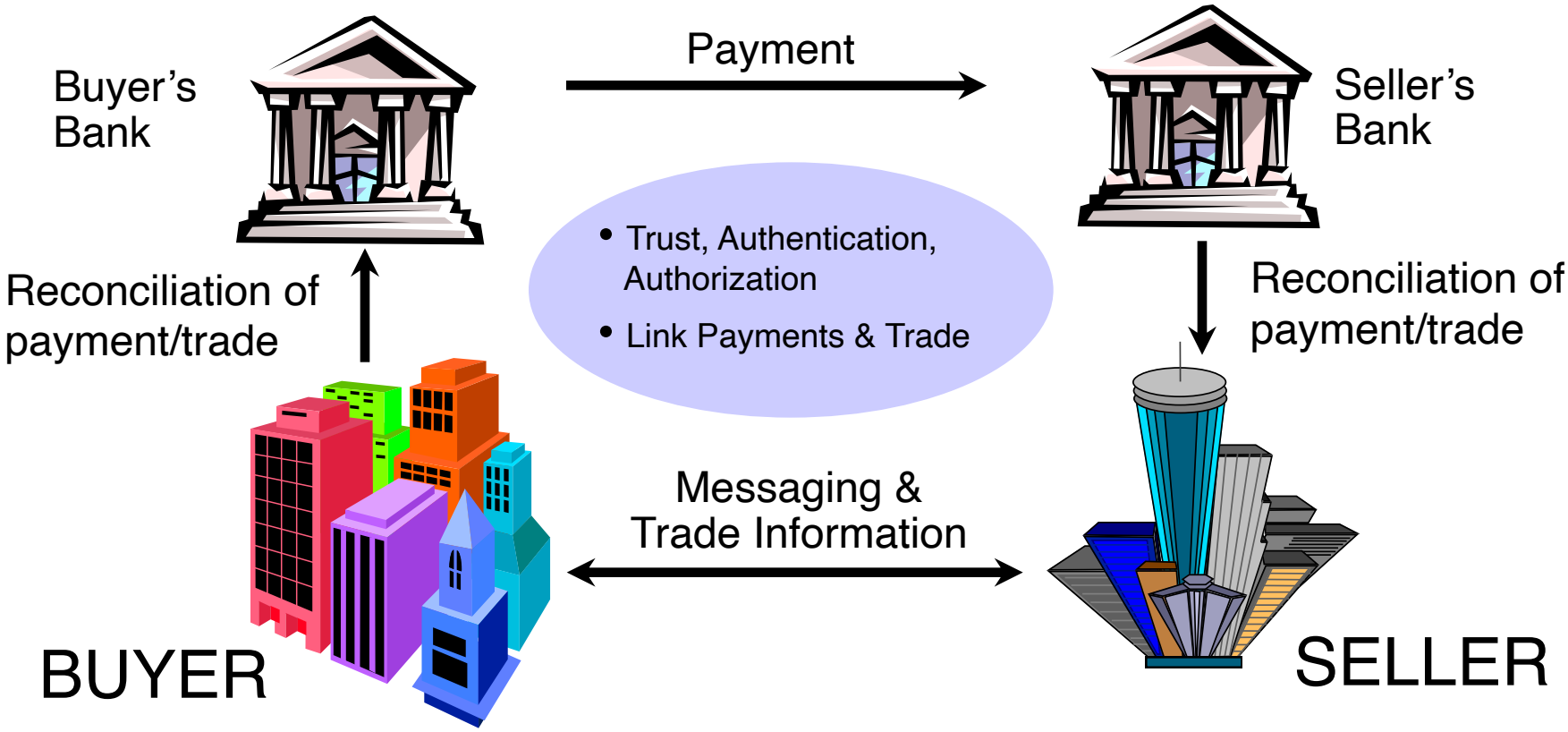
# M2 in Details



# How Much Money got exchanged ?

- U.S. interbank payments: 1.5 trillion USD per day (2015)
- World foreign exchange:  6.6 trillion USD per day (2019)
- World stock trading volume: ~100 trillion USD in 2018
- US Stock trading volume per year (2018): 33 trillion USD
  - NYSE had $169 billion traded daily on average in 2013
- Global Credit Card transactions values: 71 billion USD in 2012
- Paypal Total Payment Volume in 2019:  > 650 billions USD
- China's Mobile Payment market reached 7.1 trillion USD in 2018Q4.
- Total SVF transaction value in HK:  5 billion USD in 2018Q2

# Fundamental B2B Payment Problem



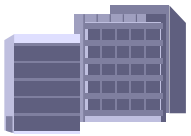

- How is authentication performed?
- How is payment made?
- How is messaging accomplished?
- How is information reconciled?
- How are exceptions handled?

SOURCE: DEBRA MITTERER

# FinNet - Financial Network for Hong Kong (subsequently replaced by SDNet/2)

Overseas Systems

Payment Systems



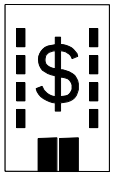
Securities Brokerage Houses

Independent Financial Planners

MPF Managers

Options Exchange

Stock Exchange



Banks

RTGS

*FinNet*

PvP

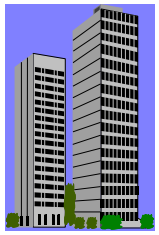
DvP

TvP

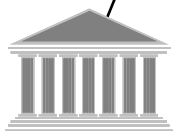
STP

Independent Insurance Agents

Futures Exchange



Insurance Companies



Regulatory Bodies

Law Firms

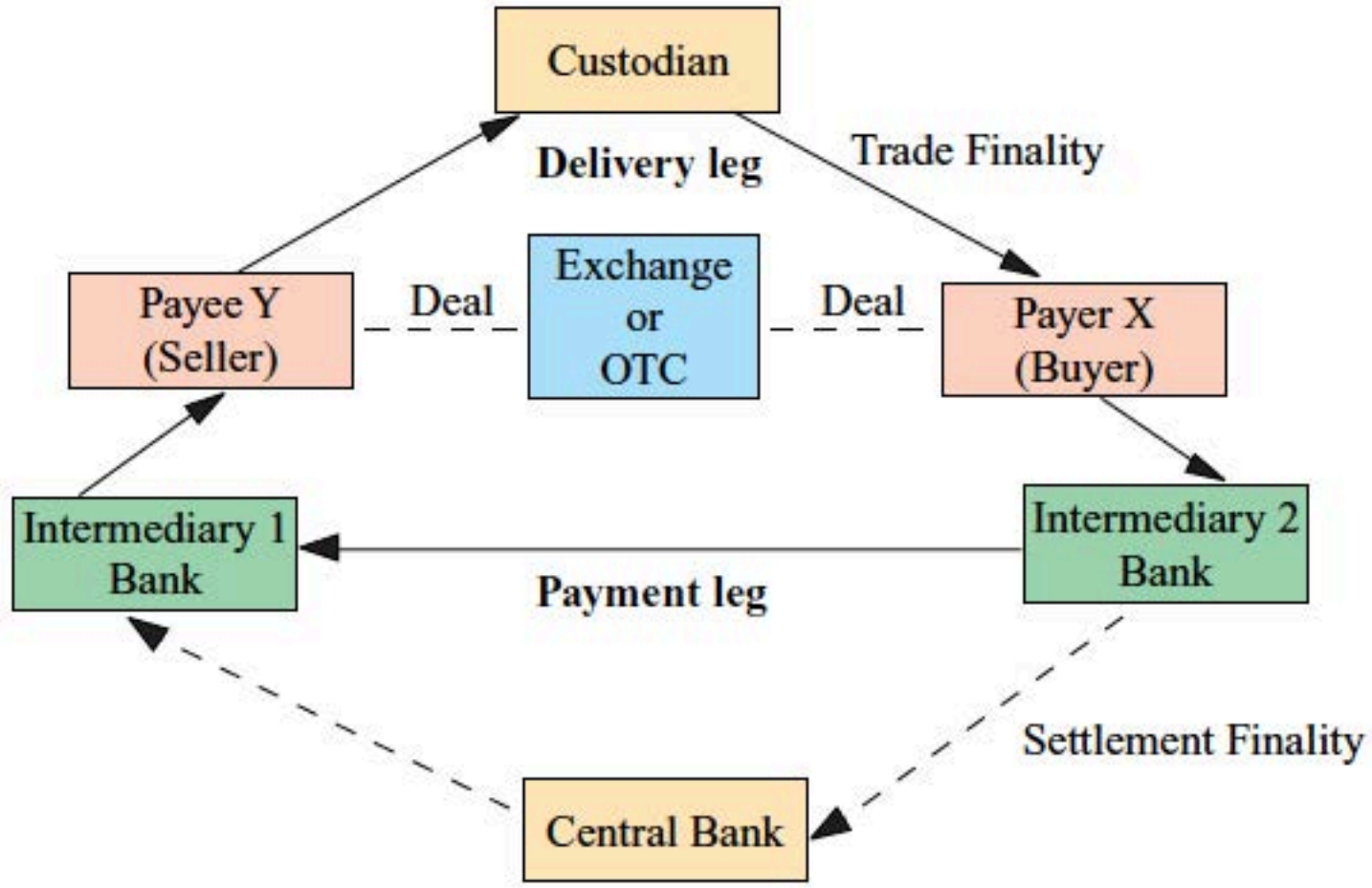
Independent Mortgage Brokers

Boutique Financial Companies

MPF = MANDATORY PROVIDENT FUND
STP = STRAIGHT-THROUGH PROCESSING
TvP = TRANSFER V. PAYMENT

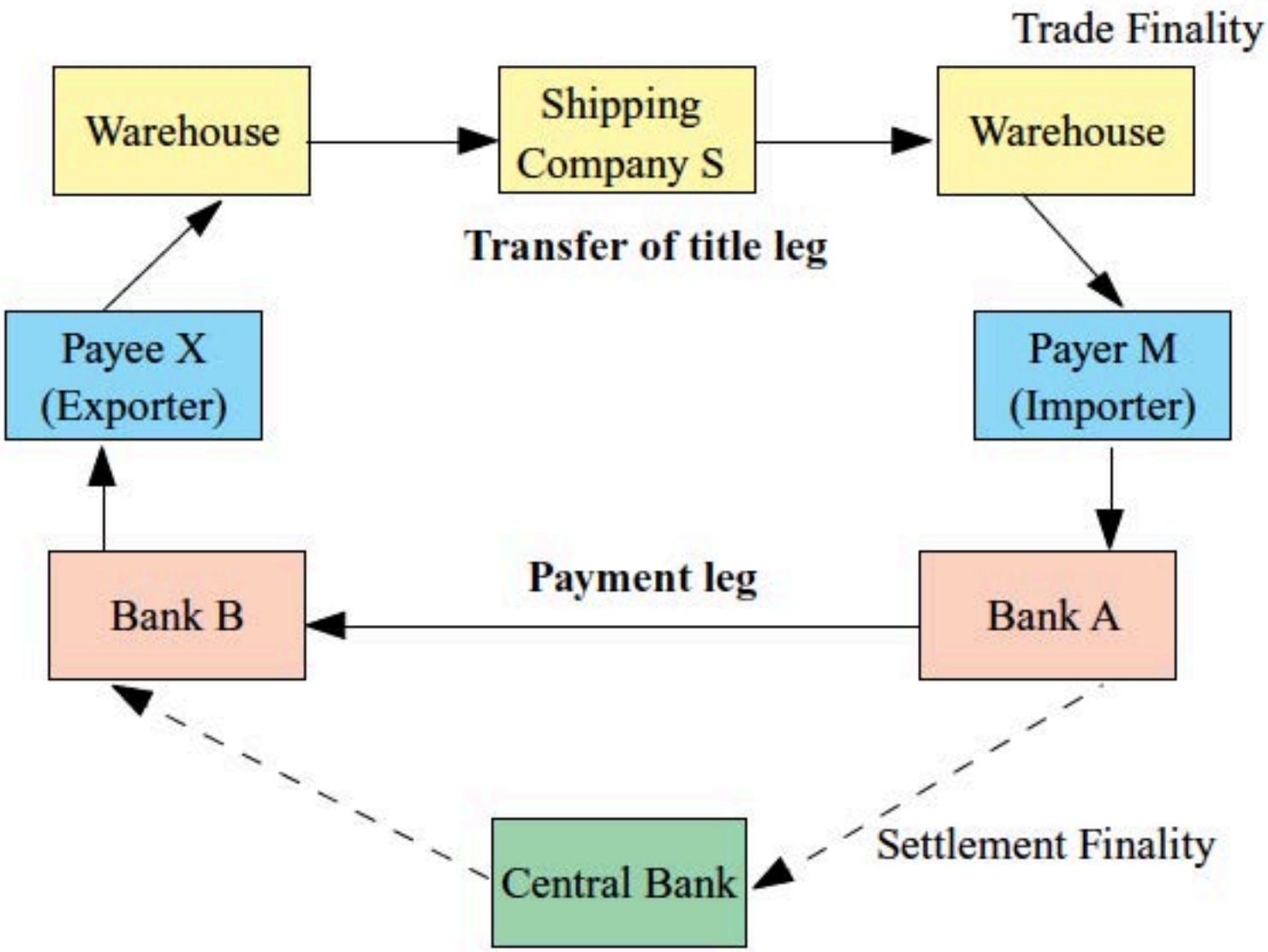
SOURCE: HONG KONG EXCHANGES AND CLEARING LTD., FINNET

**Chart 3: Delivery versus Payment Legs (DvP)**



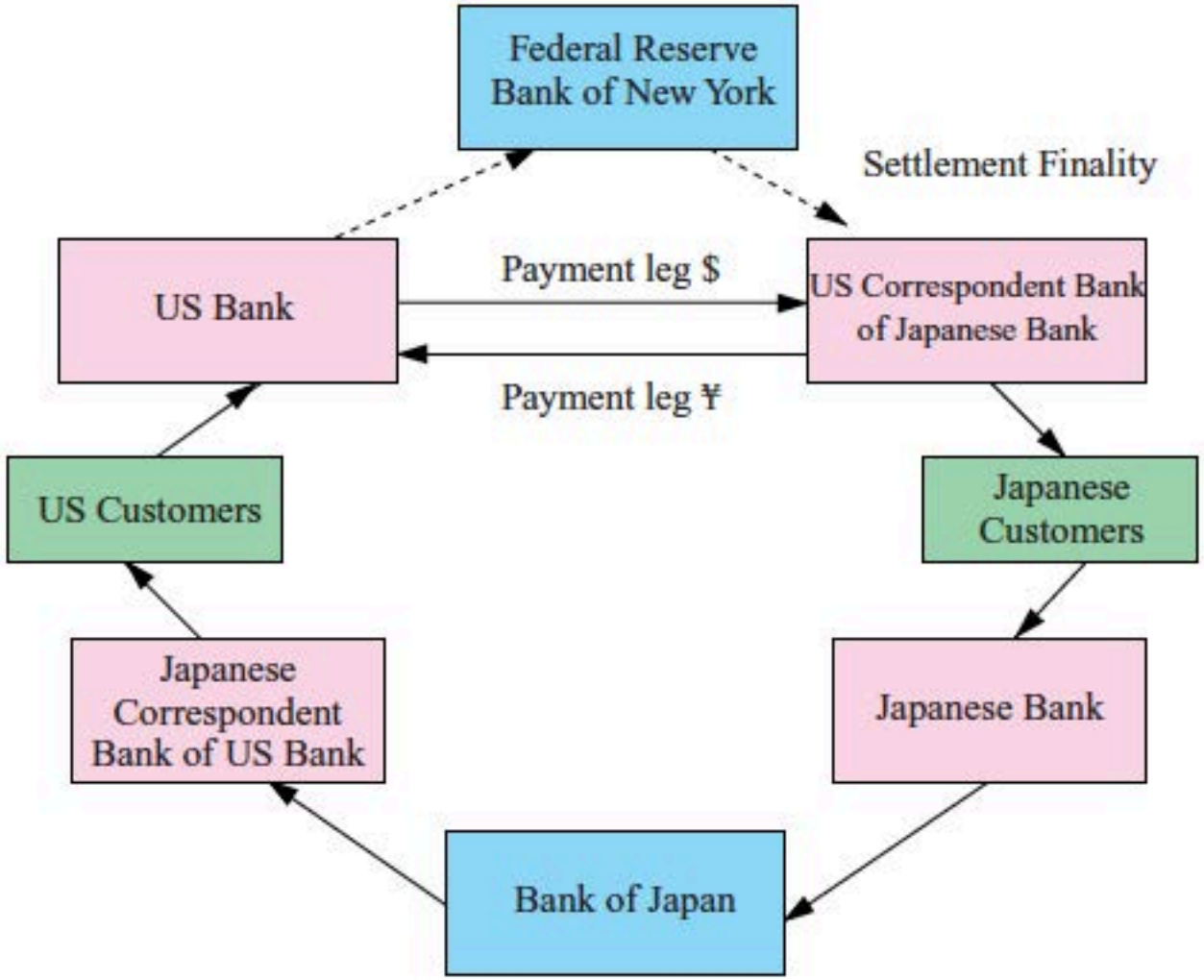

Source: Financial Technology Infrastructure for Hong Kong, HK SAR Gov, Dec 1997

**Chart 6: Transfer of title versus Payment Legs (TvP)**



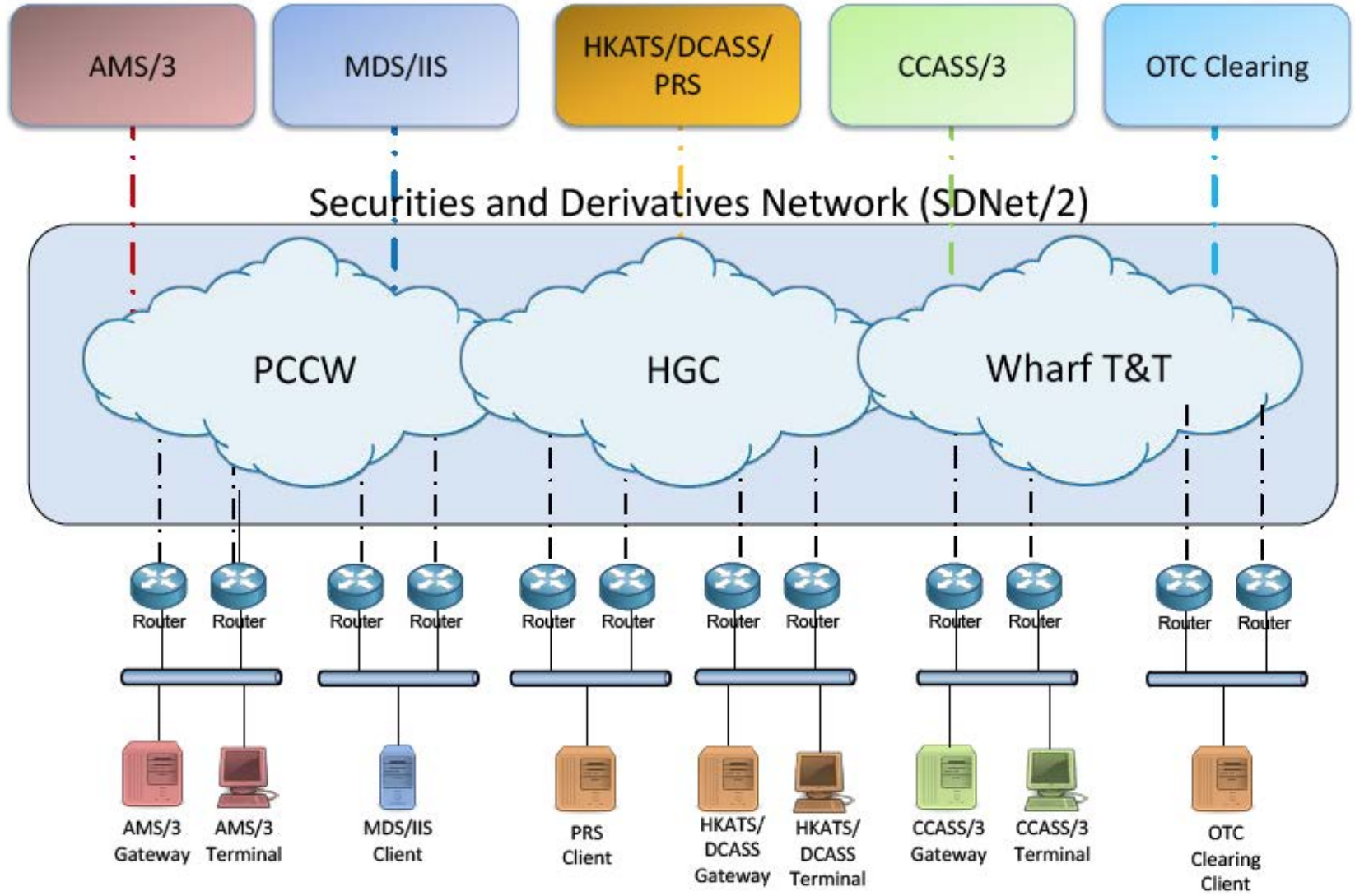

Source: Financial Technology Infrastructure for Hong Kong, HK SAR Gov, Dec 1997

## Chart 5: Payment versus Payment Legs (PvP)




Source: Financial Technology Infrastructure for Hong Kong, HK SAR Gov, Dec 1997

# The Security and Derivatives Network SDNet/ from the Hong Kong Exchange

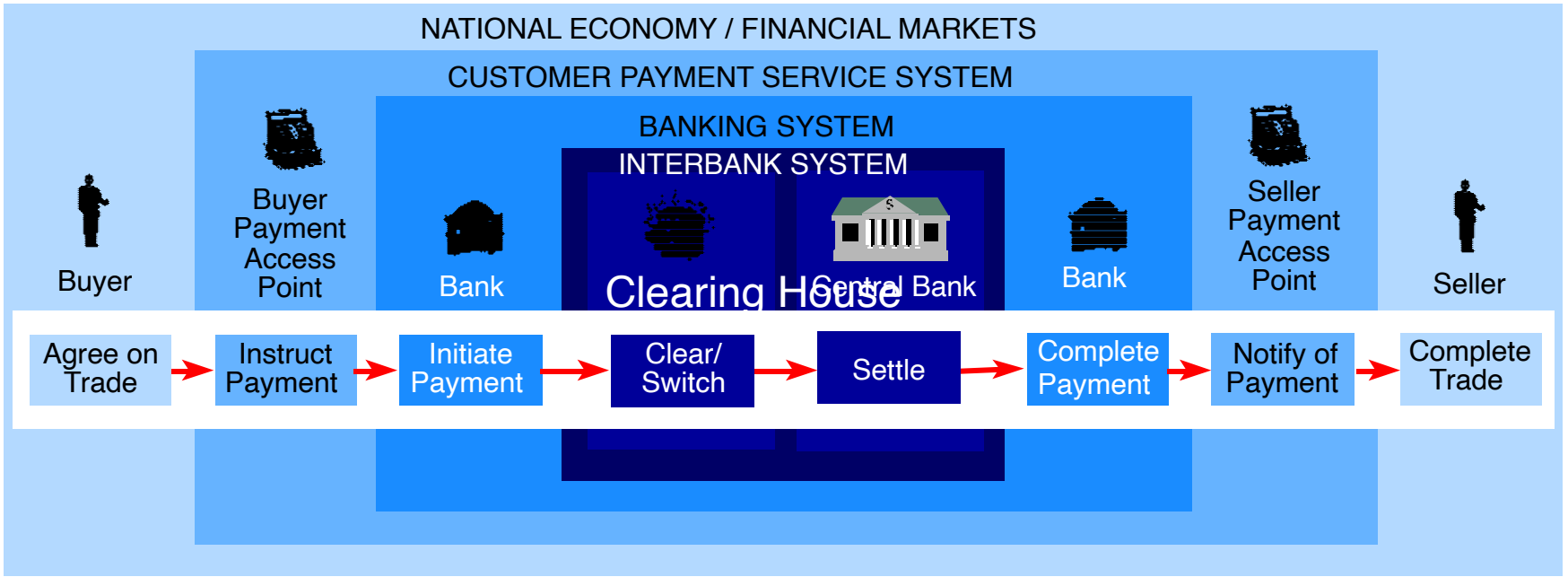



(Remark: HGC does not provide OTC connection Service)

SOURCE: HONG KONG EXCHANGES AND CLEARING LTD, Jan 2017

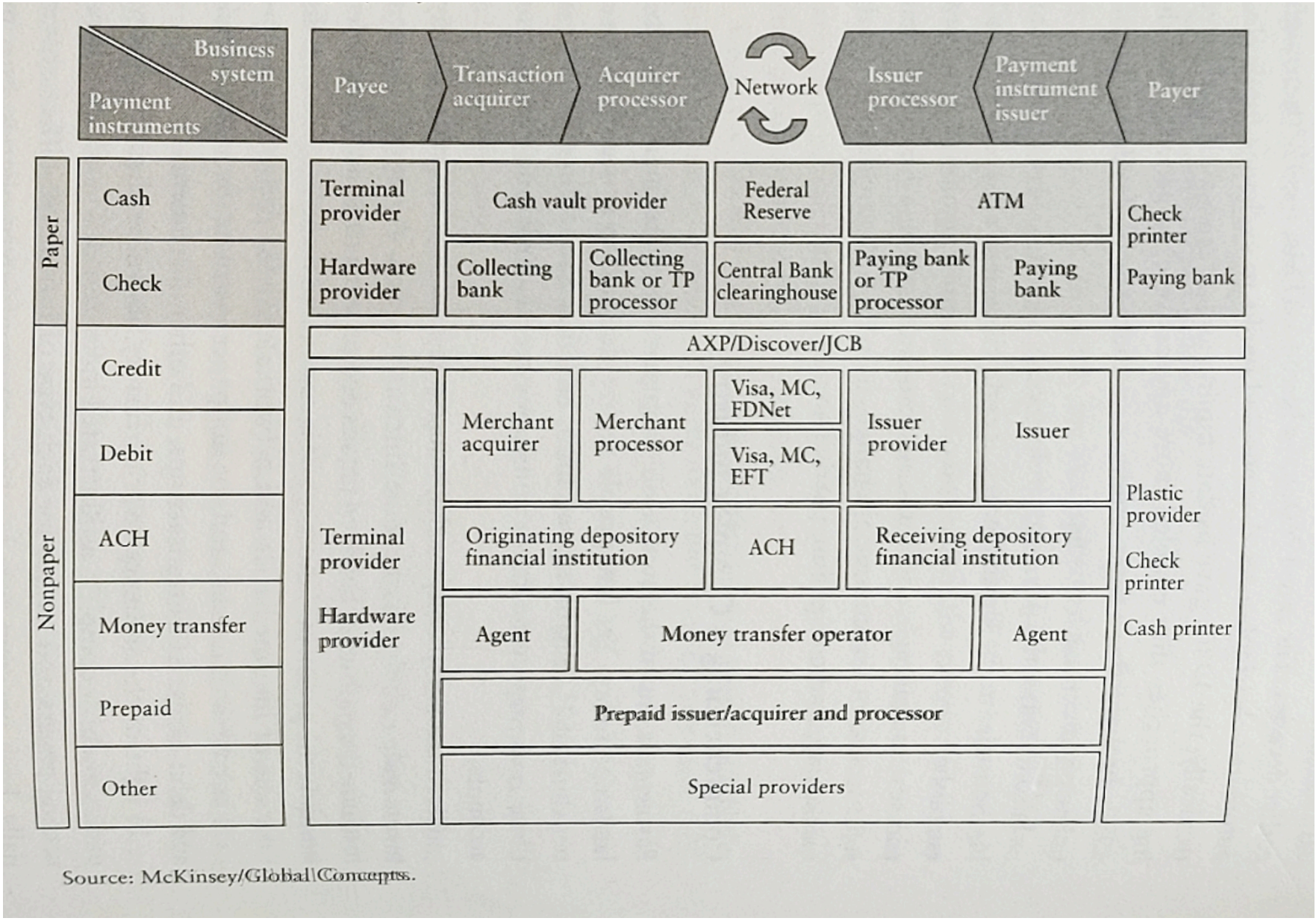
# The Payment Process

Payment is just ONE component of eCommerce,
but a VERY IMPORTANT component



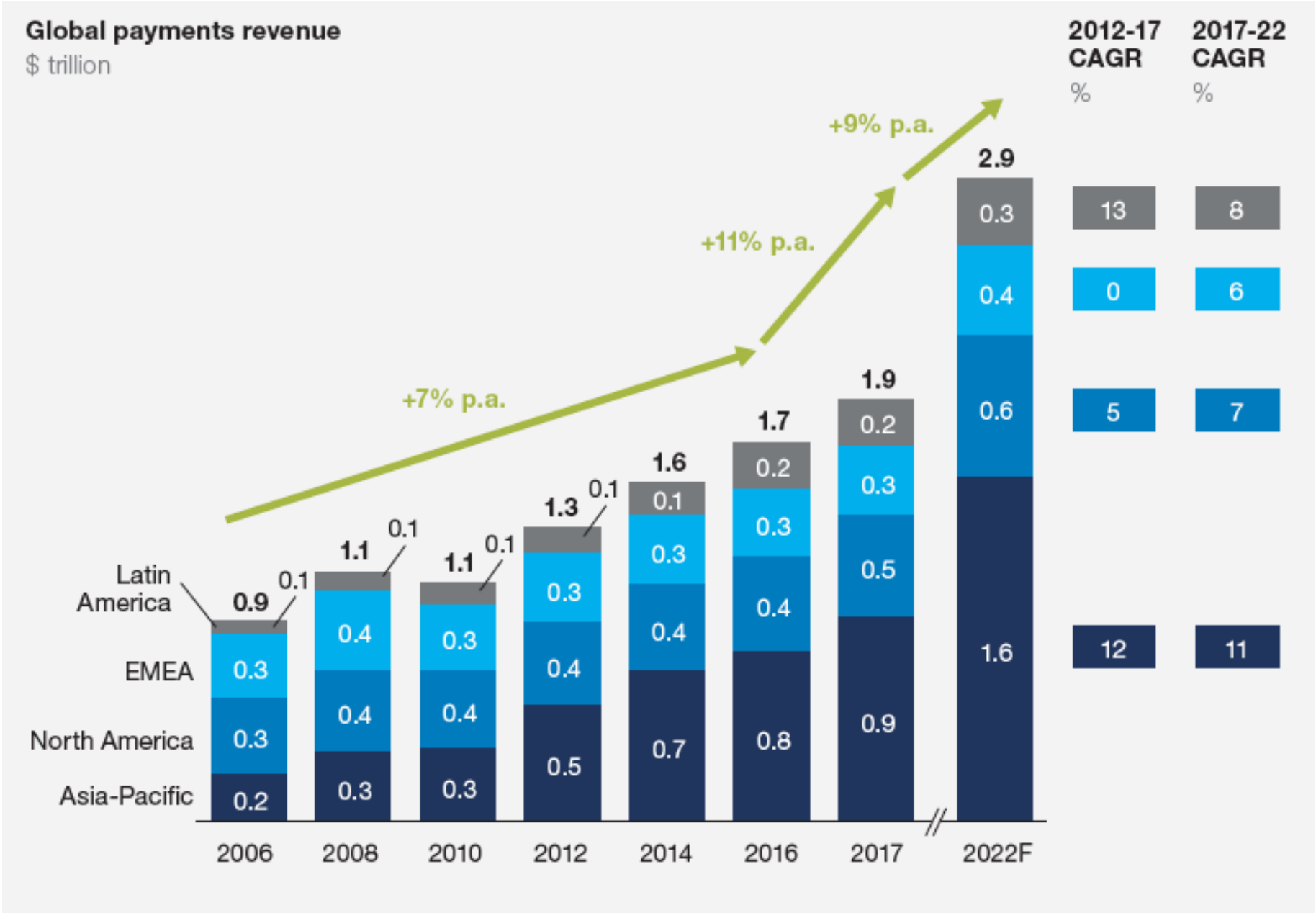

SOURCE: PHILIP TROMP, PERAGO.COM

# Complexity of Payments Value Chain



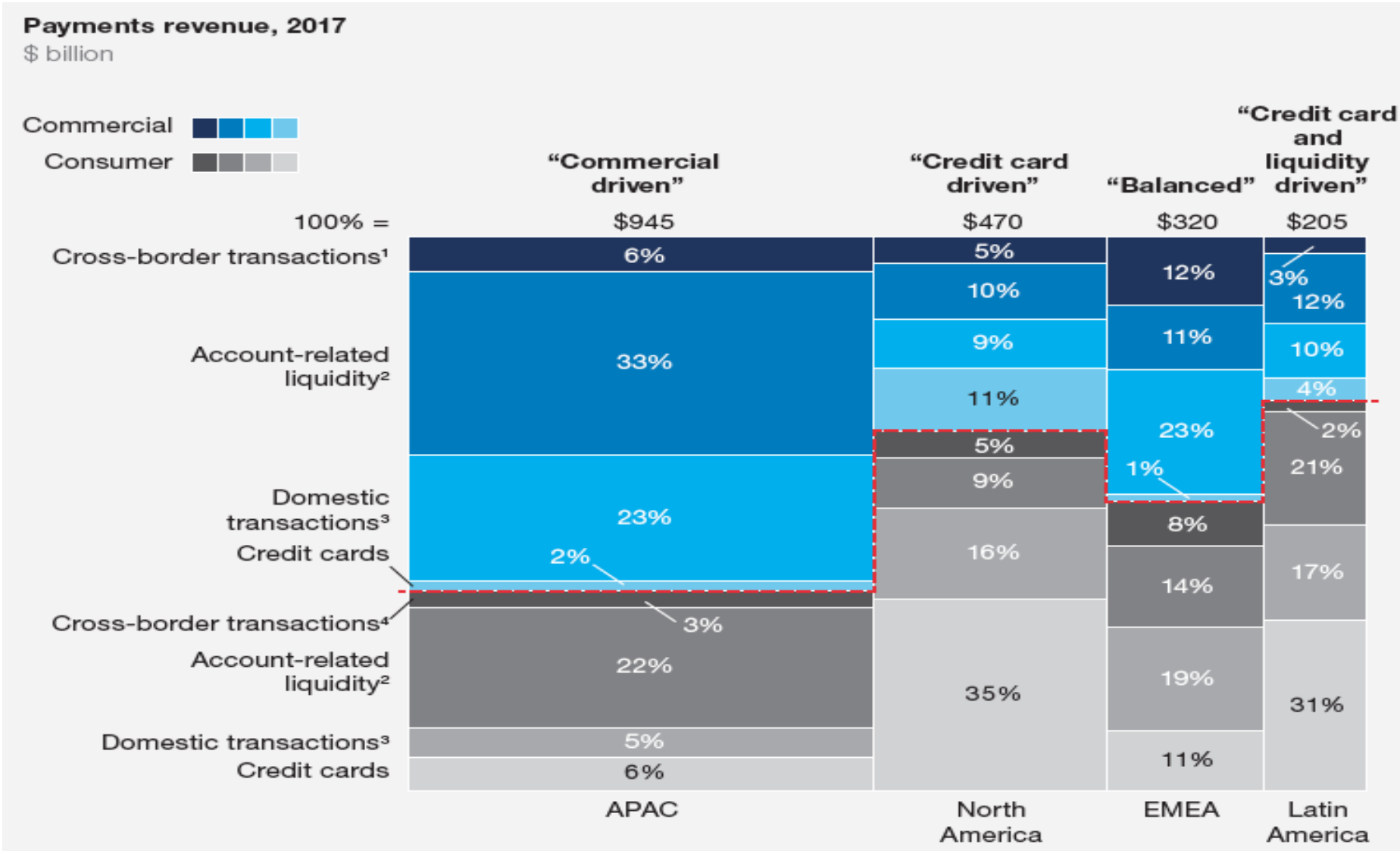

Source: McKinsey/Global Concepts.

# Global Payment Revenues



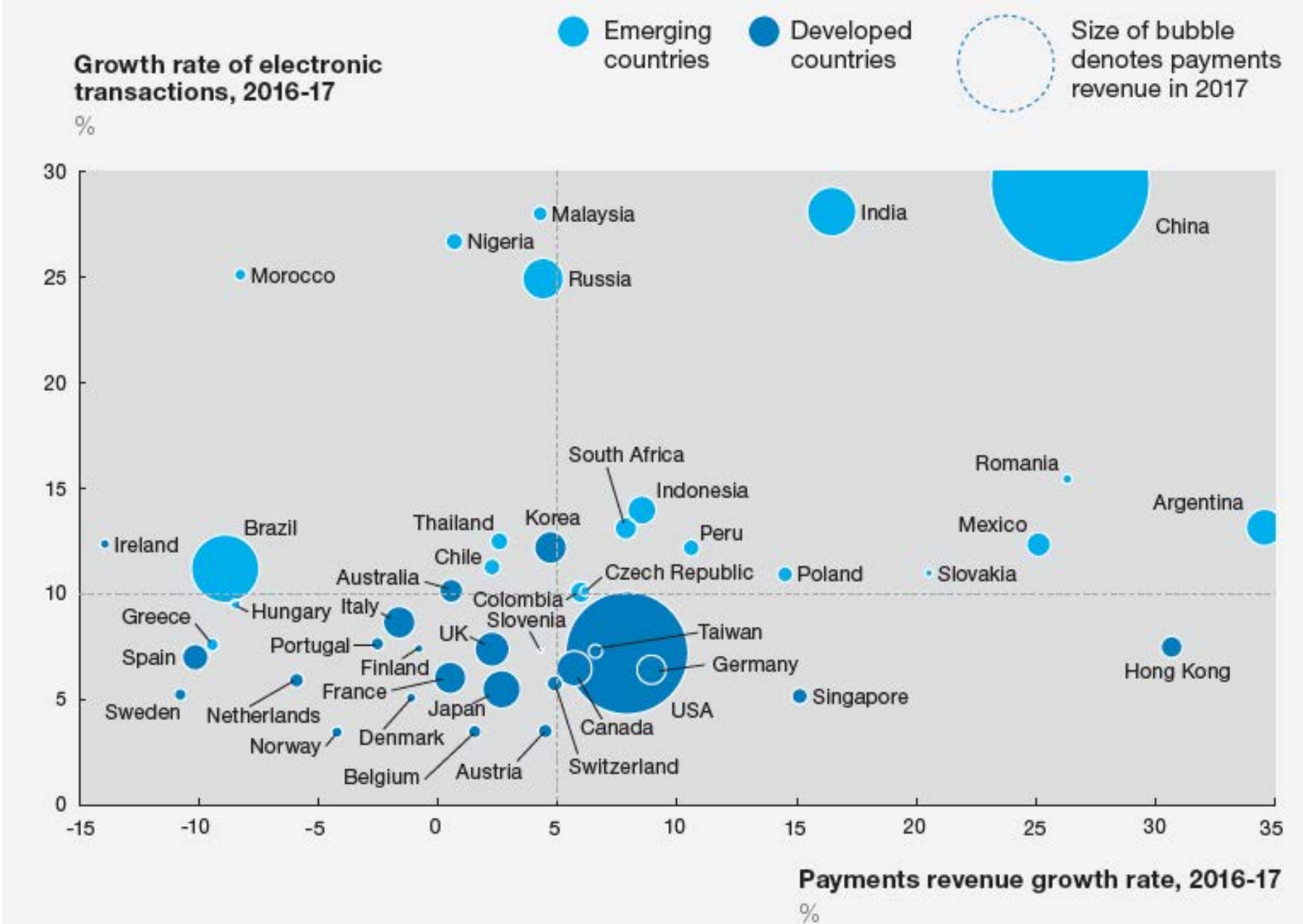

Source: McKinsey Global Payments Map

# Global Payment Revenue Pool



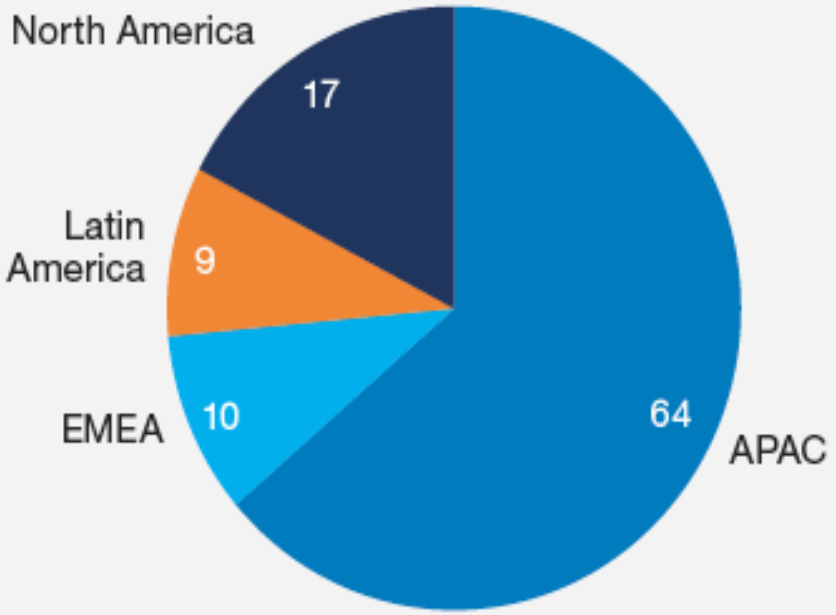

¹ Trade finance and cross-border payments services (B2B, B2C).
² Net interest income on current accounts and overdrafts.
³ Fee revenue on domestic payments transactions and account maintenance (excluding credit cards).
⁴ Remittance services and C2B cross-border payments services.
Source: McKinsey Global Payments Map

# Payment Revenue Growth by Country



# Payment Revenue Growth Decomposition

**Payments revenue growth decomposition[1], 2017-22**
% (100% = $1,022 billion)




**Payments revenue growth decomposition[1], 2017-22**
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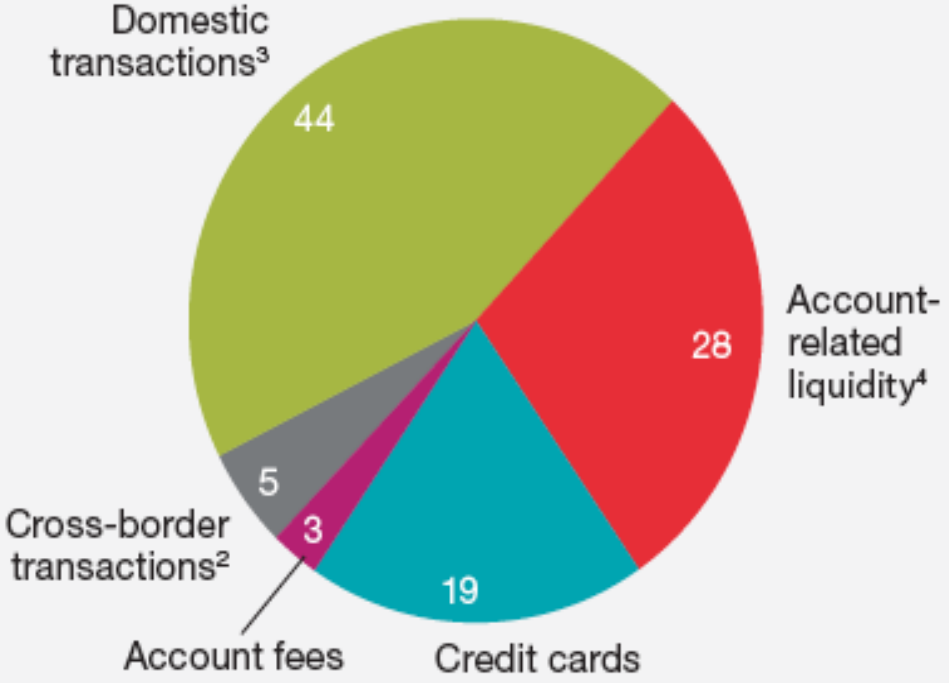



[1] At fixed 2017 USD exchange rates.
[2] Trade finance and cross-border payments services, including remittance services.
[3] Fee revenue on domestic payments transactions.
[4] Net interest income on current accounts and overdrafts.
Source: McKinsey Global Payments Map

# Global Transaction Banking Revenues

Global transaction banking revenues are estimated at nearly $1 trillion, or 43 percent of wholesale banking revenues.

**Core global transaction banking products**

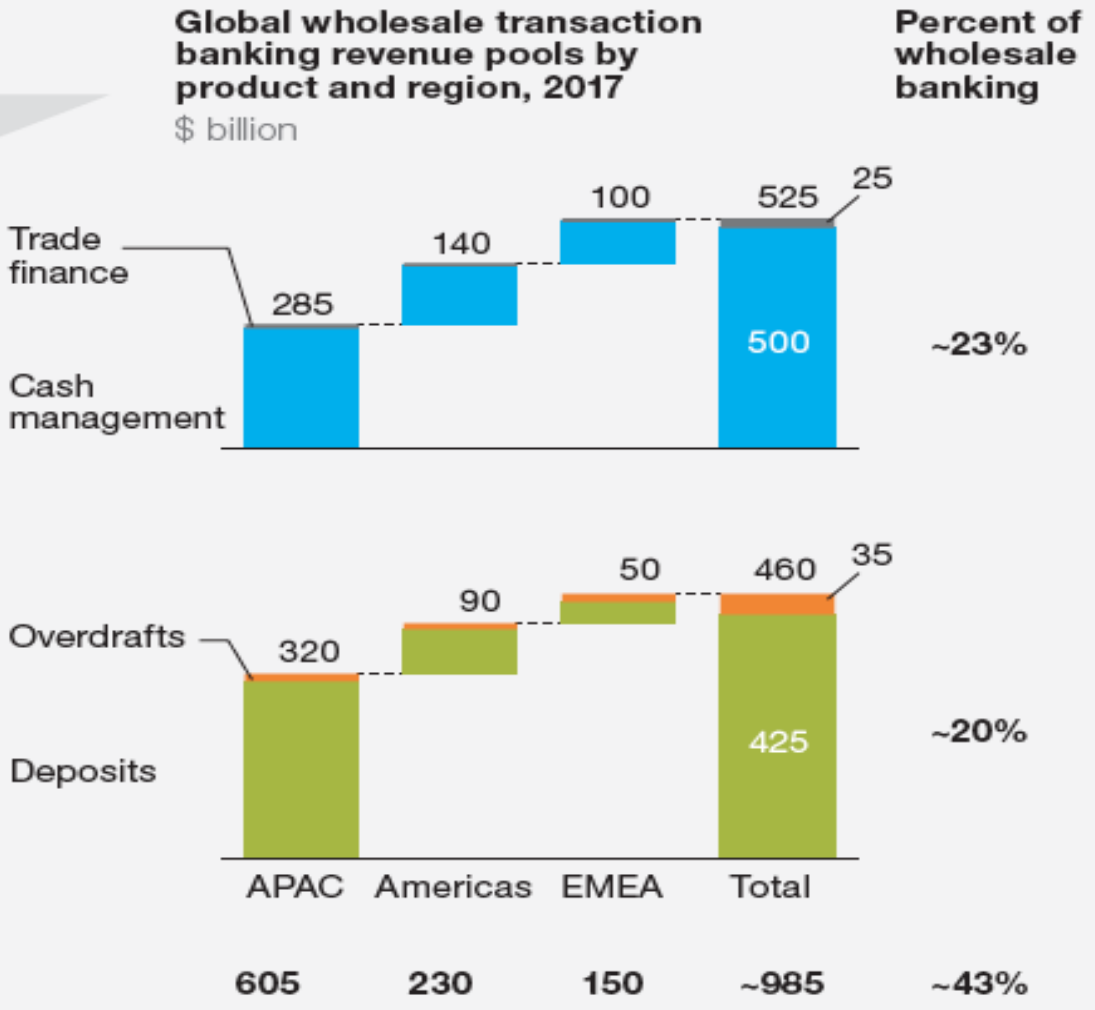
**Trade finance:** All documentary business for international trade, including letter of credit confirmation.

**Cash management:** domestic and cross-border payments, including liquidity management.

**Other working capital instruments**

**Overdrafts:** Pre-arranged or unarranged overdrafts at domestic banks.

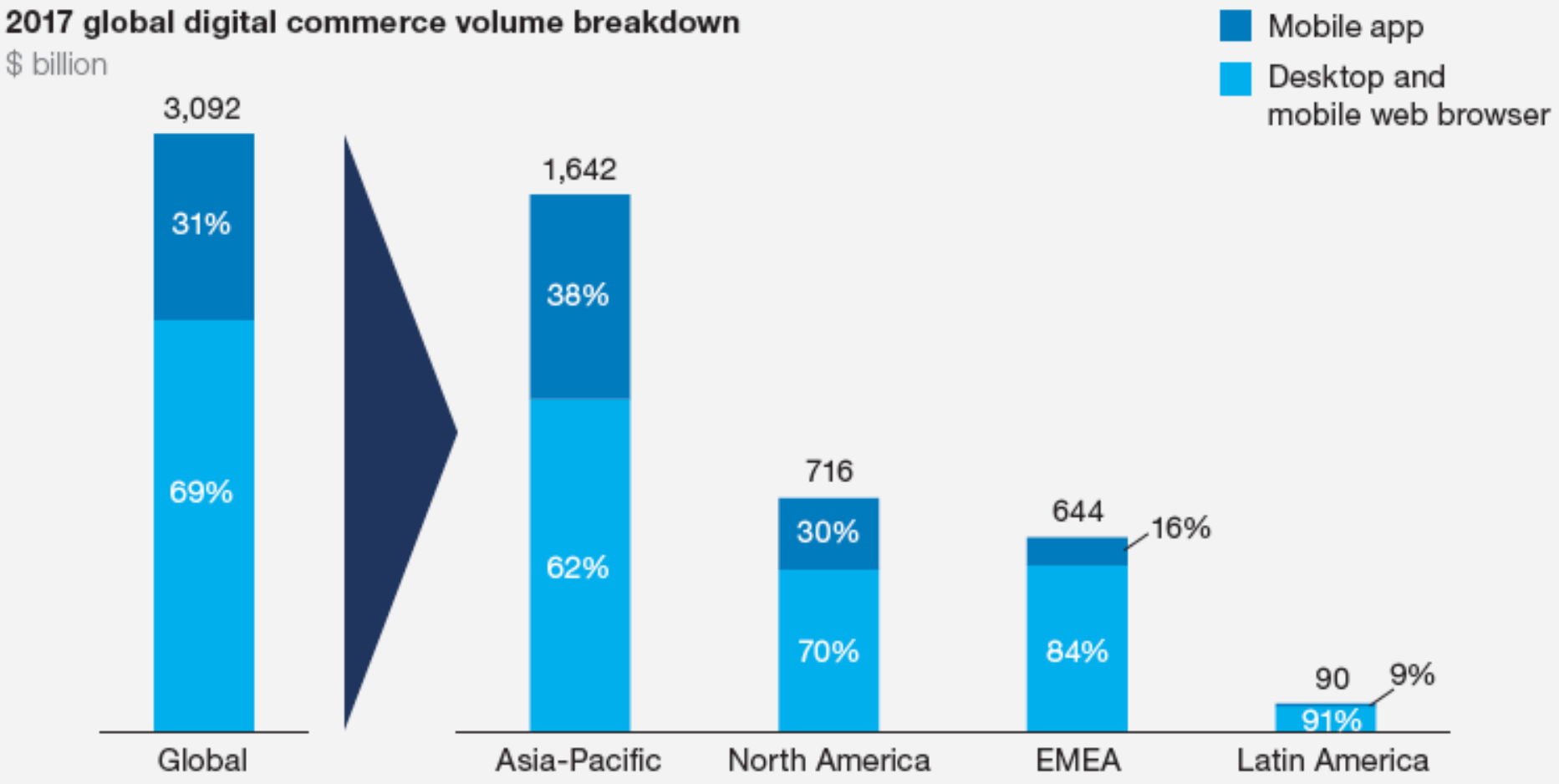
**Deposits:** C/As and transactional savings deposits at domestic banks.




Source: McKinsey Panorama Global Banking Pools; McKinsey Global Payments Map

# Mobile Apps Impact on Global Digital Commerce

Mobile apps accounted for more than 30 percent of global digital commerce volume in 2017.

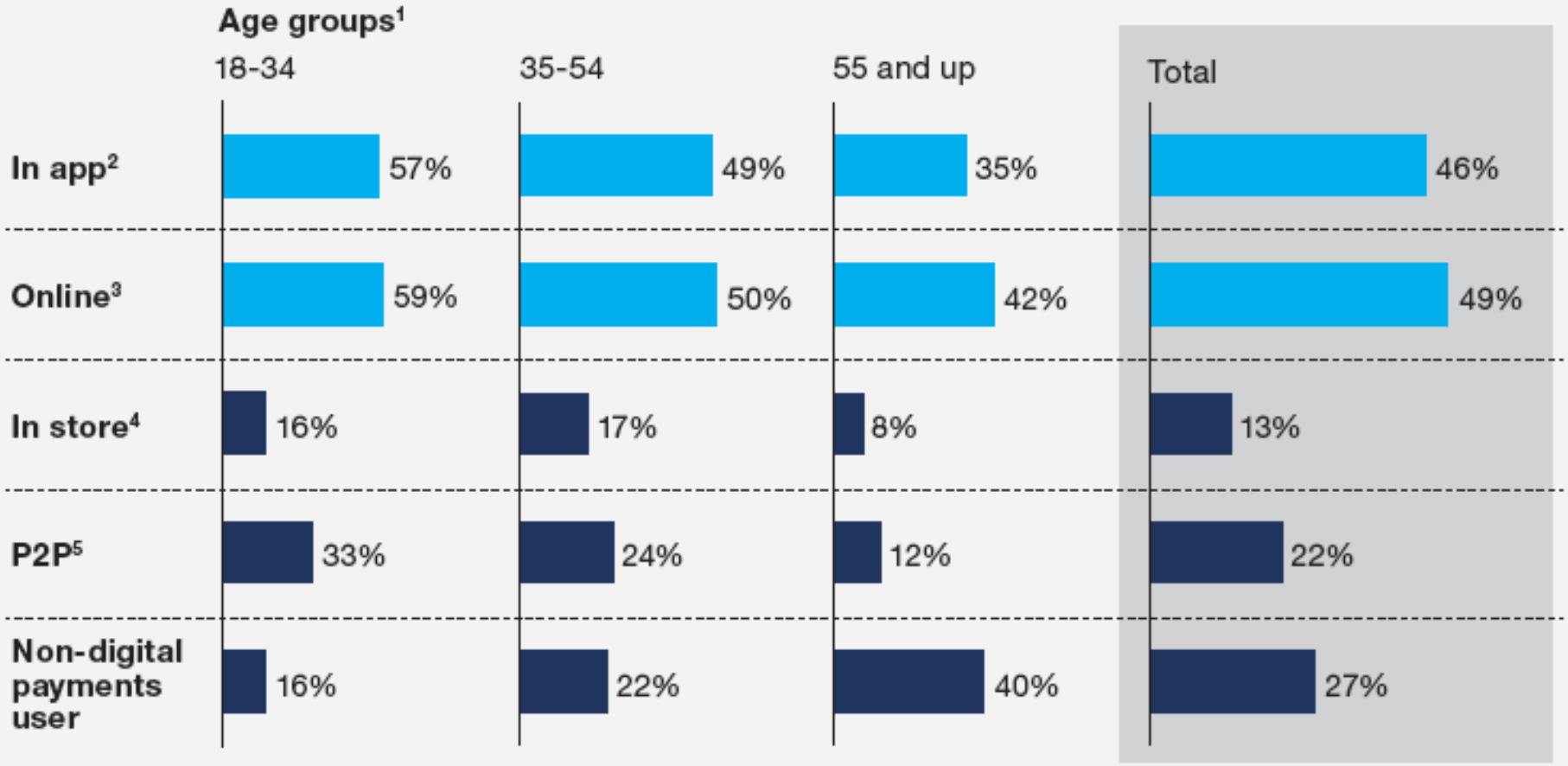



Source: GCI Analytics

# Digital Payment Penetration Rate in US

**In the past 12 months, have you performed any of these activities?**

% of respondents, US




[1] N= 18-34 (283); 35-54 (396); 55 and up (422); total (1,101)

[2] Buy things and/or pay for services using a retailer's app on my device (e.g., Amazon, Starbucks, Uber).

[3] Buy things through a website on my device (e.g., Target.com).

[4] Use my device to pay at retail locations by interacting with a terminal (e.g., Apple Pay, Android Pay, Samsung Pay, LevelUp).

[5] Transfer money to friends, family, or acquaintances through an app (e.g., PayPal, Venmo, Square Pay).

Source: McKinsey Digital Payments Survey, 2016

# Development of Money

- Definition: "***something generally accepted as a medium of exchange, a measure of value, or a means of payment.***"

Monetary History:

ABSTRACTION

- Barter (direct exchange of goods)
- Medium of exchange (arrowheads, salt)
- Coins (gold, silver)
- Tokens (paper)
- Notational money (bank accounts)

NEED BANKS

- Dematerialized schemes (pure information)

# Barter

- Direct exchange of goods and services -- possible when production exceeds individual needs
- Problem: “double coincidence of wants”
  - Trade a bicycle for a cow
  - Alice must have a bicycle and want a cow
  - Bob must have a cow and want a bicycle

  } UNLIKELY
- But: Internet allows rapid discovery of wants
- Problem: remote barter requires an escrow (or risk)
- Problem: outside the monetary and tax systems
- When money is not trusted, barter returns
- Electronic Barter Systems/ Online services exist:
  - https://electronics.howstuffworks.com/family-tech/tech-for-parents/online-bartering-websites-tips.htm

# Types of Money: Fiduciary vs. Scriptural

- Fiduciary money (fiat money, legal tender)
  - Issued by a central (government) bank
  - Has real "discharging power" (to discharge debts)
  - Cannot be refused
- Scriptural money (not legal tender)
  - Money not issued by a central bank
  - Examples: bank accounts, travelers cheques, gift certificates, Octopus
  - Discharging power based on trust in issuer
  - Can be refused

# Types of Money: Token vs. Notational

- Token money
  - Represented by a physical article (e.g. cash)
  - Can be lost
- Notational money
  - Examples: bank accounts, frequent flyer miles
  - Electronic (scriptural) money: wide recognition
  - Jeton = electronic token with limited recognition
- Hybrid money
  - Check/ Cheque
  - Telephone card (carries Jetons for future service)

# The Money Matrix

| | TOKEN | NOTATIONAL | HYBRID |
|---|---|---|---|
| **FIDUCIARY** | • CASH<br>• GOVERNMENT BEARER BOND | • ACCOUNT WITH CENTRAL BANK | • GOVERNMENT CHECK |
| **SCRIPTURAL** | • CERTIFIED CHECK<br>• TRAVELER'S CHECK | • BANK ACCOUNT<br>• FREQUENT FLYER MILES | • PERSONAL CHECK<br>• GIFT CERTIFICATE |

# Specialized Payment Instruments

- Money order (allows named person to claim money)
- Traveler's check (limited to one spender)
- Gift certificate (limited to one merchant)
- Coupons, food stamps (limited to certain goods)
- Bill of Lading (sight draft), Letter of Credit
  - Purpose: atomicity (connect goods and payment)

# Trends in Non-Cash Payments

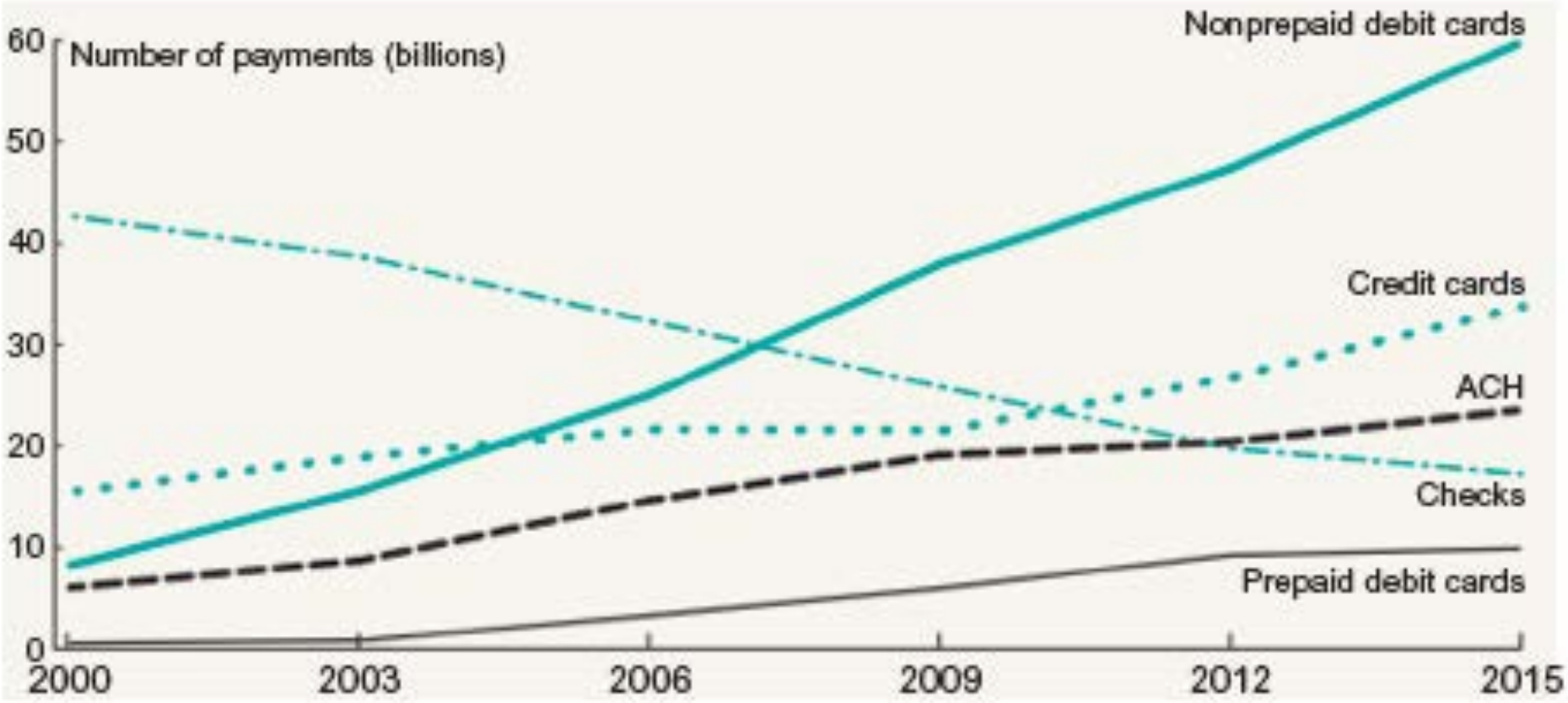
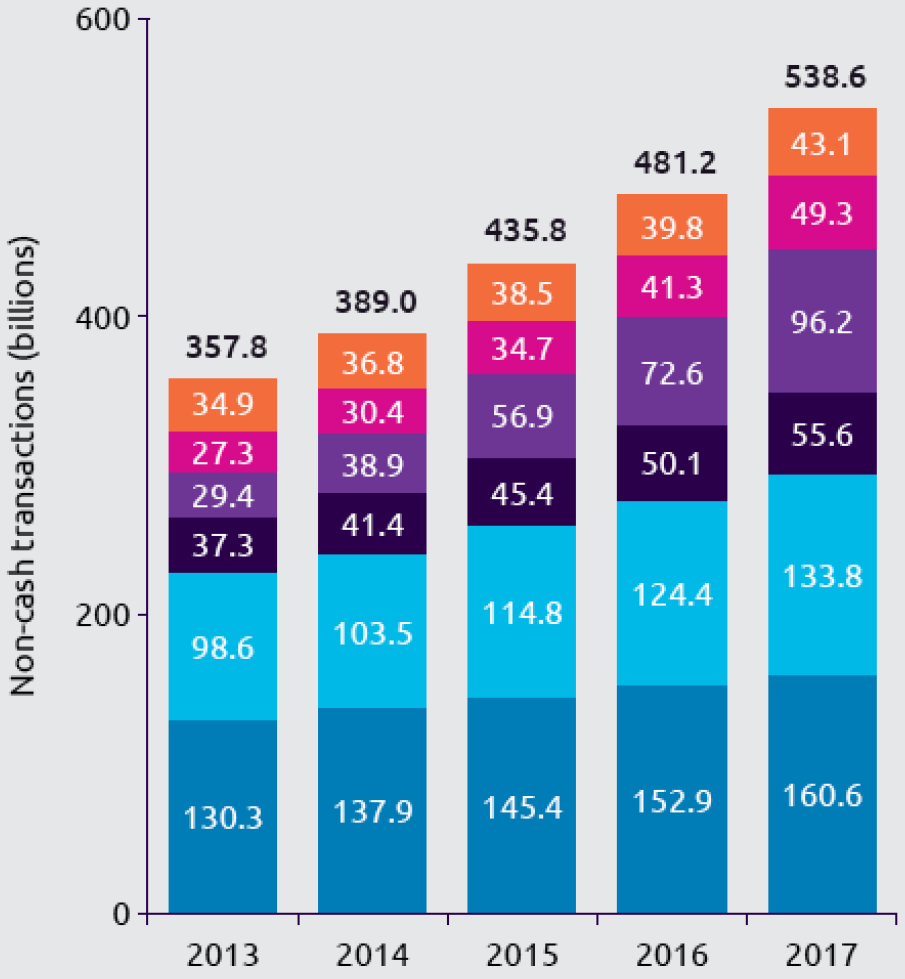


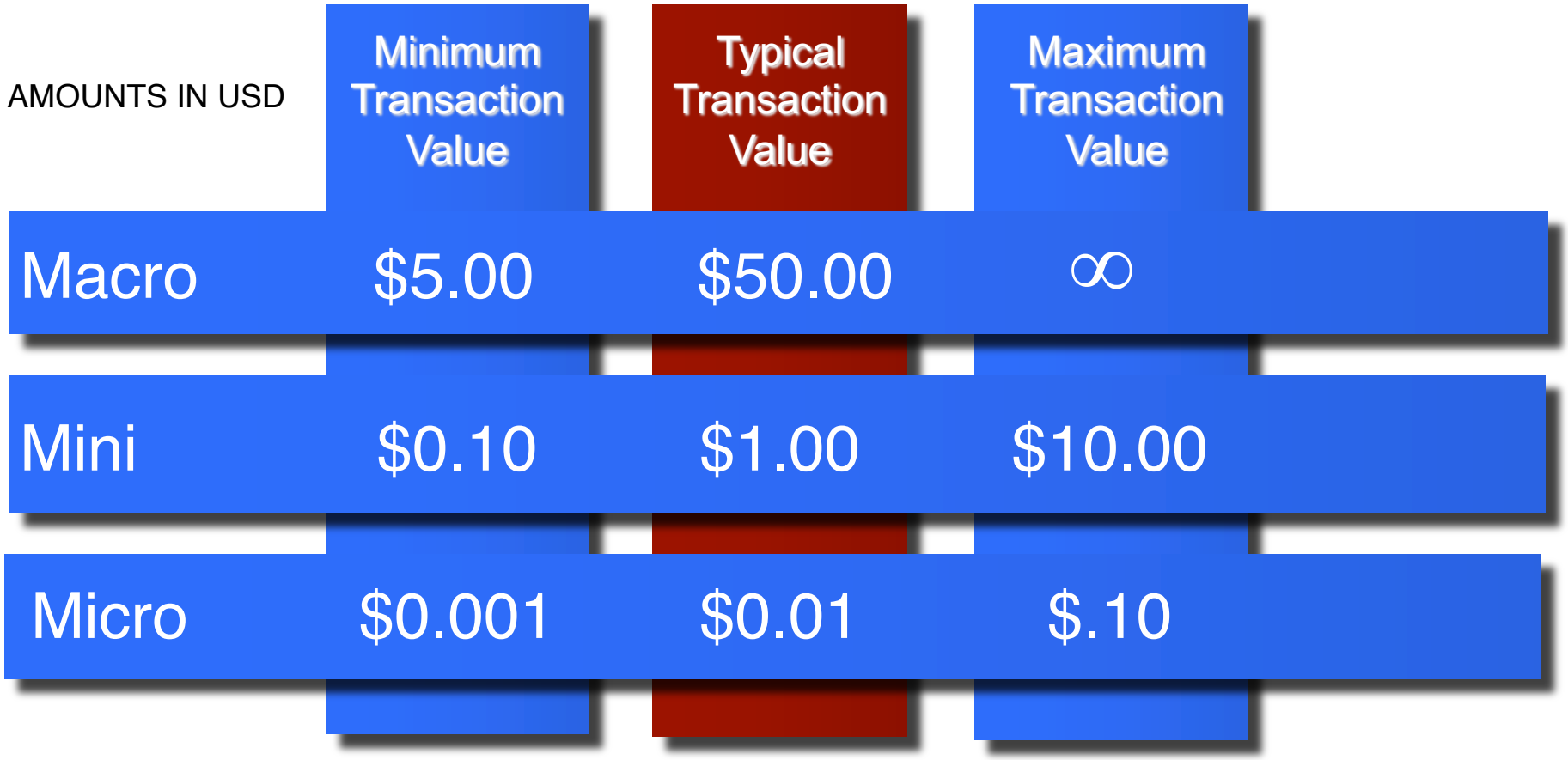

**Figure 3.4** Trends in noncash payments 2000–2015, by number. *Source: FRB. Note: Prepaid debit card includes general purpose, private label, and electronic benefit transfer.*

# World-wide Non-cash Transactions by regions




| | CAGR (2013–17) | Growth (2015–16) | Growth (2016–17) | | |
|---|---|---|---|---|---|
| **Global** | **10.8%** | **10.4%** | **12.0%** | | |
| Latin America | 5.4% | 3.4% | 8.3% | Developing | 22.6% |
| MEA | 15.9% | 19.0% | 19.3% | | |
| Emerging Asia | 34.6% | 27.6% | 32.5% | | |
| Mature Asia-Pacific | 10.5% | 10.4% | 11.0% | Mature | 6.9% |
| Europe (Including Eurozone) | 7.9% | 8.4% | 7.6% | | |
| North America | 5.4% | 5.1% | 5.1% | | |

# Ecommerce Payment Ranges

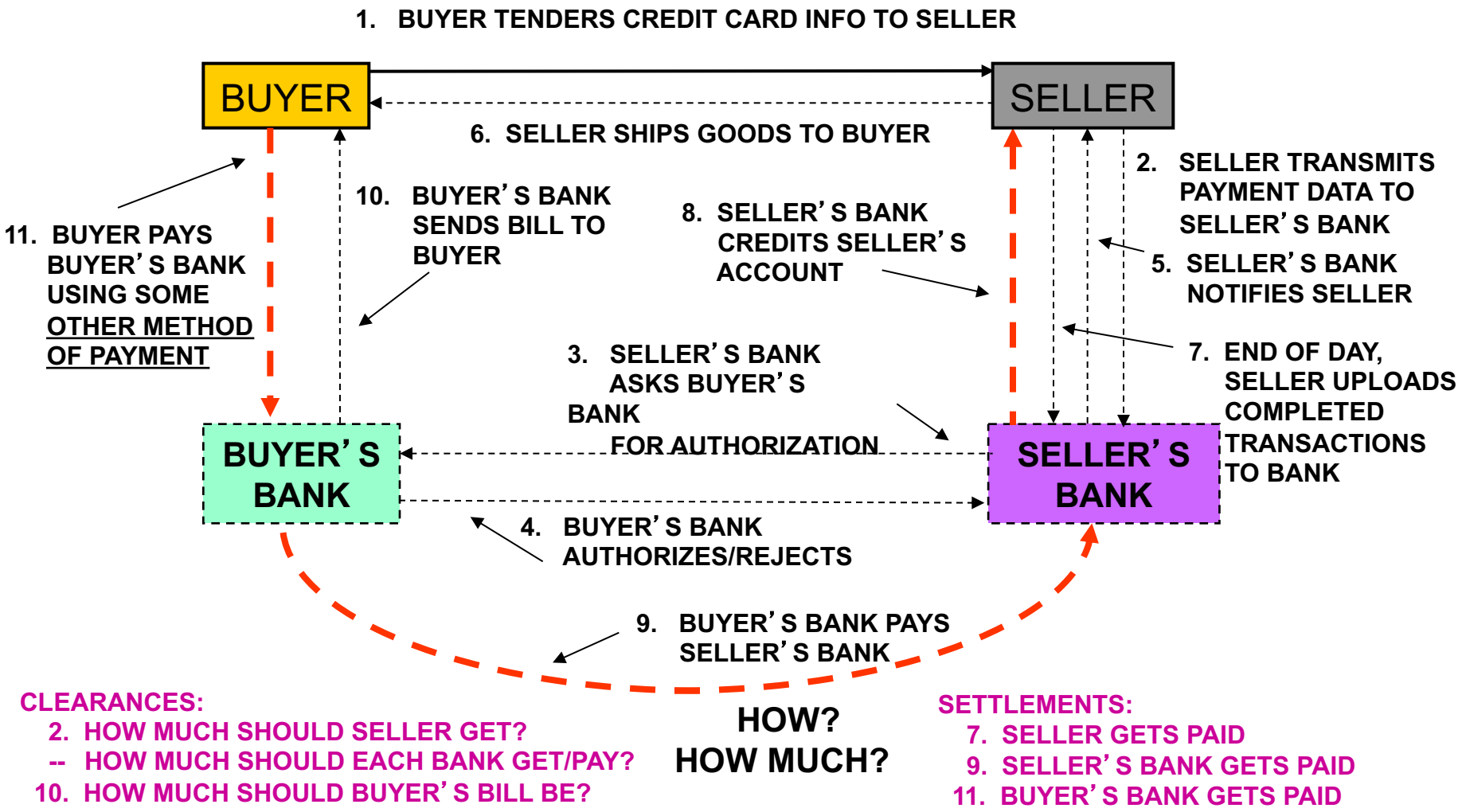



SOURCE: COMPAQ CORP.

# Objective of Payment Systems

- To allow the payee to obtain money, fiduciary or its equivalent
  - Usually in his/her  bank account (convertible to fiduciary)
  - Cash is rare except for low-value face-to-face payments
  - How does the money get into the bank account?
- Payment in real money is called settlement
- Most payments are not settled individually
  - Example: bank checks, ATM withdrawals – too small for separate transfers of funds; batched for efficiency
- Batching to determine how much money must be paid is called clearance or clearing
- Payment systems must provide for both clearance and settlement

# Credit Card Transaction



# Payment Issues

- How does the payer know how much to pay? (bill presentment, invoicing)
- What mechanism will be used to “pay” (payment)?
- When will payment be made (before, during, after)
- How will the payments be added up? (clearance)?
- How will the payee receive real money (settlement)?
- How will the payee credit the payer (reconciliation)?
- What records are available to the parties (audit)?
- Security for all the above
  - authentication of parties
  - prevention of forgery

# Payment Systems by Timing

- Prepaid Systems  (Bank access before transaction)
  - Cash
  - Octopus, phone card
  - Bank stored-value cards (GeldKarte)
- Instant-Paid Systems  (Access during transaction)
  - Debit card
- Post-Paid Systems (Access after transaction = credit)
  - Credit card, EZPass, Speedpass
  - Checks & electronic forms, eChecks
  - Commercial invoice
- Huge differences in risk, authentication, cost

# Some “Payment” Methods

- Cash
- Check/ Cheque
- Travellers Check
- Point-of-sale debit
- ATM
- Credit transfer (giro), Automated Clearing-House (ACH)
- Interbank transfer (FPS, EFT – electronic funds transfer)
- Credit cards
- Payment cards, smart cards (Octopus, Mondex)
- Loyalty Systems (Frequent Flyer Mileage programs)
- Intermediates, P2P systems: Paypal, Venmo, Payme, O!ePay
  - Mobile Payment Services, e.g. Alipay, WeChat Pay, Paybox
- Electronic Cash (by David Chaum of DigiCash), still issued by a bank
- Crypto-currencies: Bitcoin, Ethereum.

# System Issues

- Physical support (smart card, files, encrypted strings)
- Value representation (denominations, numbers)
- Location of value store (bank, electronic wallet)
- Discharging power (who accepts it?)
- Mode of use (remote, face-to-face)
- Methods of payment (credit transfer, jeton exchange)
- Genuineness (is it valid? stolen? double-spent?)
- Authentication (of user)
- Traceability (anonymity, privacy)
- Scalability, cost

# Desired Properties of Money

- Universal acceptance
- Transferability, portability
- Safety (unforgeable, unstealable)
- Privacy (no one except parties know the amount)
- Anonymity (no one can identify the payor)
- Work off-line (no need for on-line verification)
- Divisible into change (pay for $10 item with $100 bill)
- Arbitrary denominations (e.g. $325.14)

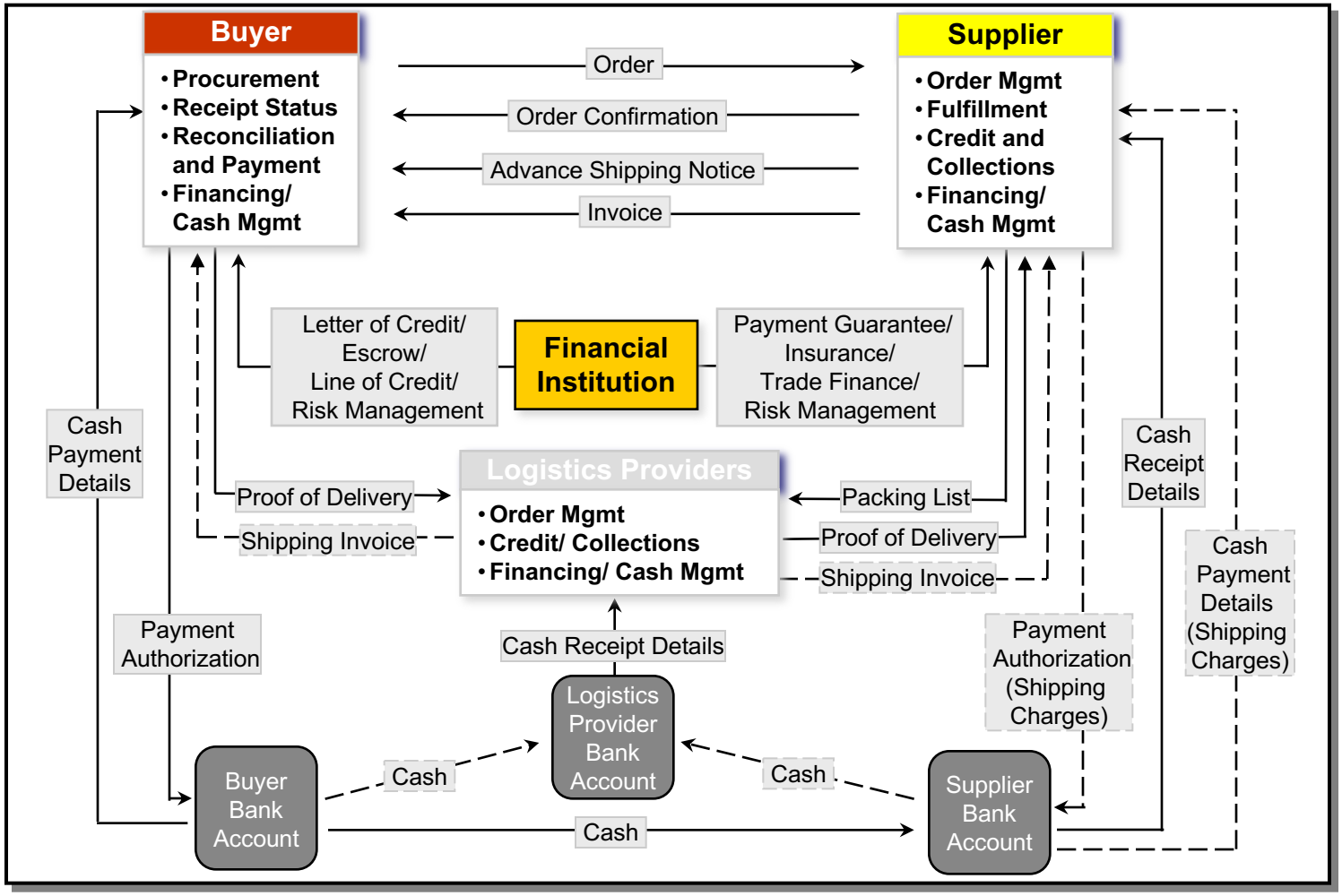
# Costs of Money

- Time
- Risk
- Physical cost (print currency, mint coins)
- System infrastructure
- Processing cost (transactions)
- Security
- Human time
- Law enforcement

# B2B Payments

- High dollar value
- Tied to paperwork
  - Requisitions, authorization, purchase order, shipping documents
- Financial controls, auditing
- Connection with legacy ERP and accounting systems
- Cash management
- International issues
  - Customs documents, foreign currency

# B2B Payments

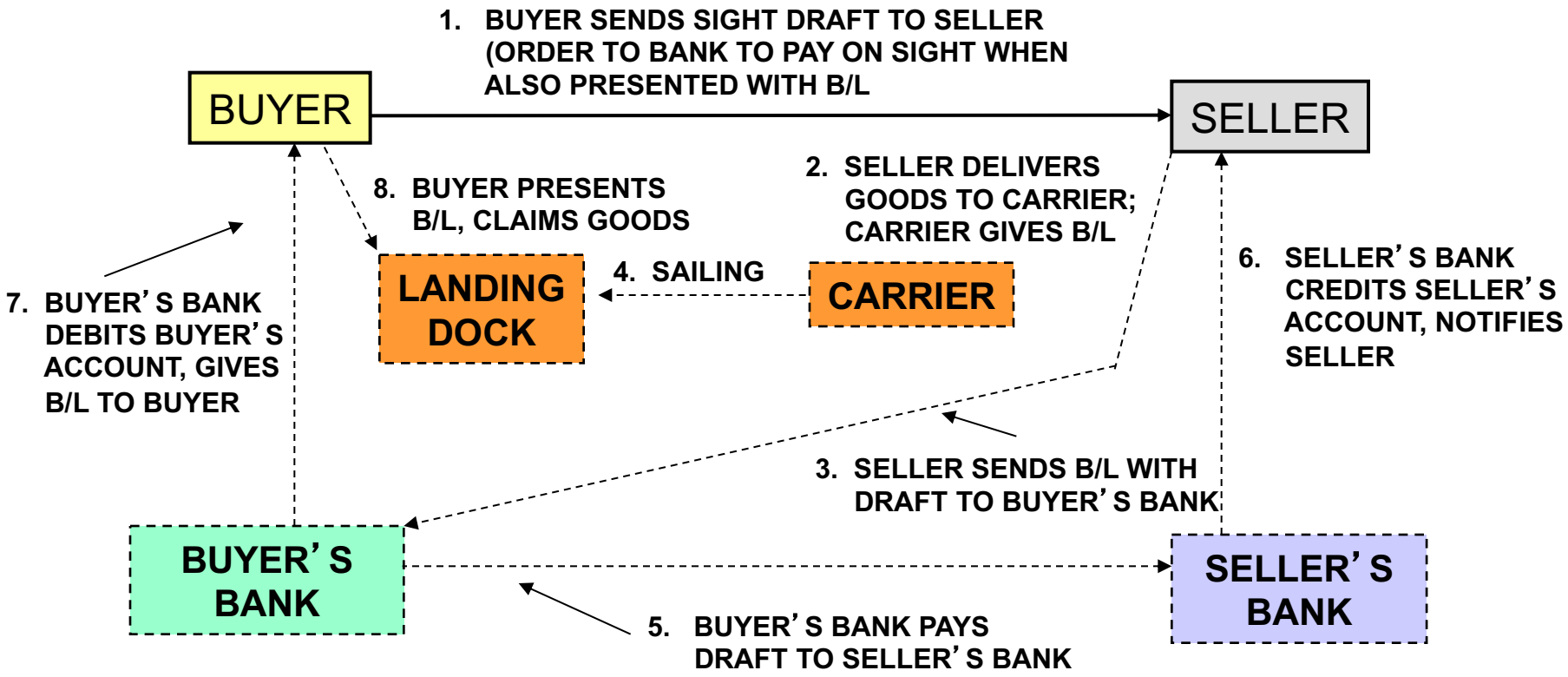



**Goods Move Faster Than Money**

**SOURCE: TRADECARD**

# Bill of Lading (B/L) Transaction

PURPOSE: LINK PAYMENT TO SHIPMENT




**CARRIER IS AN ESCROW AGENT. IF B/L IS NOT PRESENTED, GOODS WILL NOT BE DELIVERED. IF SELLER NEVER SHIPS GOODS, THERE WILL BE NO B/L AND BUYER'S BANK WILL NOT PAY**

# Additional Considerations

# Payment Risks

- ALL RISK HAS COST
  - Suffering loss has cost
  - Protecting against loss has cost
- System design must respond to risk posture (willingness to accept various kinds of risk)
- Transferable v. non-transferable risk
  - Insurance
  - Hedging
- Example tradeoff: open v. closed payment networks

# Payment Risks

System design must respond to risk posture

- Operational (reliability and integrity)
  - Security (unauthorized access)
  - Employee fraud
  - Counterfeiting (ecash)
  - System design, implementation, maintenance
  - Customer misuse
  - Service provider risk
  - System obsolescence
  - Transaction repudiation by customer

# Payment Risks

- Reputational
  - Negative public opinion ?==? loss of business
    - Bank of New York Russian money laundering
    - Lose both legitimate customers AND launderers
  - System deficiencies
  - Security breach
  - Failure of similar systems
- Systemic
  - Risk that failure to meet an obligation spreads through the system, causing others to fail to meet obligations

# Payment Risks

- Legal
  - Violation of law, ambiguity, legal sanctions
  - Money laundering
  - Inadequate disclosure
  - Violation of privacy
  - Violation by linked site
  - Certificate authority risk
  - Foreign law

# Payment Risks

- Banking
  - Credit (non-payment, insolvency)
  - Liquidity (demand for redemption of ecash)
  - Interest rate (spread)
  - Market (inflation, foreign exchange)
  - Cross-border (social, political, economic)
- Crime
  - Fraud, forgery
  - Theft
  - Kiting (illegal use of float)

# Summary of Major Ideas

- Money classifications
  - Token v. notational (what form does it take?)
  - Fiduciary v. scriptural (government or issuer-based)
  - Prepaid, Instant-Paid, Postpaid
- Payment methods
- Cash is very expensive to use
- B2B payments are complex
- Atomicity between shipments and payments is difficult to achieve